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Innovation, Universities, Science and Skills Committee

Engineering: turning ideas into reality

Fourth Report of Session 2008–09

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Oral and written evidence

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The Innovation, Universities, Science & Skills Committee

The Innovation, Universities, Science & Skills Committee is appointed by the House of Commons to examine the expenditure, administration and policy of the Department for Innovation, Universities and Skills.

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A list of reports from the Committee in this Parliament is included at the back of this volume.

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Witnesses [Nuclear Engineering]

Monday 7 July 2008 [HC (2007-08) 640-i] *Page*

Professor Sir Chris Llewellyn Smith, Director, United Kingdom Atomic Energy Authority (Culham Division), **Professor Jonathan Billowes,** Director of Education, Dalton Nuclear Institute, **Dr Stephen Garwood**, Director, Engineering & Technology-Submarines, Rolls-Royce and **Dr Graham Baldwin**, Pro Vice Chancellor (Nuclear Industries), University of Central Lancashire Ev 368

Clive Smith OBE, Skills Development Director Nuclear, Cogent Sector Skills Council (also representing the National Skills Academy for Nuclear), **Robert Skelton**, Vice President, Institution of Nuclear Engineers, and **Michael Grave**, Vice President, British Nuclear Energy Society Ev 378

Wednesday 16 July 2008 [HC (2007-08) 640-ii]

Dr Ian Hudson, Engineering, Technology & Skills Director, Nuclear Decommissioning Authority, **Mr Alex Walsh**, Head of Civil Nuclear Programmes, BAE Systems, **Ms Fiona Ware**, Vice President Operational Excellence and Transformation, AMEC's Nuclear Business, and **Mr Bill Bryce**, Chair, New Build Working Group, Nuclear Industry Association Ev 383

Adrian Bull, UK Stakeholder Relations Manager, Westinghouse, **Dr Mike Weightman**, HM Chief Inspector, Nuclear Installations Inspectorate, **David Barber**, Head of Technical Training, British Energy, and **Robert Davies**, Marketing Director, Areva Ev 392

Monday 3 November 2008 [HC (2007-08) 640-iii]

Mr Mike O'Brien MP, Minister of State, **Mr Michael Sugden** Assistant Director, Nuclear Supply Chain and Skills, and **Dr Nicola Baggley**, Director Nuclear Strategy, Department of Energy and Climate Change Ev 402

List of written evidence

		Page
1	Department for Innovation, Universities, and Skills, and the Department for Business, Enterprise and Regulatory Reform	Ev 410
2	Professor Bernard Kelly	Ev 414
3	Dalton Nuclear Institute	Ev 415
4	Institution of Mechanical Engineers	Ev 419
5	British Energy Group	Ev 420
6	AMEC Nuclear UK Limited	Ev 424
7	Nuclear Physics Forum	Ev 428
8	Institute of Materials, Minerals and Mining	Ev 429
9	Institute of Physics	Ev 431
10	Cogent Sector Skills Council and National Skills Academy Nuclear	Ev 435
11	Professor R G Faulkner, Loughborough University	Ev 440
12	Institution of Engineers and the British Nuclear Energy Society	Ev 441
13	Nuclear Industry Association	Ev 446
14	Institution of Civil engineers	Ev 447
15	EDF Energy	Ev 448
16	University of Central Lancashire	Ev 450
17	Royal Academy of Engineering	Ev 453
18	Research Councils UK	Ev 456
19	Institution of Engineering and Technology	Ev 463
20	Westinghouse Electric Company	Ev 467
21	Babcock International Group Plc	Ev 469
22	Rolls-Royce	Ev 471
23	David Lindsley	Ev 473
24	The Royal Society	Ev 475
25	BAE Systems	Ev 476
26	Society of British Aerospace Companies	Ev 481
27	Engineering Professors' Council	Ev 483
28	High Power laser Energy Research project	Ev 484
29	The United Kingdom Energy Authority, Culham	Ev 487
30	Nexia Solutions	Ev 489
31	Sellafield Limited	Ev 491
32	HM Nuclear Installations Inspectorate	Ev 494
33	Professor J Billowes	Ev 497
34	National Nuclear Laboratory	Ev 498
35	Professor Steven Cowley	Ev 502
36	Adrian Bull	Ev 502
37	Ms Fiona Ware	Ev 505

Witnesses [Plastic electronics engineering]

Wednesday 18 June 2008 [HC (2007-08) 599-i] *Page*

Professor Sir Richard Friend, Cavendish Professor of Physics, University of Cambridge, appearing on behalf of the Institute of Physics, **Dr Ian French**, Philips Research Laboratories, and **Dr Sue Ion**, Vice President, Royal Academy of Engineering Ev 507

Mr Mike Biddle, Technical Strategy Board, **Mr Vince Osgood**, Engineering and Physical Sciences Research Council, **Dr Hermann Hauser**, Amadeus Capital Partners Ltd, and **Mr Fergus Harradence**, Deputy Director of Innovation Policy, Department for Innovation, Universities and Skills Ev 514

Wednesday 2 July 2008 [HC (2007-08) 599-ii]

Professor Sir David King, former Government Chief Scientific Adviser, **Mr Chris Williams**, UK Displays and Lighting, Knowledge Transfer Network, **Dr Tom Taylor**, Plastic Electronics Technology Centre, and **Mr Nigel Perry**, Centre for Process Innovation Ltd Ev 523

Dr Richard Price, Nano e-Print, **Mr Stuart Evans**, Plastic Logic Ltd, and **Dr Keith Rollins**, DuPont Teijin Films Ev 532

Monday 3 November 2008 [HC (2007-08) 599-iii]

Rt Hon Lord Drayson, a Member of the House of Lords, Minister of State, Department for Innovation, Universities and Skills, and **Lord Carter of Barnes**, a Member of the House of Lords, Parliamentary Under-Secretary of State, Department for Business, Enterprise and Regulatory Reform Ev 538

List of written evidence

		Page
38	Department for Innovation, Universities and Skills, and the Department for Business, Enterprise and Regulatory Reform	Ev 547
39	Nano e-Print	Ev 550
40	Engineering Professors' Council	Ev 555
41	Royal Academy of Engineering	Ev 557
42	Technology Strategy Board	Ev 560
43	Cambridge Integrated Knowledge Centre	Ev 563
44	cintelliq Ltd	Ev 566
45	Plastic Logic	Ev 572
46	Silvaco Data Systems	Ev 575
47	Logystyx UK Ltd	Ev 576
48	UK Displays and Lighting KTN	Ev 580
49	Engineering and Physical Sciences Research Council	Ev 584
50	DuPont Teijin Films	Ev 588
51	OLED-T	Ev 591
52	"CEESI-Training"	Ev 592
53	Centre of Excellence for Nano, Micro and Photonic Systems (Cenamps) and the Centre for Process Innovation	Ev 594
54	Institute of Physics	Ev 597
55	M-solv Limited	Ev 599
56	Polymer Vision	Ev 601
57	High Force Research Limited	Ev 601
58	Merck	Ev 602
59	Department for Innovation, Universities and Skills	Ev 604

Witnesses [Geo-Engineering]

Monday 10 November 2008 [HC (2007-08) 1064-i] *Page*

Professor Brian Launder, University of Manchester, **Dr Dan Lunt**, University of Bristol, and **Dr David Santillo**, Greenpeace Ev 605

Professor Stephen Salter, University of Edinburgh, **Professor Ken Caldeira**, Carnegie Institution, **Professor Klaus Lackner,** Columbia University (via video-link) and **Dr Vicky Pope**, Met Office Ev 612

Monday 17 November 2008 [HC (2007-08) 1202-i]

Dr Phil Williamson, Research Councils UK, **Professor Nick Jenkins**, Royal Academy of Engineering, **Dr Tim Fox**, Institution of Mechanical Engineers, and **Professor Steve Rayner**, University of Oxford Ev 707

Rt Hon Lord Drayson, a Member of the House of Lords, Minister of State, Department for Innovation, Universities and Skills, **Joan Ruddock**, a Member of the House, Parliamentary Under-Secretary of State, Department of Energy and Climate Change, and **Professor Bob Watson**, Chief Scientific Adviser, Department for Environment, Food and Rural Affairs Ev 714

List of written evidence

		Page
60	Department for Innovation, Universities and Skills	Ev 619
61	Professor Ian Main and Dr Gary Couples	Ev 621
62	School of Engineering and Electronics and the School of Geosciences, University of Edinburgh	Ev 622
63	PODEnergy	Ev 627
64	Professor Stephen Salter	Ev 634
65	Professor Brian Launder	Ev 638
66	Dr Dan Lunt	Ev 639
67	British Geophysical Association, Geological Society, Royal Astronomical Society, Industrial Geophysics Group Institute of Physics	Ev 640
68	Royal Academy of Engineering	Ev 645
69	Tyndall Centre for Climate Change Research	Ev 649
70	Colin Forrest	Ev 650
71	Ground Forum	Ev 654
72	John C D Nissen	Ev 659
73	National Oceanography Centre, Southampton	Ev 662
74	Research Councils UK	Ev 664, 774
75	John Gorman	Ev 671
76	Professor John Latham	Ev 675
77	Dr Ken Caldeira	Ev 678
78	Professor James Griffiths and Professor Iain Stewart	Ev 680
79	David Hutchinson	Ev 683
80	Engineering Professors' Council	Ev 685
81	Institution of Mechanical Engineering	Ev 690
82	Engineering Group of the Geological Society of London	Ev 691
83	The Royal Society	Ev 695, 771
84	Department for Environment, Food and Rural Affairs	Ev 696
85	Greenpeace	Ev 700
86	Professor Klaus S Lackner	Ev 702
87	Professor Steve Rayner	Ev 703
88	Met Office	Ev 706

Witnesses: [Engineering in Government]

Wednesday 19 November 2008 [HC (2007-08) 1194-i] *Page*

Professor David Fisk, Imperial College London, **Professor Michael Kelly**, Chief Scientific Adviser, Department for Communities and Local Government, and **Professor Wendy Hall**, Member, Council for Science and Technology Ev 721

List of written evidence

89	Department for Innovation, Universities and Skills	Ev 736, 782
90	Professor David Fisk	Ev 751
91	Semta	Ev 754
92	Royal Academy of Engineering	Ev 756
93	Institute of Engineering and Technology	Ev 764
94	Engineering and Technology Board	Ev 766
95	Engineering Council UK	Ev 768
96	Prospect	Ev 770
97	Professor Sir Martin Sweeting	Ev 780
98	Committee Staff note on E-consultation with employers	Ev 792
99	Committee Staff note on E-consultation with young engineers	Ev 795

List of Reports from the Committee during the current Parliament

The reference number of the Government's response to each Report is printed in brackets after the HC printing number.

Session 2007–08

First Report	Re-skilling for recovery: After Leitch, implementing skills and training policies	HC 48-I (HC 365)
Second Report	The Work of the Committee 2007-08	HC 49
Third Report	DIUS's Departmental Report 2008	HC 51-I

Session 2007–08

First Report	UK Centre for Medical Research and Innovation	HC 185 (HC 459)
Second Report	The work and operation of the Copyright Tribunal	HC 245 (HC 637)
Third Report	Withdrawal of funding for equivalent or lower level qualifications (ELQs)	HC 187–I (HC 638)
Fourth Report	Science Budget Allocations	HC 215 (HC 639)
Fifth Report	Renewable electricity-generation technologies	HC 216–I (HC 1063)
Sixth Report	Biosecurity in UK research laboratories	HC 360–I (HC 1111)
Seventh Report	Pre-legislative Scrutiny of the Draft Apprenticeships Bill	HC 1062-I (HC (2008-09)262)
First Special Report	The Funding of Science and Discovery Centres: Government Response to the Eleventh Report from the Science and Technology Committee, Session 2006–07	HC 214
Second Special Report	The Last Report: Government Response to the Thirteenth Report from the Science and Technology Committee, Session 2006–07	HC 244
Fourth Special Report	Investigating the Oceans: Government Response to the Science and Technology Committee's Tenth Report of Session 2006–07	HC 506 [incorporating HC 469–i]

Oral evidence

Taken before the Innovation, Universities, Science and Skills Committee

on Monday 7 July 2008

Members present

Mr Phil Willis, in the Chair

Dr Roberta Blackman-Woods	Mr Gordon Marsden
Dr Brian Iddon	Graham Stringer

Witnesses: **Professor Sir Chris Llewellyn Smith,** Director, United Kingdom Atomic Energy Authority (Culham Division), **Professor Jonathan Billowes** Director of Education, Dalton Nuclear Institute, **Dr Stephen Garwood**, Director, Engineering & Technology-Submarines, Rolls-Royce and **Dr Graham Baldwin**, Pro Vice Chancellor (Nuclear Industries), University of Central Lancashire, gave evidence.

Q1 Chairman: May I welcome our first panel of witnesses this afternoon. Thank you all very much indeed for coming to this the first evidence session for our nuclear engineering case study, as part of our major inquiry into United Kingdom engineering. We are particularly grateful that you have come along, because obviously nuclear engineering and the development of new nuclear power stations is very much high on the Government's agenda at the moment and the one question that we are asking as a Committee in engineering terms is, are we capable of actually building a whole set of new nuclear power stations? Do we have the capacity to do that and if not, what do we need to put in place? I wonder if I could introduce our witnesses this afternoon: Professor Sir Chris Llewellyn Smith, the Director of UKAEA at Culham; Professor Jonathan Billowes, the Director of Education at the Dalton Nuclear Institute; Dr Stephen Garwood, the Director of Engineering & Technology-Submarines, at Rolls-Royce; and Dr Graham Baldwin, the Pro Vice Chancellor (Nuclear Industries) at the University of Central Lancashire. I wonder if I could I start with you, Professor Billowes. Could you give the Committee a definition of what you see as nuclear engineering; what is it? Your colleagues will then check to see whether you get the right answer.
Professor Billowes: The narrow definition, if you have an undergraduate programme called nuclear engineering; it would have reactor physics and criticality, nuclear fuel cycle, some hydraulics, basic nuclear physics and radio protection. If you ask what a nuclear power programme would require, it is rather broader, so it would have chemistry, radio-chemistry materials, socio-economics and social sciences.

Q2 Chairman: Colleagues, would anybody like to add to that?
Dr Garwood: I can give a slightly modified, industrial view, Chairman. In the industrial arena, I think it would be broader, in the sense that people with an engineering background and a graduate degree who are then trained in the nuclear arena in their specialisations which could be done by the industry would also be nuclear engineers in the broad.
Dr Baldwin: From our point of view, we took a fairly broad definition and looked at engineering applied to the nuclear sector, so that we did not just narrow it down to those people who required specific nuclear activities but the engineering that is required to underpin the nuclear industry broadly.

Q3 Chairman: So, if you were building a nuclear power station, a significant amount of it, taking away the reactor, is standard engineering, but would you include that because it was part of the nuclear installation as nuclear engineering?
Dr Baldwin: Yes, we see a need for specific programmes as well as more generic programmes and within those generic programmes we would have a stream of core engineering elements but then some nuclear modules attached to that. But then when a graduate goes into the industry they would then be able to apply that in the various different contexts and they would get training on the ground.

Q4 Chairman: Sir Chris, is it important for us as a Committee to make it absolutely clear what we understand by nuclear engineering?
Professor Llewellyn Smith: Yes, I should think so. Fusion is in the research phase at the moment and is mainly dominated by plasma physics, but in the future it is going to become increasingly dominated by engineering and development and the United Kingdom programme must move in that direction because that is where the intellectual value will be and that is where the centre of gravity will be. We have lots of engineering skills in what we are doing in particular to operate the Joint European Torus at Culham at the moment in cryogenics, controls, high vacuum, super conductivity and radio frequency systems but in the future we are going to need just these skills, fuel cycle and others, fluid transfer, high heat flux, which are broader than nuclear. In building a fusion power station, there will be a core of some nuclear skills but a very broad range of engineering will be needed. At the moment we only have a limited range of specifically nuclear activities to do with the activation of materials and the tritium handling cycle, which we will probably have unique expertise in the world—I am talking about half a

dozen people, at the moment. But if we are not moving there in 15 years, the United Kingdom will not be there as a major player.

Q5 Graham Stringer: That leads neatly on to a question of what are the nuclear engineering strengths and weaknesses. What are the strengths in this country of nuclear engineering and what are the weaknesses?
Dr Garwood: There is a very strong strength on design still in this country. My company has been designing pressurised water reactors for 50 years. We have 850 nuclear engineers in the broader sense working today on that activity and that is a continuing skill. There is also a skill out in the supply chain, which has come from the legacy issues in nuclear engineering and I think it is that supply chain that we need to advance with the new civil build. We still have a very strong capability out in the supply chain and in certain industries in the nuclear area.

Q6 Graham Stringer: Anybody else on weaknesses?
Professor Llewellyn Smith: Yes, if I look at the skills we need, it is much broader than just nuclear, so the physicists we want we can get; the mechanical engineers we want, with some difficulty; high voltage electrical engineers, not for love or money; mechanical engineers with design and project leadership skills, very difficult to get; in the future when we need nuclear engineers, I expect they will be difficult to get too.

Q7 Graham Stringer: What do you think the Government should do about those weaknesses, those areas where we do not have the skills?
Professor Llewellyn Smith: It needs things to encourage young people at all levels. Starting off, we are doing things in primary schools, for example. By the way, I would like to invite the Committee to come and visit us, in particular, to see what we are doing with primary schools, which is very interesting. We get the kids in and I can give you a quote from an independent reviewer, "I used to think that science was boring but now I see it can actually be interesting", etc. All the way up, we are doing what we can at schools for the very long term; at university we have summer placements, and so on, and we are trying to get engineering graduates in, but there is competition out there, but we are growing our own. We have also restarted our own apprenticeship scheme, which was dead for many years, and it is going well. The first entry is just coming through; two of them are now doing part-time degrees. We are doing what we can, but it is a drop in the ocean, so it needs something to really stimulate engineering generally in schools. I have got some ideas on that.

Q8 Chairman: Is there anything you want to add?
Professor Billowes: Yes, on the weakness side, which apart from the fusion programme, in the fission area, our engagement with Europe and America is weak in basic R&D and if we could get that done at universities and with the National Nuclear Laboratory, it would encourage young people, it opens up a pipeline to general engineers to get into that area, so GEN 4 type systems, GNEP.
Dr Baldwin: I think we need clarity of message. I would agree that we have got a long history and experience of delivering high-quality engineering education and that capability still exists, but there is a challenge in the throughput of new people into the industry, or into the subject area, so we have to be innovative in terms of our delivery. We have to have clarity of message because we have not recruited significantly as there has been hesitancy and uncertainty around nuclear and its future. So, we welcome the fact that there is that clear message but we need that clarity and we need to translate that into innovative programme design and to encourage young people to come through and take on science, technology and engineering subjects, as we have heard, at school and right the way through into university. We have got to have that clarity and joined-up approach.

Q9 Graham Stringer: So, we have got an immediate skill shortage in certain areas. What are the other big challenges over the next 50 years?
Professor Billowes: I think there are three areas that we need to work in. One is that we are going to need operators to operate plant from 2018, and they should be in the educational system now and they need a career path; they have got to be suitably qualified and experienced, and getting experience takes years. In the short term, the expertise is in the country, it will probably be in the National Nuclear Laboratory, the Nexia Solutions people, provide enough expertise in the licensing process to start off with, but that expertise needs to be carried over to the next generation as well because those people are older than average and will be retiring soon.

Q10 Chairman: All this is pie in the sky. We were talking about major civil build for four and up to 10 nuclear power stations, starting within the next six to eight years—if we are going to meet the 2018 target that the Government has set, some of them are going to have to be coming out of the ground within five to eight years. If that is the case, we have missed the boat, have we not? We are not going to be able to grow the new group of engineers in that space of time, so where are we going to get them from?
Professor Billowes: I do not think we have missed the boat. I think the bigger problem may be the bottlenecks in the supply chain.
Dr Garwood: I agree with what Jon says. I do not think we have missed the boat. We have a new generation design going on in the military field and obviously there is somewhat of a threat in the civil programme of drawing people from the military programme which will only just resource it. But I believe the United Kingdom can support those programmes. Timing and resources are everything though, because the next generation of civil build will not be designed in the United Kingdom, the design will come from abroad, whereas the military

designs are UK-based. So you can see that the designers currently learning their skills in the military field will then move on to the civil field when we go on to the GEN IV programmes. Equally, the resource basis can be partly filled by the people from Europe in the interim, but we need to build a United Kingdom resource for the longer term when we are operating these plants. So, timing and resource planning is the key to this.

Q11 Graham Stringer: May I take you back to the answer about one of the weaknesses being our relationship with Europe and the United States. I would be grateful if you could expand on that and explain why that is a weakness, and also explain what the United Kingdom's nuclear engineers' role will be internationally over the next 20 years or so.
Professor Billowes: At the moment, I think the United Kingdom has a lot of expertise in different reactor systems; some of the technology is in the GEN IV system. The DTI pulled out of GEN IV three or four years ago and since then we, for example, are trying to do basic science and we cannot get research money from EPSRC for that because there is the perception that the United Kingdom is not longer supporting advanced reactor R&D. So, it is GEN IV we have pulled out of; we are in GNEP.

Q12 Graham Stringer: Can you quantify that a bit in terms of the damage in terms of fund allocations? Just ballpark figures.
Professor Billowes: I am not sure I can give a ballpark figure but it might have been £4 million spread around several universities and companies like AMEC, Nexia and Serco. It allows research to be done and it brings in young people; new blood.

Q13 Graham Stringer: So you would like that decision reversed, essentially?
Professor Billowes: Yes, and also investment in R&D in the long term, you recover that money by factors or two or three further down the road.
Dr Garwood: It is important to note that we have not missed the boat because on the military programmes the R&D has started. The Government, through the Ministry of Defence, have already put in £25 million of R&D money into those programmes. So, that activity is going on and that is giving an unpinning to the skill base. But I agree with Jon, for the future programmes, we need a future into the R&D.
Dr Baldwin: We have also got to take into account that we are looking at new blood into the industry but also looking at the reskilling and the upskilling agenda and as we go through the phase of nuclear decommissioning and we see that there are people who are no longer required within that activity, then there is an opportunity for reskilling and upskilling work to increase the pool of people who could work in the new build.

Q14 Chairman: In terms, Sir Chris, of the learned societies and the professional bodies, how significant does nuclear engineering feature?
Professor Llewellyn Smith: I am probably not the right person to ask that because the professional bodies that I belong to have no interest in it whatsoever, as far as I know. I am not an engineer.

Q15 Chairman: Are you all members of professional bodies?
Dr Garwood: Yes. The Royal Academy of Engineering is now a large focus and the Academy is looking at this very seriously. I do not know whether you are taking evidence from Academy members. It is back on the engineering agenda and I would just like to say that we have recruited 230 engineers in the past two years in Rolls-Royce to do nuclear engineering in the broader sense. They are engineers who would either be trained to do engineering or are from a nuclear background. These guys are coming into the programme because there is a future in the programme now. They can see 40 years of design and operation of these new plants and that is what stimulates engineers to come into a future.

Q16 Chairman: I can see that. You have all displayed a real enthusiasm for nuclear engineering this afternoon. I was with a group of people this morning who were telling me there was a huge disconnect between the vision of the learned societies and the institutions, and what was actually happening on the ground. I wonder whether you share that view?
Dr Garwood: Not really, no.

Q17 Mr Marsden: I wonder if we could just drill down a little further on some of the issues of skill shortages in nuclear engineering. Perhaps I could start off by asking you, Professor Llewellyn Smith: the statistics that are knocking around, or the reported statistics that we have received, are pretty worrying. Professor Faulkner said, in his written evidence to us, that the nuclear engineering skill base reduced approximately 10% per annum for the past 15 years. We have got other reports from British Energy and elsewhere that suggest that the United Kingdom needs to double the number of STEM graduates it produces in general from 45,000 to 97,000 by 2014. Has the melt-down, if one can put it that way, in terms of skill shortage been so much worse in nuclear than other branches of engineering, and if so, why?
Professor Llewellyn Smith: For us, in fusion, we do not really need nuclear skills today; we foresee the need in the future. We are not feeling a melt down, we are feeling a problem in the many areas of engineering. As a citizen, I am concerned about the figures that you quoted and we can see a problem in the future, but it is not actually affecting what we are doing today.

Q18 Mr Marsden: Do any other members of the panel want to comment on the broader aspects affecting the industry?
Dr Baldwin: I think you are right, we do need a significant increase in the number of engineers over the next few years. With regard to nuclear, there are a number of factors that have influenced its

attractiveness. The uncertainty that I alluded to earlier, people not sure about what the future will be for nuclear, the advent of nuclear decommissioning was not necessarily very well understood. The fact that nuclear decommissioning has quite a significant lifespan but the term decommissioning suggests an end game and therefore does not necessarily attract new people into it. With the increasing interest in energy generally, and with a greater understanding of the future of nuclear, there is now an opportunity to attract more people into education and into the STEM subjects. There is an awful lot of work being done now that will pay dividends over the next few years, so there is a reason for confidence that we can meet the demands as we move forward, but it will take significant action.

Q19 Mr Marsden: Just on that specific point, the issue as always with these things—to quote Keynes' famous dictum "in the long term we are all dead"—is whether in fact the degradation in terms of skills, the statistics that I have quoted, can be sufficiently reversed in the medium term to preserve the position for the summing up plans that the broader picture suggests. I wonder whether you think that we have got the time to do that.
Dr Baldwin: I think we are doing the right things in terms of making sure that we do have the skills in the timeframe that we are discussing.
Professor Billowes: There are two points. One is that until Lancaster University started their nuclear engineering undergraduate degree two years ago, there was not a single nuclear engineering undergraduate degree in the country. So, that is one reason why you do not have people coming through that route. There have been a few masters programmes in the nuclear engineering area—Birmingham's physics and technology of nuclear reactors has been running for over 50 years; HMS Sultan have been doing courses for graduates within the nuclear department, and we have now a national Nuclear Technology Education Consortium involving 11 universities. These are producing masters-level people doing nuclear engineering who come from a general background, so it nuclearises them.

Q20 Mr Marsden: I will not go down that route at the moment, because I think we have some very specific questions about that later on. What I would like to pick up from there is what you were saying about the difference between pure skills and generic skills, if I can put it that way, are there any sectors in the United Kingdom nuclear industry which are particularly badly affected in terms of these shortages?
Dr Garwood: I can tell you from our recruitment campaign, electrical engineering is one area in which we have had particular difficulty in getting high-quality people through. And, of course, they underpin the nuclear programmes. Systems engineering is another area we have had difficulty with.

Q21 Mr Marsden: Back to the issue that my colleague, Graham Stringer raised, which is the whole issue of international co-operation and collaboration, particularly with the United States. You could say, if you wanted to be mischievous or the devil's advocate, does it matter if the United Kingdom is potentially reliant on overseas capability? What is the push-pull factor between the United Kingdom capability being sought overseas? After all, we live in a globalised world where some of the people we are talking about are highly skilled, does it matter that we develop our own home grown ability?
Dr Garwood: May I answer first, because for the defence programmes, they have to be United Kingdom nationals, so it is essential that we have this resource keeping on coming through from our universities to fulfil those programmes. Also, I believe in the longer term, particularly when there are civil build programmes worldwide, we will be competing in the worldwide market place for resources, so that if we have not got our own indigenous enthusiastic population, we will be struggling.

Q22 Mr Marsden: Dr Baldwin, UCLan has a strong reputation not just for attracting overseas students but also for doing some fairly enterprising pioneering things overseas. So, from your perspective at UCLan you must see both sides of the coin. What is your perspective on it?
Dr Baldwin: We would want to support overseas students and welcome the opportunity to prepare people who would be valuable overseas and could support the industry globally. There is an opportunity to work in partnership and we would want to see people going in both directions. I would, however, agree that we need a home grown supply of people who can work in the industry. As it becomes a global phenomenon and more new build occurs, then there will be more demand and although we want to ensure that we have people properly skilled that we can have going both ways, I still think that it is important to ensure that if new build occurs in one particular location and that attracts a lot of people, we have still got enough people who want to remain here in this country to support the activities that we have got. In summary, yes, it is very important that we have partnership. some of the people who are training overseas can come and work with us in the short term and provide a short-term opportunity for us. Likewise, we want to prepare people to go the other way but I think we need a long-term partnership but for that to be a balanced partnership we have to produce home grown, quality science and engineering graduates.

Q23 Mr Marsden: While I have got you on the balance, as it were, I cannot resist asking you this question—obviously, as a Blackpool MP—you have got Springfields just around the corner from you, there was a reference earlier to decommissioning and ancillary aspects, have we got the balance right, in terms of bringing people with skills into reprocessing, for example, as opposed to new build? Is there an understanding out there that those sorts of offshoots of the nuclear industry are going to continue to be profitable and useful?

Dr Baldwin: We have to be careful with the message that we give and that has been part of the problem in recent years. There has been a little bit of uncertainty about what we mean by certain terms and what activities are involved in which part of the industry or sector. There is a lot of work being done at the moment to ensure that career pathways are properly mapped out so that young people, or anybody coming into the industry, has a full understanding of what sits where within the industry and that will allow a much better and much more informed decisions to be made. We are addressing that and ensuring that people understand all the implications of the various sections of the nuclear industry and to make sure that we have a balanced approach to skill development.

Professor Llewellyn Smith: I wanted to say that just on the matter of rebuild, of course, you need a certain skill level just to act as intelligent customer and my colleagues would know more about this than me but I would be worried that we were even there, not necessarily got enough. It was the remark about fusion being a bit different for international collaboration—an earlier question—if I could just quickly go back to that. Fusion is strongly co-ordinated across Europe; very international. I happen to chair the body that advises EURATOM which plays a co-ordinating role. There, we have recognised Europe-wide the skills shortage and have introduced a training scheme which is taking on about 40 people a year, some of them in physics but also in engineering, but a multinational training scheme where they move around. So, we are looking after our own very specific needs in fusion. We are also moving to a level of world collaboration. The next big project is ITER, the International Tokamak Experimental Reactor, in which over half the population of the world is involved, all the major countries. I chair the council of that body. That has had a major stimulating effect on young people getting involved in fusion. They have suddenly seen that there is this huge project, the major governments of the world—the United States, China, Japan and the European Union—are taking this very seriously as an option. It looks interesting, it is a good thing to get into and because of this project, which will be there for 30 years probably, there is a future and it has had a tremendous effect on recruitment.

Q24 Mr Marsden: Dr Garwood, can I turn to you and ask you about the role both of industry but also of the United Kingdom Government in maintaining and revitalising nuclear engineering skills, which again it seems to me is not without controversy, certainly as far as the Government's side is concerned, because after all the commitments that have been made to producing a new generation of nuclear power stations have been based on the assumption that there is going to be no sustained level of Government spending on that, it has all got to come from the private sector, we had the previously inquiry which Malcolm Wicks, the Energy Minister was adamant on that point. So, industry is going to have to pick up most of the stretch for this is it not?

Dr Garwood: It is important that future programmes are defined to give the pull to industry to know that its investment is going to create wealth for the country and for the industry. So, some level of security going forward is very important, of course, for industrial backing. I can see that this is a very holistic problem between Government, academia and industry in our skills generation. We already have the commitment for the design of the new generation of military reactors, which has started that enthusiasm off for recruitment, so with the civil build programme, as long as industry is willing to come to the table and say, we are going to build these reactors, that would cause the necessary enthusiasm in the resource pool to start the training schemes up. You have already heard from my academic colleagues that the universities are responding to that, but it has to be the three getting together—Government, academia and industry.

Q25 Mr Marsden: Professor Billowes, from the academic perspective, you know what the Government's position is—it has been restated—does it concern you therefore that you cannot guarantee that there is going to be a major Government initiative, certainly a major Government funding initiative, to include skills in nuclear engineering?

Professor Billowes: I was about to talk about the masters-level programmes. Undergraduate programmes will spring up; Imperial are starting nuclear engineering strands to three undergraduate programmes and I think others will follow. Undergraduate programmes attract money for students arriving on the programme. At masters-level, it is much more vulnerable. The Birmingham programme, running for 50 years, almost disappeared about four years ago when EPSRC stopped the Collaborative Training Account award to them. That programme and the national NTEC programme lose the funding next September and it is not clear what is going to happen beyond that. EPSRC are stopping the CTA scheme; they are moving to a KTA scheme, which will have a different focus.

Q26 Mr Marsden: You are losing us with acronyms.

Professor Billowes: The CTA—Collaborative Training Account—which has been supporting masters programmes, fees and stipends for full-time students; the KTA, I do not know what the rules are yet because they are not released, but I think it will be looking for knowledge transfer from universities to industry and not specifically supporting fees and stipends on masters programmes. The two university programmes in nuclear engineering are very vulnerable from next year.

7 July 2008 Professor Sir Chris Llewellyn Smith, Professor Jonathan Billowes, Dr Stephen Garwood and Dr Graham Baldwin

Q27 Mr Marsden: You are going to have to go along to DIAS to start this, are you?
Professor Billowes: At the moment it is EPSRC that have taken on the responsibility. On the NTEC programme, we were hoping that we would be self-sustaining with industry uptake of the courses.

Q28 Mr Marsden: I am sorry to interrupt you, but we are getting a bit technical here. The thrust of my question is this—and you are producing some very interesting examples which I think might be useful to have a written note of to the Committee—what you are producing already, to me at least, gives the game away on some of the tensions. You are saying, these are things were you are going to want a Government steer on funding, yet we know what the overall Government position on this is, the Government overall position is that industry must take up the slack.
Professor Billowes: I think there might be a responsibility of to the Government to provide a workforce—if companies want to come and build a reactor, they want to know that the workforce is there which they can get in to help.

Q29 Mr Marsden: That would lead to some interesting conversations between Ministers in that case. Can I just finally come back to you, Dr Garwood, just picking up on something that you said earlier, which was in response to a question about United Kingdom nationals in the military industry, and that raises the question in my mind as to what the actual transfer is likely to be between the skills that are demonstrated in the military nuclear engineering sector and the provisions of skills for civil new build. We have seen in the past—I am going back to the 1970s and 1980s, when there were great debates about knowledge transfer between military and civil purposes—that there were all sorts of imaginative schemes coming forward but the actual amount of transfer is relatively negligible. You are fairly bullish about this are you?
Dr Garwood: I am, yes. The reason being that we are now in a situation where the design of the military reactor plant is the same, in principle, as the design of the likely civil build programmes and this gives a great opportunity for more transfer than was historically the case. Also, as I said before, the dovetailing of design which we are currently doing in the military programmes whereas the new design was not required immediately on the civil programme, it will be later. So, you can balance the two programmes quite nicely together, if that is done skilfully.
Chairman: I want to return later, Professor Billowes, to this issue of demarcation between what the State should be doing in terms of investing in its skills, probably at undergraduate level, and what should be happening post-graduate level at masters and doctorate level. It is a crucial issue and that is pertinent in terms of what is happening in terms of Central Lancashire as well.

Q30 Dr Iddon: The British Government were active participants in the Generation 4 international forum, GIF, I will call it. Nine countries, six reactor types being examined, why on earth did we pull out of what appears to me to be an important project like that, as an active participant? Does anybody know? That looks like a question for the Minister then. Can anybody tell us what were the advantages and disadvantages of being an active participant in the GIF programme?
Professor Billowes: First of all, the United Kingdom has a lot to offer in their experience in some of the technology, as I said before. Working internationally, we are doing research that attracts young people, we are getting leverage from the knowledge of other countries in the advanced reactor area. In 30 years' time we will probably want to build advanced reactors ourselves in this country and it is a way of understanding them early on. Also, the research you can do in that area carries over into the reactors that are already operating in this country which also need R&D support to keep them running. So, there are people being trained as experts in the area that the country then has for its own civil programme.

Q31 Dr Iddon: Anyone else?
Dr Garwood: Yes, I agree totally with Jon's comments. What is good about looking to the future in new reactor systems is that we are looking beyond the next generation of reactors for the future and it is very good investment because relatively small amounts of money in the concept stage can buy you a lot of knowledge. Much of our R&D currently is being spent on development of existing products, which is quite expensive compared to the concept. It is very important, if our future generation is to be good nuclear engineers that we get involved in this type of programme.

Q32 Dr Iddon: I am getting the message, Dr Garwood, that you feel that we ought to re-engage actively in this programme.
Dr Garwood: That is not quite what I said. It is actually a Government policy decision whether we should engage or not. I was saying that it is important that we look at future programmes and use the resource appropriately for concept type designs.

Q33 Dr Iddon: If you were the Government, would you do it?
Dr Garwood: If I was in the Government, would I do it?

Q34 Dr Iddon: Yes. You are the Prime Minister now, you can make the decision this afternoon.
Dr Garwood: I would have to pass on that one because he has a lot of difficult balances to make.

Q35 Dr Iddon: Anybody else feel that we should really be in on this programme, as we were at the beginning in 2000?

Professor Billowes: Can I add that it is not just the GEN-IV programme. There are other things in Europe, but I think that the United Kingdom is the only country missing from the table, like the accelerator-driven systems and energy amplifier systems. We do not seem to be engaging even with Europe in nuclear engineering areas.

Q36 Dr Iddon: Do you think the Government feels that we might have access to these programmes through the back door, for example, through the Framework 7 programmes, and so on, or EURATOM which was mentioned earlier, which is part of that general parcel? Are we getting information out of these programmes indirectly, rather than being actively involved in them, or are we just missing out completely?
Professor Billowes: There is very little university involvement.
Professor Llewellyn Smith: I think we can get the information out of them which is often published, but that is not the useful information, the tacit information, the hands-on knowledge, and we are not getting the advantage of being in exciting schemes and that is what stimulates young people to come in.

Q37 Dr Iddon: I got the feeling from you, Jonathan, that you want more involvement in international programmes and that we are just not there at the moment. Is that a general feeling across the panel?
Professor Billowes: It is important in universities that we can do basic science and get research money for it, because otherwise faculty members are not reappointed, you lose that research area from university, you lose that education on undergraduate programmes, it is the reason why nuclear engineering disappeared from the United Kingdom in the 1980s and 1990s, the funding of R&D dropped almost to zero.

Q38 Dr Iddon: Is that because we do not have enough universities actively interested enough in this area of research?
Professor Billowes: No, I think it is having new faculty members appointed to replace old faculty members and unless they are doing internationally competitive research, they will not reappoint in that area.

Q39 Dr Iddon: Do you think they will reappoint, now that the atmosphere is changing?
Professor Billowes: In the last couple of years, there have been four or five new chairs in decommissioning, fuel technology, nuclear engineering, that have been filled, so it is going in the right direction.
Dr Baldwin: Also, recently, one of the calls for funding suggested that universities that did not necessarily have a track record in a particular area but had some capability or emerging capability should also be included in the research proposals. That is something that should be further incentivised because there are a number of universities out there, some of them with developing capability, and it is important that we look right across the piece and try to bring some of those institutions on, where they have not previously been active in those areas. Clearly, international projects and opportunities to collaborate would be attractive and are likely to bring more people in.
Professor Llewellyn Smith: I would think the universities will get into these areas if they see there is a demand from young people who see a future in them. I can give fusion as an example: 10 years ago, there was very little in British universities; Culham was more or less isolated. Today we have 40 PhD students who we co-supervise, we have links with 20 universities and a number of those universities—Imperial was always in there—but Warwick, York and others, are setting up courses in these areas because young people suddenly see this as a very exciting area to be in and the universities respond to that and then will create posts.

Q40 Dr Iddon: You talked about the progression from plasma physics to a requirement for engineers. Personally, as a member of the former Science and Technology Select Committee, I have been to Japan to see their fusion experiment and I have also visited you at Culham in the past. What kind of roles will the engineers be playing? Are they going to be building the plant? There was a big problem, of course, with the ceramic linings at one time, is that still a major problem?
Professor Llewellyn Smith: No, that is not a problem. Developing the nuclear components in the walls which will turn the neutrons that come out of fusion, capture them and create the heat; these are very challenging areas of extremely exciting engineering. There are huge materials issues, we have links with a very large number of universities in the relevant materials research where there is a big overlap with Generation IV needs, finding suitable materials, which will stand up to high neutrons and also to high temperature where there is a big overlap also with any thermal power plant, you want to get the highest possible temperature that gives you the highest efficiency. The area we want to get into is designing the trickiest part, which is where the intellectual value will lie. Whatever industry takes the lead in those will get the profit eventually, assuming we succeed.

Q41 Chairman: In how many years' time?
Professor Llewellyn Smith: Let me tell you why it is always 50 years ahead before I give an answer to that.

Q42 Dr Iddon: Well, it was 30 once was it not?
Professor Llewellyn Smith: It is less than that. My colleagues in America, in the mid-1970s, gave a prediction at the time and they gave it as a function of the money. They said that if we get this amount of money, we will have a prototype reactor in about 35 years. They said, if you give us 20% less, it will be 40 years; 30% less, and at a certain level they said we will never get there with budgets at less than that

level. So the predictions were correct. As a function of money, the money was not there as a function of time, it was not taken sufficiently seriously. The fact is that we are now building ITER, the International Tokamak Experimental Reactor which will take about 10 years. We will then want to run it for about 10 years to have competence before building a real power station, then we will be ready to build a real power station. So that is another 10 years, it is 30 I am afraid.

Q43 Dr Iddon: That is assuming you get over the planning problems?
Professor Llewellyn Smith: No, that is solved. It is going ahead in the South of France. I will be there on Wednesday.

Q44 Dr Iddon: That is good. This is a difficult question for you. Do you think there is a future for Culham's research once ITER is up and running?
Professor Llewellyn Smith: Absolutely, because ITER, like CERN, is going to be a user organisation. It is not going to have an in-house team of people operating it. The users will come from outside so there will be a need outside to be designing experiments and then commuting to and from the site to carry out the experiments. There will be a need in parallel, ITER alone is not sufficient, there is a huge need to develop the technology. That is why I and my successor who will be taking over in a few months want to move the British programme slowly over the next decade into the engineering phase, which is where the future will lie.

Q45 Dr Iddon: I am aware of your research, the Japanese research and the Russian research in this area. Is that the triangle, or are more people interested in it?
Professor Llewellyn Smith: I would say that the leaders in the world are Europe, followed by the United States and Japan.

Q46 Dr Blackman-Woods: We know that some universities have departments of nuclear physics, but they also have the capability in nuclear engineering that might sit somewhere else in the university, are we confident that they are doing different things? Should there really be stronger links between them?
Dr Baldwin: I wanted to ask whether that was in an institution or across institutions?

Q47 Dr Blackman-Woods: I guess it can be both, but I suppose links within an institution to start with.
Dr Baldwin: I think that it is very important that there are clear links within an institution and certainly the institutions that I am familiar with are looking to engage by having some sort of umbrella oversight of all the activity that is taking place in a relevant discipline. We are all very aware of the challenges of duplication and we want to make sure that the work we do is complementary. In terms of internally, we would definitely be looking to take a co-ordinated approach and to ensure that the relevant activity, wherever it lies within the university is co-ordinated and joined up. We are certainly doing that with our university-wide strategy for nuclear activity. Then if you go across the institutions, it is also very important that we are talking to maximise the opportunities in terms of research and also in terms of delivering learning and teaching programmes. The industry is not that big when you compare it with other industries, so it would be silly for us all to compete within the same programme areas. Consequently, it is important that we work together. In the North West, we are just pulling a group together which consists of ourselves and Manchester and Lancaster, to name some of them, and what we are doing within that group is trying to adopt a co-ordinated approach to our activity in the region.
Professor Billowes: Nuclear physics is the fundamental science which underpins all nuclear applications in energy, health, decommissioning. The nuclear physics groups in United Kingdom universities exist because they can do international leading research, which is not in areas that will affect the energy programme directly. We would not get money to do any work in, for example, nuclear data because it would not be regarded as internationally leading. The advantage of having nuclear physics expertise in universities, is that they do an awful lot of the undergraduate teaching at nuclear level to a lot of physicists. When we started running this national masters programme, most of the full-time students joining that programme came in from physics and not engineering schools. Many of the nuclear physicists are also involved with health physics teaching and radiometrics and they go on to transfer and like the Head of the Nuclear Department at HMS Sultan who is an ex-nuclear physicist, and Malcolm Joyce is a Lancaster nuclear engineer and an ex-nuclear physicist. So nuclear physics produces people who are showing leadership in nuclear engineering areas and they provide the early nuclear education for undergraduates on physics programmes, not on engineering programmes, so I think it is very important.

Q48 Dr Blackman-Woods: So, your argument is that we need both, but also that we need links between them?
Professor Billowes: Absolutely, yes.

Q49 Dr Blackman-Woods: I came in just as you were discussing the skills gap and I was wondering whether we could just look in a bit more detail at whether we have enough capability in nuclear engineering at the academic level to support the skills gap so that we get nuclear engineers for the future?
Dr Garwood: I think it is important to recognise that there is a skills gap, not only in nuclear engineering which it clearly is, but in engineering in general and so unfortunately we need both those things to be supported, both the specialised nuclear courses and

good quality engineers giving us the background, the feedstock, for the nuclear engineers in the broader sense for the future.

Q50 Dr Blackman-Woods: Do you think the issue is being sufficiently addressed at the moment, so that we ensure that we have enough trained graduates for the future?
Dr Baldwin: The question we have is that the capability still exists within the universities to provide the required education. The key for us all is increasing the numbers of people coming into those subjects. I agree with my colleague that it is really general engineering that we need to promote and then there will be elements of nuclear activity that goes around that. I was alluding earlier to the fact that I think we have a number of initiatives that are now in place or are being put in place that will address that issue and we are looking at it from all levels from foundation degree through to undergraduate levels to post-graduate programmes. The fact that we have already been able to identify that we are coming together across universities, between universities and with increasing amounts of employer engagement so that we are directly responding to what the employers want, we have got a number of initiatives coming through that will address the issues that we have got. We have got a lot to do to reach the numbers that we require, but I think we are moving in the right direction.

Q51 Dr Blackman-Woods: How far advanced are plans for the National Nuclear Laboratory and can you tell us what you think it is going to do and what you would like to see it do?
Professor Billowes: What I think it will do is: it will be the people in Nexia Solutions who are the rump of the experts from the nuclear industry, and they will get no new money and they will be earning money from their customers and providing them with the expertise in plutonium chemistry or whatever the need is at the time. What I think they should be allowed to do is get engaged also in international research and development work, which would have to be funded by the Government.

Q52 Dr Blackman-Woods: Are there any other comments?
Dr Garwood: I would just say that it is good that the National Nuclear Laboratory is forming. It is necessary, but not sufficient. We also need industry to develop its skill base to support the whole industry.

Q53 Dr Blackman-Woods: So, if there were two things that you would like it to do that it is not doing, what are they, in summary: two things that you think it is not going to do that it should do.
Professor Billowes: It will not be doing basic R&D, because it will not be able to afford it. It has to earn money from its customer base and that is keeping existing plant running.

Q54 Dr Blackman-Woods: How advanced are plans for C-NET, the Centre for Nuclear Energy Technology?
Professor Billowes: We are raising money for Phase 1. It is the Centre for Nuclear Energy Technology at Manchester University. The Director has not been appointed yet, but he will be a professor in reactor technology and safety assessment. There are four main areas which we want to cover and they are areas where we perceive there to be critical skills shortages in the fission industry. So the areas that we will have are reactor systems and engineering, materials performance, mechanical engineering, and society and sustainability. Phase 1 funding, we hope, will come partly from the Northwest Regional Development Agency, self-funding by the University of Manchester; we have got private funding for a new chair in nuclear fuel technology, with candidates being interviewed this month. We have recently had the University of Manchester receive its largest single endowment in its history specifically to support this nuclear area.

Q55 Dr Blackman-Woods: How can it relate to the National Nuclear Laboratory?
Professor Billowes: Again, because it is university based, it will be basic research, it will be people, increasing the skills that we have within the university so that we can provide independent advice where necessary, and it will produce people. We see the National Laboratory as transferring application of that research into the industry so, obviously, we would want to work closely with the National Laboratory in that basic research area.

Q56 Dr Blackman-Woods: Is the level of industry and Government support to both these projects sufficient?
Professor Billowes: I cannot say yet, we are still trying to raise money. But it is going ok.

Q57 Chairman: Professor Billowes, can I very briefly take you back to a conversation we had earlier: whether our universities through HEFCE should be creating—this is something you have alluded to before—the basic engineering qualifications, which should be bringing students through at undergraduate level that have got a good broad base in engineering, and therefore it is the industry which after that should be picking them up and at masters-level, sponsoring them and supporting them under the Government's co-funding model, in order to do that. Is that a model you would favour?
Professor Billowes: That is the model that we have tried. Undergraduate level is going to work as long as you can get school leavers to go on those programmes. There is no problem there, other than people doing maths, physics and chemistry in schools, there might be a problem there. At masters-level, if we rely simply on industry uptake of those courses, they are not viable at the moment.

Q58 Chairman: Right, so it will not happen at the moment?

Professor Billowes: To be viable, if we do not get funding next year from the Research Council, we will probably have to change our business model and knock out a large part of the portfolio. In the portfolio, we try to cover all the areas that we identify as being necessary—materials aspect, regulation, licensing, and safety assessments. We would have to start knocking this down to a basic core, and one of the courses that would have to go at the moment is the NTEC programme, which is the only programme that offers students experience on a working reactor: they can operate a working reactor, they can measure properties of a working reactor and to do that, we fly our students to Vienna on the TRIGA reactor at the Atom Institute. That is expensive to do and we do not get funding to do that. Imperial have lost their reactor at Ascot, which used to do this for the United Kingdom.

Q59 Chairman: Yours is a university that is very entrepreneurial in the way in which you approach higher education at the moment. That is not a criticism, that is a compliment.
Professor Billowes: I took it as a compliment.

Q60 Chairman: Good, just for the record. In terms of our European counterparts, do you feel that they are supporting much more strongly the programmes for nuclear engineering, particularly the masters and doctoral programmes?
Dr Baldwin: We are just looking at our relationships and partnerships in Europe, so it is perhaps a bit early to say whether they are being better supported. I would feel happier commenting on the system that we are using in this country. I think we have probably got a model that is developing that is potentially is fit for purpose. The key is that it is going to require quite a shift. It requires a shift in the employers' and industrial organisations' understanding of the needs of education. Then there is a two-way process because it is then incumbent upon us within education to identify what are the key issues and how we can work together to address those. We need to incentivise employers, in terms of the engagement, and the co-funding approach is an incentive. I also think that the Higher Level Skills Pathfinder, which has funded considerable development of programmes, has been an incentive and once you have the opportunity to collaborate on development in the initial phases with resource support, you then get the buy-in from the employers and the recognition, by working together, that you can meet the training requirements and you can significantly reduce costs. There has to be greater partnership activity and greater levels of employer engagement between universities and education providers and the industry to ensure that the systems work. The framework is there and in place but we have just got to begin to exploit it better.

Q61 Chairman: Let me just come back to you, Professor Billowes. In terms of the Research Councils themselves, I presume that you bid for funding from both STFC and EPSRC?
Professor Billowes: I do, and STFC support the nuclear physics side and EPSRC support the nuclear engineering side and perhaps applied nuclear physics.

Q62 Chairman: Does that cause a problem? Do you feel that the pathway is there for some joined-up thinking?
Professor Billowes: Some things can fall between the gaps and STFC are also beginning to see this. They are beginning to get concerned about knowledge transfer from nuclear physics into the industry, particularly in the applied nuclear physics area which also covers reactor physics and nuclear data. I have had personal experience of trying to see how to get funding for people to specialise in physics of reactors and nuclear data because it is not classed as world-leading research, so EPSRC and STFC would not normally fund it as a standard grant.

Q63 Chairman: So there is some work to do in that direction?
Professor Billowes: Yes.

Q64 Chairman: Can I finish with you, Dr Garwood. In terms of Rolls-Royce, how much work do you do with universities in terms of propulsion?
Dr Garwood: An enormous amount.[1]

Q65 Chairman: Do you fund that or do you expect the State to fund that?
Dr Garwood: We fund it but, of course, it is the Ministry of Defence's money. However, as you probably know we are forming a small group looking at where Rolls-Royce could operate within the energy business, in civil nuclear in particular, in the future and we are looking at a UTC in this area, too. Rolls-Royce itself puts £4 million of funding into our nuclear research and development. It is swamped by the Ministry of Defence money, which is about £100 million, but it is still a significant contribution, which goes directly to the universities, and is the seed corn money which concepts develop from.
Chairman: On that note, I am going to finish this first session. May I thank Professor Sir Chris Llewellyn Smith, Professor Jonathan Billowes, Dr Stephen Garwood and Dr Graham Baldwin. Thank you all very much indeed.

[1] *Note from the witness*: "In the specific area of Nuclear Propulsion research funded by the MoD via contracts with Rolls-Royce, £1.5m of funding is currently in place with UK universities. This is planned to increase with the development of studies on the next generation of submarine reactor plant."

Witnesses: **Clive Smith, OBE**, Skills Development Director Nuclear, Cogent Sector Skills Council (also representing the National Skills Academy for Nuclear), **Robert Skelton**, Vice President, Institution of Nuclear Engineers and **Michael Grave**, Vice President, British Nuclear Energy Society, gave evidence.

Q66 Chairman: May I welcome our second panel this afternoon, Clive Smith OBE, the Skills Development Director Nuclear of Cogent, also representing the National Skills Academy for Nuclear, Robert Skelton, the Vice President of the Institution of Nuclear Engineers, and Michael Grave, the Vice President of the British Nuclear Energy Society. Welcome to you all and thank you very much for coming into the earlier session. May I start with you, Clive, please. There are reported United Kingdom skill shortages in nuclear engineering. Are they simply a reflection of this general shortage of engineering skills, or are they very much specifically to nuclear because we just have not done nuclear for a long time with serious intent?
Clive Smith: There are some very specific hot spots: reactor physicists, for example, have risen on the Immigration Border Agency shortage category to allow immigration in that area; there are reported shortages in the Health and Safety Executive with nuclear inspectors—perhaps not surprisingly, as you need very experienced chaps, so they would be very much at the latter end of the age spectrum—and some other very particular areas. It is a general shortage and I think it goes back to what you were discussing in the last session, that there is a general shortage of engineers and scientists. Indeed, what employers generally tell us is that what they want is good engineers and scientists, which we can then "nuclearise" so that they can work in the context of nuclear. Many of the skills across nuclear, or oil and gas, or any other industry, are transferable engineering and science skills.

Q67 Chairman: Do you share that, Michael?
Michael Grave: I certainly do. Not with a BNES hat on, my company works in all the major industries such as oil and gas, conventional power, nuclear, and we are basically looking for graduate chemical engineers, mechanical engineers and project managers, which is another area that is particularly difficult to get hold of. These graduate trainees, when they come into the company, could end up in any industry at the end of the day and I strongly support what Clive said that it is important to get people with the right sort of engineering good general background qualifications at the beginning and then we can give them career development training into other areas.

Q68 Chairman: Robert, do you share that view?
Robert Skelton: Yes, I think that is correct. One of the problems that the nuclear industry has got is that it was *the* industry to go into in the 1950s and 1960; it was the growth industry, so of course the age profile is significantly higher than perhaps most others. I know from the Institution of Nuclear Engineers, our age profile is significantly weighted towards the older age group, although in fact it quite surprised me to see that applies to professional engineers in general, it is not just nuclear engineers.

Q69 Chairman: Can I raise this issue with you, when I was a young chap and the first wave of nuclear power stations were being built and nuclear engineering was very lively in our universities and in colleges at technician level, it was all basically owned by the Government. It was under one roof and since then it has been fragmented significantly to a point at which it is very much now all within the private sector, within different small pieces. If you take, for instance, the decision about Westinghouse being sold off, is not the fragmentation of the industry causing the skills problems as well?
Robert Skelton: It makes the industry less attractive. We are beginning to see the corner turned on this one, we are seeing organisations like the NDA setting up graduate training programmes. Certainly a lot of graduates, I am also from the University of Cambridge and the chemical engineering departments, and the graduates like to go into companies where they can see good training and a good future. To train people in general engineering with perhaps specialities in nuclear engineering is really the way to go, because I think it is more attractive to both the companies and the students. I, personally, think fragmentation is a very big problem. When I joined the industry, it was either the Atomic Energy Authority, BNFL or CEGB and that was basically it.

Q70 Graham Stringer: Has not the fragmentation and privatisation meant that there are higher salaries at the top end for engineers?
Robert Skelton: At the top end, yes, but I am not certain just how far down that applies. I do not honestly know. People like to see a training programme, someone who can give them an integrated training programme and that is why our students in chemical engineering would far rather go into companies like the oil companies, Proctor & Gamble, the big companies like that are much more attractive to them generally than the smaller companies.

Q71 Chairman: But, Clive, not so long ago, the BNFL would have offered exactly the sorts of career path and opportunities that Robert is talking about and as far as training, it had a reputation that was very high indeed in terms of training and progression. Do you think that the National Nuclear Laboratory is going to fill that gap?
Clive Smith: It might, in part. We were talking about the fragmentation being part of the picture. The other part of the picture was the image of the industry; it was very much a nuclear industry in decline. Everything was working towards shut-down, towards decommissioning and, whilst there are some pretty exciting challenges in decommissioning, the overall perception is knocking things down. For a young graduate, newly-qualified technician or craftsman, knocking something down does not seem quite as bright and exciting as building something new and operating a new plant and getting to grips with running a new plant. The

7 July 2008 Clive Smith, OBE, Robert Skelton and Michael Grave

image of the industry as well was something that was not attractive for this limited field of engineers and scientists to come in. The formation of the National Nuclear Laboratory, the potential for new build and all of these initiatives—I think you heard at the last session, that student numbers are increasing, it is pretty crude and rough data, but the number of students on the Birmingham MSc is the most this year that they have ever had; there are universities opening up nuclear undergraduate courses. So it is becoming more exciting and more people are now starting to come in, and starting up the NNL will assist in that perception.

Q72 Chairman: Michael, just briefly, is the NNL a good idea?
Michael Grave: Yes, it is a good idea. I am doing some work with the National Nuclear Laboratory[2] at the moment, in terms of the European Framework programmes that you mentioned, in the field of decommissioning. I rather agree with one of the previous speakers at the previous session who was concerned about whether they will get involved in fundamental forward thinking research or not. The bit I deal with at the moment is very much associated with decommissioning.

Q73 Dr Blackman-Woods: Given that the shortage in nuclear engineering skills is an international problem, do you think the United Kingdom will be able to attract people with the necessary skills, even if we load points into our points system to attract nuclear engineers here? Is that really going to happen?
Robert Skelton: So much depends on career prospects and the end of the stop-go policy, which is another thing that has put people off. We have had this stop-go policy for so long. The last major project I was involved in was Sizewell B. It was going to be one of six reactors and everybody was extremely enthusiastic; we were going to have a new design and were going to build six of them for once. We were then going to build four of them but only one was actually built. We have got to show some continuity to attract anybody, both from overseas or from the United Kingdom.
Clive Smith: I want to back up what Robert just said. All the messages coming out are for a bright, attractive and vibrant industry, and that should assist in that attraction.
Michael Grave: You must not forget about the excitement of the part of the industry; the thing that excites companies; the level that my company works from is the possibility of making a profit. You put your business plan together and then you can recruit the people. The energy industry in general at the moment is so buoyant, it is quite easy to recruit new people into the industry because there is a big future seen there. You have got two sorts of problems: not only is there a world situation about the nuclear industry, but there is a big world resurgence in energy in general at the moment and there are other energy industries competing with the nuclear industry for resources as well. I have just been to the German Nuclear Society annual conference in Hamburg a few weeks ago, and almost the identical stories were being told over there that we have got here. It is a pretty worldwide problem, as you say.

Q74 Dr Blackman-Woods: Ideally, putting the current shortages aside and looking at what we would really like, what would the skills landscape look like in order to ensure that we can move forward in the United Kingdom to new build intelligently? What would we need that we have not got, or what would you like to see?
Clive Smith: A much larger pool of engineers and scientists in the United Kingdom from which all our industries can fish from. That is a big joining-up problem across Government, not just for the support to make different energy solutions, but across the universities and the school sectors, making sure that were getting a constant message to have that pull-through of people.
Michael Grave: It is not only getting the engineers, it is getting the school children motivated right and getting a joined-up path from school children through to university through post-graduates and PhDs and continuous development right to the end of their careers. And not only at the engineering professional levels, it is important to have the technicians and supporting people with the skills and the trades. Underpinning all that, it is important that we need scientists as well, because engineers basically start off studying science in most cases.

Q75 Dr Blackman-Woods: Is the capability of the supply chain necessary to deliver new nuclear power stations important as well?
Michael Grave: The supply chain capability will appear, in our experience, if there is the market to do it; engineering companies will come along and do it.
Robert Skelton: A guaranteed market for more than one reactor, that is the problem. If we can see, as they have in France, a guarantee that Britain is going to implement a nuclear power programme then, not just the education establishment, but everybody will see that it is worthwhile tooling up to do it.
Michael Grave: There is global risk, for example the company that owns the company that I work for is building five nuclear power stations at the moment in Korea and we are invited "if you fancy a career in Korea, to go and work in Korea", so there is a draw all over the world for engineers. We have a lot of Koreans over here as well.
Clive Smith: That would be very much a global supply chain.
Michael Grave: It is a global issue.

Q76 Mr Marsden: I would like to go down a bit on this skills shortages issue, but if I can take you back to something that was just said in response to the Chairman to Roberta: you talked about the industry having a bright, attractive, vibrant future, and the Chairman referred to his salad days when it was the done thing to go into this area. That was the time when we were all moonstruck too and we know what happened to some elements of that. The serious

[2] *Note from the witness*: "I am doing some work with Nexia Solutions Ltd, which will become the NNL"

point I want to make is, you are talking about having this grand design connecting between schools, colleges and universities, do you not still have a major image and cultural obstacle to overcome? The written evidence that we had from the Department about the actual diversity in the nuclear industry at the moment says, "The nuclear industry is 82% male, and overwhelmingly white, with females mostly in stereotypical roles". First of all, is that a fair description at the moment, and if it is a fair description and you think it is something you need to overcome, how are you going to overcome it?
Clive Smith: I thought the percentage of white males was higher than that in the nuclear industry, so you have been quite generous. We have discussed the history of the industry and the fact that it went into decline. There was not a large recruitment; many of the people who were recruited into the industry in the 1960s and 1970s into engineering jobs, particularly the nuclear industry, were white and male. There is also a geographical factor; the diversity around the remote sites where many of the nuclear power station staff come from is a generally white population; it is not reflective of the multicultural city mix and so we will not ever get it towards that much greater mix, but there is the ability to increase the gender and ethnic mix.
Robert Skelton: There is an historic factor here. When I joined the industry most of us who did joined the Atomic Energy Authority or BFNL. No matter at what sort of level you were working, you needed a fairly high level of security clearance. Even contractors, way into the 1980s, had to be United Kingdom citizens. It was not just for the Ministry of Defence projects or BFNL projects in those days. This automatically of course tends to bias you certainly towards the white, if not necessarily male.

Q77 Mr Marsden: I hope you are not going to suggest that women would be less secure than men.
Robert Skelton: No, but it must be the age profile of the industry. In my undergraduate days, there probably was not a single woman in engineering. Even now, at Cambridge, we have only got about 20%.

Q78 Mr Marsden: Is this a problem?
Michael Grave: I see it as something else. We have an organisation in the British Nuclear Energy Society which we call the Young Generation Network[3] and, interestingly, against all the trends, since the enthusiasm for decommissioning and nuclear and even keeping the existing stations operational, our membership has changed from about 1,000 people with 10% of people who we call young—and I will not tell you why it is under the age of 37, but there is a reason for that—now 40% of our membership is of the YGN age and we have about 1500 or 1,600, and 50% of the chairmen of the YGN in the last six years have been women and very good at that, in fact.

[3] *Note from the witness*: "Associated with the European Nuclear Society also"

Q79 Mr Marsden: Can we move to the issue of competition. We have heard from UCLAN that they believe there is going to be competition between decommissioning and new build for talent in this sector. Is that inevitable; is it a good thing or a bad thing?
Clive Smith: It is inevitable, and if you take the military programmes also, there will be competition with those programmes, it is an inevitable fact that the industry has got to get over and ensure that salaries are attractive enough to retain people within the legacy part of the programmes, as well as the new build.

Q80 Mr Marsden: Is it showing new build to do that?
Clive Smith: We have not actually started much on the new build yet, so there is little evidence.

Q81 Mr Marsden: So, it is too early to tell. Can I move on to the issue of the qualification levels at which there is a shortage of engineers and perhaps again to take the view from Clive, although I welcome the comments from Michael and others as well. According to the graph that was submitted to us by Cogent and NSAN, there appears to be an oversupply of engineers at NVQ levels 1, 4 and 5, and a shortage at levels 2 and 3. Why, therefore, has the discussion around the solutions to skill shortages been so focused on universities. Again, picking up your previous point about the seamless track, do we need to do more in FE colleges and industry in providing nuclear engineers?
Clive Smith: From the last session, where it was mainly the HE sector, certainly the discussion there would have been focused on 4 and 5. The NVQ level 1, I think we can discount; there are very few elementary trades, much less than 5% of the industry are at that level, and that is part of making sure that people leave school with the right levels of qualification. Generally, for the people entering the industry, the bottom qualification is NVQ level 2. We are starting to get solutions and see a seamless track through there; the implementation of the diplomas in engineering and in 2011, the diploma in science will give qualification routes through from the traditional GCSEs but now in the diplomas, entry into foundation degrees, foundation degrees up into honours degrees, to give learning and career pathways for people to progress, and also the right qualifications for people to operate a skilled trade or technicians.

Q82 Mr Marsden: Michael, Robert, do you see that in your areas?
Michael Grave: I generally agree with that. In the industry I work in, we are largely concerned with keeping existing nuclear power stations going and our work requires largely number of trades people, some who progress to become site engineers and site managers. I was reading an article in the paper the other day by Sir John Rose from Rolls-Royce, who was making a comment that a large number of their apprentices go on through career development to getting a degree at some stage. There is going to be an interchange between people who perhaps start off

at what I call a skilled trade level who, through career progression, also eventually get degrees. It is quite a complex matter.

Q83 Mr Marsden: There are lots of ins and outs.
Michael Grave: Yes, lots of ins and outs.
Robert Skelton: There is a problem, not just faced by the nuclear industry. Bodies like the Health Service face this sort of problem as well. There is a significant shortage at technician level, which is basically where that gap appears. I wonder if it is partly because of the way our education system has gone. Many people in the past may have been interested in a career, becoming an apprentice, or joining organisations, say, post-O-level as technical trainees at various levels, experimental officers, to use the old Civil Service term. These people now go on to something totally different. It is a national problem which we really have to address. Countries like Germany perhaps address this a lot better. Coming from Cambridge, I am a little bit biased, but I am not 100% certain that sending so many people on degrees in various non-technical subjects is really the right thing for the nation. It is a reflection of our education policy that this gap has opened up and people who in the past would have become technicians, experimental officers, now go off elsewhere.

Q84 Graham Stringer: I want to go back to something we have touched on before. The Government are changing the image of the nuclear industry from being a sunset industry to having more of a future. Is there anything the industry itself can do to change that image as well? The Government has given it a big boost, is there anything else that can be done? What else would you do to change the image?
Clive Smith: It has been in the background that the media reported the contamination, the dirty image of the industry, that is very much cleaned up. I do not think there is an awful lot more the industry can do to present itself now as the clean industry for the future. It has put a lot of effort into making sure its image is much better than it certainly has been in the past.
Michael Grave: One of the things that concerns us in the British Nuclear Energy Society—we do not represent the industry, we represent professional people who work in it—was that one of the fragmentation issues, which somebody raised earlier, has led to a lot of the visitor centres at nuclear power stations, which have always been a major source of keeping the public informed, are not there. There is one very good example still left at Sellafield, which does excellent work, but in the British Nuclear Energy Society, when we were looking at our education and training initiatives that we might do in the future, I remember pointing out to our trustees two or three years ago that the British public at some stage are probably going to have to be in a position to make a political decision, if you like, on new build and therefore the public needed to be made aware of the issues of nuclear power. So, we are funding this year, for example, out of our education and training committee budget, a small study by somebody at City University, to look to see how we could possibly make up this deficiency which has started to develop. We would not be able to do it on our own, but we are looking at the issues that might improve knowledge exchange amongst the public at large, not just the engineering people who we normally work with.

Q85 Graham Stringer: That is a very interesting point. Why is Sellafield so different from other nuclear installations? Why are they not all doing it?
Robert Skelton: What happened, as I understand it, the old CEGB used to have excellent visitor centres at all of their power stations; they used to lay on all sorts of things for schools and did a marvellous public relations job. When British Energy got into their serious financial difficulties—what must be four or five years ago—they basically closed all of their visitor centres as an economy measure. We used to take people to Sizewell and that closed; as far as I know they have all closed. It was a commercial decision taken at the time when they were in a very serious financial position. Most of the buildings are still there and it is time they thought very seriously about reopening them.

Q86 Graham Stringer: That is very interesting. We talked a lot about skills gaps and shortages, are the solutions in training and skills gap, are they primarily resource-based financial, or are there structural changes that can be made?
Clive Smith: There was a general lack of apprenticeships at one stage. The new National Apprenticeship Service is coming on; the National Skills Academy for Nuclear is invigorating apprenticeships for nuclear, which will assist in filling what could be classified as a structural gap, in that we were not putting apprentices through the system. There is a lot of work going on in filling that gap and putting in place apprenticeships and through the network of regional training providers that NSAN is establishing, making sure that there is sufficient joined up thinking between the colleges and industry to provide those apprenticeships in the areas where they are required and to an acceptable quality assured standard.

Q87 Graham Stringer: Can you tell us how the nuclear skills passport will help in this process and is that passport tailored to apprenticeship level or to the authoritative intelligent customer capability?
Clive Smith: It is focused across the skills pyramid. The work being done at the moment takes it up to about the NVQ level 3 and 4, but the ambition is to make it go through the whole of the skills pyramid and it will include within it the apprenticeships. Initially, the backbone of the passport, the Nuclear Industry Training Framework, will be to lodge four qualifications but with a view to, by 2010, putting on bite-sized qualifications so that people can see what qualifications they have got, what they need to achieve to continue to move up through the learning pathway and the career progression pathway, all the way from entry NVQ level 2 up through level NVQ level 4.

Q88 Dr Iddon: We are also looking at the Leitch Report with respect to skills across the engineering sector. One of the things that comes out is that there are just too many organisations trying to do essentially the same thing. Does that apply to your industry also?

Robert Skelton: Basically, we knew this question was coming, or at least we thought there was a good chance that it would. The first thing we can say is that Michael and I at the moment represent two different organisations and we have come today from a meeting where we are discussing merging, and it is almost certain that the two bodies in the nuclear industry will be merged by the end of the year. There are a lot of engineering institutions; we are looking at ways of working more closely. We have had discussions with the Institution of Chemical Engineers to see how we can work more closely with them. We are doing our best to ensure that in terms of our learned society activities, organising meetings, etc., all the major engineering institutions work together. Historically, it is just the way things have developed and I am sure you will know that many people—going back to Sir Monty Finniston and quite a few other people—have tried to knock the heads together of the various engineering institutions with very little success. It is a system which, in the United Kingdom, does actually seem to work.

Michael Grave: I would just like to add a comment to that. The BNES was actually founded in 1962 by all the major professional institutions, recognising that there needed to be a co-ordinated nuclear approach. It is nothing new and continues today and will form part of the new Nuclear Institute also and we continue to work closely with all the other professional institutions. It is very important. Not only that, putting an industrial side on it, one of the big problems that we found in our company is the different training qualifications that are required if you want to work with this nuclear site here and that nuclear site there. Our big hope and aspiration, and we support it 100%, lots of industries are joining and working on NSAN which is driven by industry need and the big hope is that NSAN will succeed in getting certain skills development level all working together and singing off the same hymn sheet. I sit on one of the NSAN steering committees as a BNES representative and I am quite heartened about what I am seeing in terms of doing this. Somebody said earlier that we have some concerns as a citizen about skills but looking at what is going on in NSAN and their plans, I have also got a lot of confidence for the future that we will sort these problems out.

Clive Smith: The funding routes are quite tortuous and diverse and it is being able to understand where they come from to assist industry. Much of industry is confused about where it can draw the funding down from LSCs, from RDAs and other sources; through the assistance of NSAN that should help in co-ordinating those funding routes.

Q89 Dr Iddon: I know of Cogent because I am a chemist and it represents pretty well all the chemical industry, but it represents quite a varied sector of industry, including your own. How successful has Cogent been for the nuclear industry?

Clive Smith: Very successful. It has managed to pull the employers together to try and undo some of that fragmentation and through establishing and now launching the National Skills Academy for Nuclear within the Cogent footprint, providing a real deliverables vehicle for training and education for the nuclear industry. Whilst you have said it is diverse, it is the same engineering science skills required by the chemical industry, as required by nuclear, as required by oil and gas—Piper Alpha has been in the news again this week—a big safety regulated industry through the HSE, the same as nuclear. Much of the same basic skills and safety regulatory requirements come to the fore in all those industries.

Q90 Dr Iddon: You mentioned Germany, Robert, as being a country which may get skills training better than ourselves. Do you admire any other countries? The French have got the biggest nuclear fleet per capita, is their system of training skills for their industry better than ours and better than Germany's? Who is ahead? Who should we be looking at as a model?

Robert Skelton: I must admit, I find it hard to comment too much beyond the graduate level. I used to work in industry and I know that a shortage of technicians has always been a problem.

Q91 Chairman: The question was, who else is there as a model?

Robert Skelton: Yes, I wonder if Clive has a better view on this.

Clive Smith: I do not think I am qualified to answer that.

Michael Grave: I cannot answer that except to repeat to you a statement by a German human resources person to me in Hamburg the other week, who envied the system we had in the United Kingdom.

Chairman: Well, I think on that note of self-congratulation, we will end this session. Clive Smith OBE, Robert Skelton and Michael Grave, thank you very much indeed for joining us this afternoon.

Wednesday 16 July 2008

Members present

Mr Phil Willis, in the Chair

Dr Roberta Blackman-Woods
Mr Tim Boswell
Mr Ian Cawsey
Dr Ian Gibson
Dr Brian Iddon
Dr Desmond Turner

Witnesses: **Dr Ian Hudson,** Engineering, Technology & Skills Director, Nuclear Decommissioning Authority; **Mr Alex Walsh,** Head of Civil Nuclear Programmes, BAE Systems; **Ms Fiona Ware,** Vice President Operational Excellence and Transformation, AMEC's Nuclear Business; and **Mr Bill Bryce,** Chair, New Build Working Group, Nuclear Industry Association, gave evidence.

Q92 Chairman: Could I welcome our first group of witnesses to this evidence session on nuclear engineering inquiry as part of our major inquiry into engineering. Dr Ian Hudson, Engineering, Technology & Skills Director, Nuclear Decommissioning Authority; Fiona Ware, Vice President Operational Excellence and Transformation at AMEC's Nuclear Business; Alex Walsh, the Head of Civil Nuclear Programmes at BAE Systems, and, last but by no means least, Bill Bryce, the Chair of the New Build Working Group at the Nuclear Industry Association. Dr Hudson, perhaps I could start with you. When we heard from the Institution of Mechanical Engineers they said that "the UK's capacity to build a new generation of nuclear power stations is uncertain." The Royal Academy of Engineering said that "the UK could by no means be self-sufficient in the building of a new generation of nuclear power stations in the timescales required." Last week, however, when we met Professor Billowes from the Dalton Nuclear Institute, he said to us that the UK had not "missed the boat". They cannot all be right or they cannot all be wrong. Who is right?
Dr Hudson: For clarity, the principle interest of the Nuclear Decommissioning Authority is in decommissioning and clean-up. Within the Energy Act we do not have any formal role in terms of new build. If you take the decommissioning mission and the clean-up mission, we can see some shortages in certain areas, and those areas tend to be areas where we are competing with other industries. In terms of attracting other engineers into the industry and having enough people to do the job, from a decommissioning perspective we do not see any real major shortages right now. We have, however, introduced skills, plans and programmes for the sites that we look after, so we understand the medium to longer term, so that from our perspective we understand the problem well enough that we can take action now.

Q93 Chairman: Are you not hugely complacent? We are talking about a level of decommissioning which this country has never seen before, with virtually all our nuclear power stations over the next 10 years being part of that process. At the same time, government is looking at encouraging new build, and perhaps four or even 10 nuclear power stations. Are you confident that all those engineers are out there?
Dr Hudson: I do not think we are complacent: I think that would be unreasonable. Three years ago, when we first started with the estate, we asked all our site licence companies to put in place a proper skills strategy which understood the need. For the first time, across all those sites, that strategy is in place. NDA itself is investing over a period of five years around £40 million. Through leveraging and partnering we have doubled that amount. There is an ongoing investment through the site licence companies of around £13.5 million per year, which equates to about £800 per person, and that is probably double the UK average in terms of investment in skills. I do not think we are complacent at all. I think it is important to us. We are starting from a base where we are starting to understand the problem, we are taking action, and we are focusing on working with the rest of the industry to meet those needs as well.

Q94 Chairman: From the rest of the panel, could I have a quick comment on my initial question.
Mr Walsh: I think there is a job of work to be done in developing the bid but it does not mean that it is not addressable. I think that actions are already in place. We are heavily recruiting at the moment and we are heavily training. There are certain contractions happening in other areas of the aerospace industry, for instance, where there are very good structural welding engineers, aeronautical engineers, who have skills which are transferable with a degree of cross-skilling. It is addressable.

Q95 Chairman: It is doable.
Mr Walsh: Yes.

Q96 Chairman: Fiona, is it doable?
Ms Ware: Yes, I think so. We now have long-term visibility for the plans for a number of the programmes: the decommissioning programmes, the new build programme. Having that long-term visibility enables AMEC and other parts of the supply chain to plan to respond to that. We are doing an awful lot of recruitment. We are working with universities and working with schools, trying to

encourage people into science and engineering, to make sure that we have the right resources available when we need them.

Mr Boswell: It is obvious there is a big lump of work to do, both in terms of decommissioning and commissioning new build. These are not identical skills but they are related. Two constraints occur to me. One is the time scale. Alex, you said, you have been at this for three years. These things do not happen immediately. Can we be sure that the training, even if it is now being embarked on, will be delivered in time for this additional work? Second, it is not only the training but also the capacity to train. Is that too being addressed?

Q97 Chairman: Bill, could I bring you in on that, please?

Mr Bryce: If I could take you back to your initial question: Is the UK self-sufficient? It obviously is not, because we do not in the UK own a nuclear design, so we therefore have to be dependent on the international nuclear system vendors. That is a good thing because we then join a worldwide club, operating the same type of reactors as many other countries throughout the world. This gives us the benefit of learning (a) from the building of these reactors and (b) from the operation of them.

Q98 Mr Boswell: And pinching their skilled people if required.

Mr Bryce: If we possibly can, yes—or maybe not pinching but interchanging, because there is the opportunity to put people from the UK into some of these other countries with the nuclear vendors or with the utilities. My own company, Doosan Babcock, is owned by Doosan Heavy Industries & Construction of Korea. We are building five nuclear stations in Korea at the moment and we are also supplying the steam generators and pressure vessels to Westinghouse for their China orders and supplying replacement bits into the USA. There is a lot that we can learn by interaction with the international nuclear club. In terms of the resources within the UK, there is a squeeze of resources. No company is sitting with spare people hanging around in the prospect of a project coming in five years time or whatever. However, the industry is gradually building up its confidence, through government initiatives, in the setting of frameworks, et cetera, and this confidence is enabling industry to put more investment into training and into recruitment. It is a hard job—it ain't easy at all—but it is manageable. Provided there is the concerted effort, I think it is going to be capable of being done. We do need continuity. I go back to Ian Hudson, the NDA, and this supply work at the moment. It must continue to supply work in a continuous way.

Q99 Chairman: When we were down at a nuclear power station yesterday, we were being told very, very strongly that what were required were engineers—electrical/mechanical/civil engineers—in order to do the major construction, fitting out and running of these major plants. But this comes at a time when there is huge pressure form other sectors of the engineering community. I do not have a clear picture yet as to where all these people are going to come from. We are being told as a committee that there is a huge shortage of engineers now.

Mr Bryce: Maybe not huge, but there is a shortage. There are more severe shortages in some areas than in others. When you talk of engineering, I would like to be clear that we need to talk about the wide spectrum, from the trade skills through to the PhD levels. We require all of these people. We require them in different numbers and we require them at different times. For new build, we do not require a large number of nuclear design engineers because the new power stations are going to be internationally designed—for example, one of the nuclear vendors says that by the time we get around to building the first one in the UK, it will be the ninth or tenth that they will have built worldwide—but we do need large numbers of general mechanical and electrical and project management people. These are the people who are going to build the things and commission the things. Where are they going to come from? They have all drifted into other industries over the years, and when they see a forward market and career opportunities, they can be attracted back.

Q100 Mr Boswell: Their skills are transferable probably.

Mr Bryce: Many of them are transferable, yes.

Q101 Chairman: You think these people already exist.

Mr Bryce: Some of them do. We need more.

Q102 Chairman: With the greatest of respect, though, that is not the information that seems to be coming in terms of the workforce survey studies. Certainly nuclear engineering, to start with, has an age profile which suggests that a significant number of people are going to retire in the next 10 years, and that profile seems to be in every branch of engineering. Are these people going to take pills and become younger?

Mr Bryce: You are correct, and that is why I say that in some areas there are shortages. We need to be taking steps to change that.

Q103 Chairman: Okay. Perhaps I could turn to you, Fiona. In terms of coming back to the nuclear industry, obviously it is an exciting time, if we are to believe that all is going to come to pass, both in terms of civil and in terms of military capacity. What do you think are the largest challenges for the UK nuclear industry over the next 20–30 years?

Ms Ware: It will be dealing with the growth and regenerating an interest in the industry, because it has been a static industry or an industry in decline. I think the industry is now responding. Visibility, again, and commitment to the Government for the sustainability of some of these longer-term programmes makes it a more exciting industry, and I think that makes it more attractive to bring more people into the industry. I do not think that decommissioning is seen as particularly exciting to a large number of the population; whereas new build is more exciting, is more attractive to bring people into the industry. One of our challenges will be to attract people into the industry.

Q104 Chairman: Dr Hudson, there seems to be a view that, because of a lack of commitment to new nuclear build over the last 15 or 20 years, we have lost that attractiveness, that capacity. What are the strengths and weaknesses of the nuclear industry as you see them at the moment?
Dr Hudson: There are a couple of strengths. To build on something Fiona said: if you look at the decommissioning industry, I would say that about five years ago the interest was not particularly great. When the NDA came on the scene you could see some things change. For instance, for the Masters degree in Decommissioning Engineering at Lancaster the intake has been trebled over the last few years, just because of the interest alone. If you look at the attractions for the industry, the first thing is that the industry offers long-term career opportunities, not just in decommissioning but across a range of operations—so that is quite important; it is an international business; and, also, it sits between government and commercial. It is quite interesting: you can experience commercial opportunities, commercial innovation, you can work with government, and you can work with the regulators, so the diversity of challenge is quite significant. With all the positive press that is associated with nuclear at the present moment in time, we are seeing a renewed interest. To some extent, from a decommissioning perspective, there is this sort of magnifying effect which we can see in some of our graduate programmes. For our nuclear graduate programme we had over 1500 people apply, and we had about 10 or 12 places; in the second tranche we are up to past 700, again for about 10 or 12 places. Just for that particular scheme alone you can see that interest ratcheting up.

Q105 Chairman: Is it the same for BAE Systems? Would you echo that?
Mr Walsh: It is not necessarily the new build which has made the industry unattractive. I went to university in 1979. That was just after Three Mile Island had happened. I decided to do a nuclear engineering degree because I considered it to be the "green" thing to do at the time. After Three Mile Island there was a big swing in public opinion.

Q106 Chairman: Slightly, yes.
Mr Walsh: I remember the nuclear engineers were the pariahs of the college. The number of youngsters who wanted to go into nuclear engineering fell off. The nuclear engineering degrees shut down before the end of the new build with Sizewell B. There was a real public swing which said that this was not an industry that you would want to get into if you were a youngster, so I do not blame the stopping of new build for the youngsters not coming in. I think we have to show that it is an attractive industry. It is a very green industry. That is the type of thing which will appeal to the youngsters and start to attract them into the industry.

Q107 Dr Gibson: I do not have a picture of how many people you think you might need to do the work that the Government are giving you. Are we talking about thousands of people? Hundreds? Somebody must have done the sums, surely. There must be some strategy, at least, somewhere.
Mr Walsh: In Sizewell B during the construction, at the peak there were about 3,000, but most of those were general engineers, civil contractors and the like, but then you would have the supply chain as well that supports that, which would probably multiply it out—I do not know, but I would guess—to 20,000.

Q108 Dr Gibson: Come on, you guys should know. You are in charge of the whole business, are you not? Who knows?
Dr Hudson: I can offer a view from a decommissioning perspective.

Q109 Dr Gibson: A view? I want the facts.
Dr Hudson: I can give you some information. On the back of the skill strategy that we have, we have about 20,000 people across all our site licence companies. Around 25% of those are engineering graduates and then 48% of those would be technical. If you map that out over the next 15–20 years, you can see a steady decline to about 2015 from our mission, then you see quite a marked reduction from 2015, and then you see another marked reduction from 2020. From an NDA perspective across those site licence companies, we can map those figures out, and we can map the technical competencies across that. Those are facts and those are based on the lifetime plans. Invisible within those plans are the various scenarios that may come out of government policy, and the decommissioning of subsequent British Energy reactors and MoD decommissioning as well. Those are not in our plans.

Q110 Dr Gibson: Are you recruiting? Are nuclear engineers being recruited?
Dr Hudson: We are recruiting.

Q111 Dr Gibson: Where are the adverts? In *The Sun,* in the *Mirror?*
Dr Hudson: We are recruiting. We take about 170 graduates a year. The strategy we have taken with the nuclear graduate scheme is not to be advertising in places like the *Times* or the *Telegraph* but to work with the career services in universities and to get the message out through that. We had an event about two weeks ago, where there were 170 people from the range of universities across the UK, and something like 25 or 30 industries from the nuclear footprint as part of the event. It was starting to build that relationship. For instance, on the nuclear graduate scheme, the numbers I told you about were without the advertising in the *Telegraph*; they were all about building the relationship with the academics and the students. It is a different approach.

Q112 Dr Gibson: Are you confident that you are going to get home-grown students? Are you going to get your workforce from people from the universities and other places, or are you having to do like the football teams do and go abroad to get three-quarters of the team?
Dr Hudson: From the clean-up perspective, we have attracted enough people from the home-grown talent. You can see that in the graduate schemes. We do get enough people like that. We also get the attraction of international people as well. If you take the recent contract award at Sellafield, it is only a small number—you are talking about a number of 20 or so in terms of the senior management team—but through that contract they bring people who are called enhancers, who come in for periods of up to two years to work with the local population, transfer some of those skills, and then go off, leaving the skills behind[1]. It is always an issue in terms of getting local home-grown talent. In decommissioning it is different: we do not have the same constraints as the military perspective. I do not know if any of my colleagues can offer a view about that, but from a decommissioning perspective we do okay.
Mr Bryce: I can quantify it a bit. Excluding the military side, which Alex may be able to enlarge on, there are currently about 40,000 people in the UK employed in the nuclear industry directly, and then there are another 80,000 to 100,000 covering the support to the generating stations, clean-up. There is really not a lot going on in new build at the moment. As time progresses, the number involved in clean up is going to reduce, as Ian has indicated, but then the new build programme is going to start kicking in, we hope. For a new build programme, excluding those things that the UK cannot supply—for example, the reactor pressure vessels and the turbo generators will need to be imported—typically we are talking of probably about 1,000 to 2,000 jobs in the manufacturing industry, we are talking of about 3,000 jobs on the site construction—these are direct jobs—and, along with that, probably about 50% more in supporting them. When we come to the operation, we are talking of probably 300 people full-time, operating a new nuclear station, with about 100 to 200 in support—that is coming from the contractor support—and then another 1,000 people in the community getting indirect jobs.

Q113 Dr Gibson: Would you put your salary on the fact that you are going to get these? Do you think the educational systems and so on are up for it?
Mr Bryce: No, we are going to have to compete for many of these jobs.

Q114 Mr Boswell: Internationally?
Mr Bryce: Internationally, yes, for a lot of the manufacturing work. For the site installation work, we would expect UK industry ought to be in a preferred position, because we do not see the nuclear vendors at Westinghouse or Areva importing large quantities of blue-collared workers. Once again, we are going to have to compete for the work, and we are going to have to have these people, and, generally, the industry is addressing the recruitment. If I could mention my own company again, we have a very intensive recruitment and training campaign that is including people from overseas; targeting the Armed Forces looking for Army, Air Force and Navy veterans; and targeting schools, getting in at the secondary school level, and all the other members of the Nuclear Industry Association are doing similar things. With that sort of effort—and, as I said earlier, it is not easy, we have to keep pushing it—we should be able to take a fair share of this work.

Q115 Dr Gibson: Do you think people from abroad are just more skilled than our people at the minute?
Mr Bryce: No, I do not think so. We have been importing quite a number of people from Poland and from Portugal. Their qualifications are not totally interchangeable, particularly for putting them on to nuclear plant, and we have had to do additional training and additional certification to use them on nuclear plants.

Q116 Chairman: In terms of the very top skills, the sort of PhD-level nuclear scientists and nuclear engineers that we are going to need on a whole range of different projects, niche people, where are we going to get those from? They are not coming from our universities at the moment?
Mr Bryce: Not at the moment, but I think in a few years time they are going to come.

Q117 Chairman: Dr Gibson's question is really quite specific. You seem to be saying that there is a market out there. Like Manchester United or Chelsea or Dundee United will simply go and get the best players—it is just an in joke—
Mr Bryce: I hope we are going to be more successful than Dundee United!

Q118 Chairman: What is industry doing to make sure that UK plc has these people? Or is it just down to the university system?
Mr Bryce: No, I think the industry is importing some of these people. They are working overseas, because this is an international market.
Chairman: I have got that point, but what are we doing to get indigenous, UK people?

Q119 Dr Gibson: Are you paying their PhD studentships for them? Are you paying off their student debts?
Mr Bryce: Are we, as my company?

Q120 Dr Gibson: Yes.
Mr Bryce: I do not think we are.
Mr Walsh: We are not paying off their student debt; we are paying good wages to graduates coming in. During the last year we have recruited five graduates specifically into the nuclear area and we have put in for a nuclear engineering training.

Q121 Chairman: I am talking now not about graduates. I am talking about post-docs.

[1] *Note from the witness:* "The contract I referred to was not 'awarded'- we announced the preferred bidder".

Mr Walsh: We have taken one in.

Q122 Chairman: One.
Mr Walsh: Our first PhD student this year into the nuclear area. We have taken in three people with a Masters degree. They are coming through things like Birmingham's Physics, Technology and Nuclear Reactors course. That is a very good course.

Q123 Dr Gibson: Are you excited by having four new people?
Mr Walsh: Yes, I am. In total, the number of graduates that we have taken on this year is 85. We have taken on 165 apprentices. We have just been out and started recruiting A-level students, to bring them in. If we get our apprentices, we run a high potential apprentice scheme for those top level apprentices we take on and we push through as fast as possible.

Q124 Dr Gibson: There are too many ifs in your answer. You are not sure.
Mr Walsh: I am sure. We do put people through university degrees.

Q125 Dr Gibson: Fiona, you are champing at the bit there. Tell me about Gen-IV. What is happening?
Ms Ware: I will, but perhaps I could go back to what you asked before. AMEC has a long heritage of looking after some of these skills and capabilities from when we built the last fleet of stations. We have put money into the PNTR MSc at Birmingham, we provide lecturers at Surrey, and we provide industrial sponsorships to sponsor PhD students. We have recently started participating in the Eng D programme. We only took one as a trial, because it was a new programme, but we are planning to take more. We are taking 70 graduate trainees on this year. The majority of those will have a Masters degree. We generally take three or four people a year from the Birmingham Masters degree. Moving on to Generation-IV: participation in the international research programmes is a way that we have managed to maintain and transfer skills. Whilst there has been no new build in the UK, through participation and work on the Gen-IV research programmes, through ITER and JET, the fusion programmes, and also through the European frameworks, those are really good packages of work where we can get our more experienced engineers to transfer their skills to the junior engineers. It is very difficult to do that on commercial contracts because the client will not pay. They will pay for one person to do the work. We have relied heavily on those research programmes, to develop, to maintain and to transfer skills.

Q126 Dr Gibson: What has happened with Generation IV? How much does this industry put in, how much do the Government put in? Do you have to buy your way to the table?
Ms Ware: The Government were due to put in £5 million, but that funding was cancelled last year, which was a disappointment.

Q127 Dr Gibson: That is bad news. How are you going to substitute for that? Are you going to put the money in yourselves? You are going to be a rich industry—or you are a rich industry.
Ms Ware: The difficulty is the long-term nature of it. We ourselves are part of the supply chain but we are not a utility. We do not have the benefit of saying, "We'll invest in future generation reactors because we will get the benefit because it will be our design later." We have taken rather an altruistic view, perhaps, to say that we will do what we can to participate in the programmes because we know that is how we would keep those high level skills alive. It has been very difficult.

Q128 Dr Gibson: But you are not going to get a Christmas card or an invite to the table to talk about these things unless you are paying your whack, basically.
Ms Ware: Yes, and I think we are disadvantaged when you look at other European countries. If you look at France, in particular, they have complementary parallel programmes, so that allows industry access to the extra funding so that they can participate in the programmes. Within the United Kingdom we have an uncoordinated approach and we do not have any parallel programmes, so that makes it more difficult to compete.

Q129 Dr Gibson: What other international programmes are we participating in or should we participate in if we want to get to the top table and get new schemes going and education, your PhD students, and double your numbers from four to eight, for example? You are going to have to get into these international programmes.
Ms Ware: The Government, I believe, are signed up to GNEP. There are no programmes of work yet that have come out of that. We would ask for continued support to that. The Government signed up to Gen-IV and then the funding was not forthcoming, so if we know that—

Q130 Dr Gibson: Who should foot that bill? Should the Government restore it or should you have some kind of collaboration?
Ms Ware: I would like to see the Government restore that funding.

Q131 Dr Gibson: Of course you would. At the same time, the Government are not going to by the sound of it, are they?
Ms Ware: I do not know. We would like to think so.

Q132 Dr Gibson: Does anybody know? You must know, Bill. You are the boss.
Mr Bryce: Before I answer your question, the thing that is going to set the industry in the UK up for the future is a healthy clean-up programme, successful clean-up and a healthy new build programme. That will start attracting people. There is no point in doing research if we do not have the application of it. Once we have both of those things—and we cannot go into new build sacrificing clean-up. This is

very important to all of industry as we go forward, to make sure that we do not pinch the guys from the clean-up side and switch them into new build.

Q133 Chairman: Can you concentrate on the question that was asked.
Mr Bryce: Coming back to the question: with that basis, if we can get ourselves into a sound clean-up and new build programme, people will be attracted into the industry and you will see the numbers increasing quite dramatically.

Q134 Dr Gibson: That is what you are saying.
Mr Bryce: But I think Government are going to have to prime the pumps on these more advanced research programmes. Industry is not going to put its money in at this stage in substantial amounts because it is a long time before payback will be achieved. There are several projects. ITER is one. Gen-IV is another. Industry is somewhat reticent to get involved there because the payback is looking very, very doubtful.

Q135 Dr Gibson: In the long term you are going to need that research, because nuclear plants and styles and so on and the operation change.
Mr Bryce: That is right. That is why I say: get ourselves established with new build of Generation-III and the rest will spin out of that.
Dr Gibson: Good luck.

Q136 Dr Iddon: Is everybody on the panel agreed that the skills required for decommissioning are roughly the same as those required for new build? In other words, if we train people for decommissioning, can we roll them over into new build?
Mr Bryce: There is a lot of new build going on to enable decommissioning to happen. There are several new facilities being built in Sellafield—and Ian can say more about these—and, therefore, these skills can roll over. In fact, they are a bit more critical because the work that is going on in decommissioning is an active plant, a radiologically active plant. There the nuclear disciplines have to be so much more severe because you are dealing with the radioactive conditions. Therefore, all the very stringent nuclear procedures are being learned and practised today in the clean-up process and these will spin over.

Q137 Dr Iddon: Perhaps I ought to turn to Ian. Do you see the NDA's role as partly to enable this roll over from decommissioning to new build? Do you think you have a role to train people through your decommissioning work, so that when new build ramps up we have sufficient skills available?
Dr Hudson: I think that is an interesting question. From an NDA perspective, let me try to answer that in two parts. The first thing is that NDA can only invest to support the clean-up mission in the way set out in the Energy Act, so our investment is around supporting the clean-up mission. We are investing quite heavily, and we can talk about that in a minute. There is a recognition, though, that some of those skills are transferable, and it has happened in the industry. Historically, if you look at the NDA, for instance, we have people who built reactors who are now pulling reactors down. We are focusing on transferable skills which are with the nuclear industry, so when we move people from operations into decommissioning we can get that flexibility of workers, so we are building that into our strategy. But it has to be dead clear, from our perspective, that we do not have a role in respect of new build. We are not allowed to do that.

Q138 Dr Iddon: In their submission BAE has suggested that the UK should ramp up decommissioning work to increase skills in readiness for new build. What sort of assurances would industry need to make significant investments in core staff and facilities?
Ms Ware: In terms of decommissioning, as I said before, we now have visibility of the lifetime plans. Seeing that there are long-term programmes and that there is funding available is enough to encourage the supply chain to respond and to grow the capability. For new build, I think it is government support. The industry suffered during the last period of new build, because we built Sizewell, and there was an expectation that that would be a programme of reactors, and it was only one. A lot of companies prepared themselves and geared up to do that and then the opportunity disappeared. What is required really is a commitment to a programme and the supply chain will respond accordingly.

Q139 Dr Iddon: AMEC have suggested that there should be a stronger interface between the civil and military activities in this area. Security is the obvious barrier, but what other barriers are there? Is the main one security or are there other barriers preventing an interface between civil and military activities?
Ms Ware: Probably there will be commercial reasons. As AMEC, we are part of the supply chain, so we provide resources into all of the sectors, into reactor operations, into clean-up, and into Rolls Royce and AWE. We see there is transferability of skills and we can help in terms of transferring best practice from one section of the industry to the other. From an AMEC perspective, I can comment that skills are transferable. How the sectors work together is probably more a matter for people in the team.

Q140 Dr Iddon: What do the rest of the panel think about this interface. Is it easy to transfer from one sector to another?
Mr Walsh: BAE Systems is heavily involved in the construction of nuclear submarines. That is what we do. There are limitations as to how we can employ foreign nationals on those projects because of the security implications. I personally have worked in the defence industry and in the civil nuclear construction industry and at Sizewell B. Half of the Sizewell B nuclear commissioning team came from America or Czechoslovakia or Spain—from all over the world. The reason for that was that when you are at the commissioning stage and you are on the critical path with one of these projects and the

16 July 2008 Dr Ian Hudson, Mr Alex Walsh, Ms Fiona Ware and Mr Bill Bryce

majority of the capital expenditure has gone, you need the best, most experienced engineers with you to mitigate the risk of something going wrong, that programme being held for a day and £1 million of electricity not being generated. You are very keen to have not just qualified engineers but people who have done it before in other power stations. That is why we went around the world. I do not doubt that when we come to do the first power station in this country, at that end of the programme we will have foreign engineers to help us, or we will have needed to take UK engineers, like the CEGB in the 1980s, place those engineers out into foreign construction projects so that they can pick up their experience and bring it back to this country. The other thing that happened at Sizewell was that in 1991, as the Cold War came to an end, the Government made the decision that we did not need as many nuclear submarines. As a result, it retired a bunch of those and an awful lot of nuclear-trained people came out of the Navy. A lot of those nuclear-trained people ended up at Sizewell B, working for me in my nuclear commissioning team. They were excellent. First class. Those skills were perfectly transferable in there and they were some of the core of the nuclear team. Having done one nuclear commissioning, they would have been ideal to have led the next nuclear commissioning in this country. The problem now is that we have a smaller nuclear Navy which is not giving the same amount of retirees coming out to help in that area, and when we go outside and go international, this time to look for those skilled engineers who have done decommissioning before, unfortunately they are going to be employed on the American programmes, because the Americans are looking for 30 power stations, and the Chinese are going to be building. There is a massive demand, so getting those people is going to be an issue. That is why, in my submission, I made the point that we really do need to help industry now get people out on foreign placement into these construction and commissioning projects, so they can bring back experience and be ready for our projects to take off.

Dr Hudson: When you think about skills, once you can get over the security implications from a military perspective, the people are transferable very applicably, as well explained by Alex. Skills are also developed through the use of certain facilities. There are some more subtle issues, in terms of carrying out military programmes and civil programmes in the same building. Whilst it would be nice to get complementary facilities where you can build up some of those skills, you have to think a bit more carefully about how you make those facilities available and use them across the different parts of the industry. It is just that point I was interested in making.

Q141 Dr Iddon: Nobody has mentioned France. They have one of the biggest nuclear fleets. Are they an international outfit working in France? Are they mainly French engineers? Is there any transferability there between our near neighbour and ourselves?

Dr Hudson: I have just a bit of anecdotal information. The French have some good programmes in terms of skills. France is comparable, from a UK perspective, with what we do. I was in the States a couple of months ago and the same issues were being discussed over there, because you have the same issue of the indigenous population, you still need those. Whilst Areva and people like that are active in the States and keen to be part of the nuclear build over in the States, they themselves recognise the fact that they are going to have to work with the local population to build up the skills. You still need to do that from a UK perspective.

Q142 Mr Boswell: I am interested in the relationship between government on the one hand, academia and industry, and whether these are all tuning in together. In AMEC's evidence you refer to "the complexity and number of the public sector . . . training initiatives where there is increasing overlap between the remits of the various bodies, and between academia and industry." Could you say rather more precisely what those problems are, and perhaps you could give us some examples?

Ms Ware: When I first got involved with some of these bodies I found it extremely confusing in terms of the remit of the sector skills councils and the overlap between the sector skills councils.

Q143 Mr Boswell: Are there about six in this area, if you tot them all up?

Ms Ware: There is Cogent and the ECITB and the CITB. There is a number and it is quite confusing. We get approached as part of the supply chain by a number of these because AMEC works across a number of sectors. One of the issues is that a lot of the skills are not sector specific, so it is quite confusing. Also, the way that they work is different. Some operate under levies and others are under voluntary contributions.

Q144 Mr Boswell: Do you have the impression that in terms of their influence as sector skills councils they get their act together and unify their offer, or are you always having to negotiate between them in order to fit into their programmes?

Ms Ware: I sit on the Cogent Nuclear Employers Steering Group and that was a way of trying to say that we want the sector skills councils to be more joined up, because they are not, and they do offer different types of training. In the nuclear industry, we have the creation of the Nuclear Skills Academy, which is great. When you look at the agenda that was set out for that, it was set out by industry. When you look at the funding, the funding has been provided by industry, because it is industry-led. If you look at the flipside, with the ECITB, where we are levied—and I can only speak for AMEC personally and, in particular, the nuclear sector—we do not get an awful lot back from that. We do not get involved in setting the agenda. Where industry is driving what is required, the funding will follow, because industry knows what it needs.

16 July 2008 Dr Ian Hudson, Mr Alex Walsh, Ms Fiona Ware and Mr Bill Bryce

Q145 Mr Boswell: To pursue that—and it may be more relevant to another inquiry we are carrying out—at least the rubric is that sector skills councils are industry-led.
Ms Ware: Yes.

Q146 Mr Boswell: Does anyone else want to comment on that sort of perception of SSCs?
Dr Hudson: When I came to the NDA about three years ago, there seemed to be quite a confusing picture around Cogent and the footprint that Cogent had. There was a change in CEO and the regime in Cogent. We sat down and spent quite a bit of time working with them to try to understand what our needs were and what they were trying to achieve. I would say we have worked pretty well with them in respect of helping create the National Skills Academy for Nuclear and built up some of the occupational standards and things like that. I would agree with Fiona, the mixture of different sector skills councils is difficult. If you look at the ECITB situation and NSAN, it seems to me there is a potential policy difference. On the one hand you have NSAN, which is run by the employers or employer-led. They do not deliver skills; they set standards and franchise people to meet those standards. On the other hand, you have ECITB, and they levy. The only way you can get your levy back is by using their products, and they may not necessarily be products that, as employers, we would want. That policy difference is still there.
Mr Bryce: Yes, there should be much more integration. There is a little bit of competition for funds but the different boards, the ECITB, the NSAN, et cetera, are willing to talk with one another. In fact, the NIA is trying to progress that so that we get everybody singing from the same hymn sheet, because they are complementary.
Mr Walsh: The ECITB we use a lot, because of the apprentice training schemes that we run, so they are very important to us. We engaged with Cogent a few years ago and very much the focus of Cogent has been driven by the focus of the industry over the last few years on nuclear decommissioning. That now needs to start swinging a bit more to what is going to be the nuclear new build as well, but that is only natural at this stage of the game, when there are no further orders and we have only just started to see the commitments going forward.

Q147 Mr Boswell: Who is the appropriate body then to rationalise these initiatives? We have identified that there is a bit of confusion. Who is going to blow the whistle on this?
Mr Bryce: That is a difficult question. Cogent is in a position to do this. The NIA has been asked if it could do this but it is quite a big task. The NIA is limited by its funds which come from a subscription from the members. If the members wanted to do this, we would be willing to do it but there would need to be a bit more money put in.

Q148 Mr Boswell: Is that a general view?
Ms Ware: I think it is wider than that because it covers a number of sectors. I think there was a recommendation in the Leitch report that the number of bodies needs to be rationalised. I do not have a short answer as to how we might do that because it goes across a number of industries in a number of sectors, so it is difficult to say one organisation would take that responsibility.

Q149 Mr Boswell: Perhaps I could stay with you and ask, concerning the proposed UK National Nuclear Lab, why you think there will be unfair competition between the academic world and industry.
Ms Ware: The point we are trying to make is that we need to make sure there is not unfair competition.

Q150 Mr Boswell: There does not have to be but there might be.
Ms Ware: Yes. The remit of the National Lab needs to be clear. I think the lab will have a remit to protect and nurture skills, and I think it needs to be very clear that industry also has a role to play and a lot of those skills belong within the supply chain and within industry where they are deployed on real jobs. Whilst we support the need for a national nuclear laboratory and some co-ordination in terms of some of the research in the programmes because the UK is fragmented, it needs to be clear that this is not just about creating programmes that would sit within academia or within the National Lab but it is about involving and engaging industry to make sure that the skills are transferred into industry.

Q151 Mr Boswell: I notice you nodding, Ian. Is that the view across the panel, that that is the right kind of way to approach this issue?
Dr Hudson: I think so, because you can maintain skills through initiatives such as the National Nuclear Lab but it is quite important that you maintain skills throughout the supply chain as well. You get different approaches. You get a slightly more commercial, innovative approach linked into the supply chain; you are able to take a slightly longer-term view through things like the National Nuclear Lab. I think the National Nuclear Lab needs to have its role linked across the supply chain as well as the academic establishment and operate around that agenda. A lot of the key skills in the National Nuclear Lab were mostly focused around the access to facilities, which are large capital facilities that carry out active work that industry does not tend to have access to because of the huge capital outlay. Making those facilities available into the broader supply chain helps build those skills.

Q152 Mr Boswell: That will be available to anybody, even if they are a comparatively minor subcontractor who could use the large facilities.
Dr Hudson: The aspiration from NDA's perspective is that you give access to the broader supply chain and into the universities. That is the aspiration.

Q153 Mr Boswell: AMEC has called for a demarcation between the application of technology in industry on the one hand and pure research taking place in universities and the National Nuclear Lab on the other. I take it that is, as it were, a management view which is not necessarily uncongenial to the other members of the panel. If we are going to do that, how are you going to bridge the gap? If you are making a conscious separation of mission in that area, how do you integrate the missions as part of the national effort to get nuclear decommissioning and new fleet build at the same time? How do you tune that?
Ms Ware: I think it comes back to being clear about the remit of the National Lab, if some of the programmes are going to be going through there. It is making sure that that industry is involved and it is not in competition with academia. Ultimately the skills need to come through from academia and they need to reside inside the National Nuclear Lab, where their needs will be nurtured if there is not a commercially acceptable way of doing that. If it is commercially viable to do it, then the supply chain is well able to do that itself. I think the role of the lab is to protect some of the skills which are critical. Currently a lot of the commercial programmes do have short term requirements as well as long term, and some of the short-term programmes perhaps do not need those skills. There is a requirement to maintain those, therefore, but I think it is just making sure that with some of the research programmes industry gets access to participate, that the skills transfer comes from academia out into industry and that they do not retain them in academia because there is a need to transfer to industry.

Q154 Mr Boswell: The point at which, as it were, the flag drops is with the National Nuclear Lab. Or, rather, it requires the active involvement of the industry as well as the academic world.
Ms Ware: Yes. Absolutely. There needs to be a partnership.

Q155 Mr Boswell: You are nodding, Ian.
Dr Hudson: Absolutely. We have been involved with BERR to support the creation of the National Lab. We see it as very strategically important to us to deliver our mission. Making those facilities available on a national and international perspective is very important.
Chairman: On that positive note, I turn on to Ian Cawsey.

Q156 Mr Cawsey: Thank you, Chairman. Earlier in the session there was a little bit of discussion about the role of the Nuclear Decommissioning Authority. As you said, it does what it says on the tin, and that is what the Energy Act allows you to do. But of course these things can change, and in a period of new commissioning it might be an appropriate time to change. Would you like to see the scope of the authority broadened? What would be the rationale behind such a move?
Dr Hudson: It is an interesting question and I do not feel particularly qualified to offer a view. I think it is a government decision, so from an NDA position it is not something I would like to speculate on.

Q157 Mr Cawsey: You do not have a personal view on whether it would be helpful?
Dr Hudson: I do not believe I can offer a personal view, sat here on behalf of NDA.

Q158 Mr Cawsey: Does anybody else want to say whether he should be expanded?
Ms Ware: I think that some co-ordination is required. With the fragmentation of BNFL—and the NDA came in to oversee that—the industry itself has fragmented, so in terms of new build there needs to be some kind of co-ordination, whether that would go to the NDA or an alternative body.
Dr Hudson: I could offer a view into it. Our skill strategy is to partner with people. For instance, in creating the National Skills Academy for Nuclear, the fact that it covers a nuclear footprint and we are able to participate in that we see as very positive. I think getting more consistent approaches to the skills agenda, getting a consistent approach in terms of understanding needs is important but you do not necessarily have to do that with respect to NDA.
Chairman: You did have a view after all.

Q159 Mr Cawsey: It took Fiona to wheedle the answer out of him.
Dr Hudson: That was not a view.

Q160 How does the authority encourage companies to ramp up the skills base?
Dr Hudson: We have taken a number of things. Skills are important to us, as set out in the Energy Act. It is also important in terms of offering value for money to the taxpayer because it improves the performance. The first thing we have done is to take a strong leadership role. We have set requirements on the site licence companies to develop these skill strategies. They are incentivised to do an effective job on skills, so they gain profit if they do a good job and they lose profit if they do a poor job. We have done that over the last three years to drive that. When we invest in infrastructure—and we have done, for instance, at the high end of skills, such as the PhDs and Masters area—we have tried to do that in partnership with other people. For instance, in partnership with Manchester University, we put in £10 million and they put in £10 million to create an institute in areas of interest to us. We have invested in infrastructure to create a company called Energis. We put £5 million in, but by working with both government and the supply chain we have generated around £20 million to improve the infrastructure. We have taken a mixture of stances. We have taken a very strong leadership stance; we have incentivised it, so it looks important to us; and we have partnered, which is really very important because it improves what we are doing as well.

Q161 Mr Cawsey: You are funding research and new facilities, and the example has been given to us of the Dalton Cumbria Facility. What involvement is there between the authority and industry?
Dr Hudson: Through the site licence companies we invest around £100 million a year. Of the order of £50 million of that goes to the Nexia, which is the precursor to the National Lab, and the balance of that goes into the supply chain, so the supply chain benefits quite significantly from that investment. In terms of things like the Nuclear Institute, we are working with the University of Manchester. The model that we apply is that we invest as a catalyst to create the capability. We focus it on world-class skills and that capability is then able to draw down the money from the industry, from the research councils, and become self-sustaining. It is quite a fine balance and an interesting model, because you invest maybe over five or seven years to create the capability but it becomes self-sustaining by operating in world-class fashion. It is a good model. It was used by BNFL to create some centres at universities. We see that as really good because it allows you to create commercial innovative work as well a long-term commitment to R&D.

Q162 Chairman: Fiona, when you were responding to Tim Boswell you talked about long-term skills that were not funded by industry but which were of national importance. What were you specifically referring to?
Ms Ware: This is probably going back to when I was in Nexia—I worked in Nexia before I came to work for AMEC—some of the programmes such as the molten salts programme would be a long-term research programme but there was no short-term benefit there. Those projects were not funded through the site licence companies. There are programmes that the NDA will fund now through their research programme, but I think it is making sure that those programmes are available to develop some of the skills which we will require and we will need to maintain but which are not currently required on a commercial basis at the present.

Q163 Chairman: Perhaps you could have a little think about that and then drop us a very brief note about some of those specific skills.
Ms Ware: Yes.

Q164 Chairman: The same with you, Ian, in terms of the decommissioning. Perhaps I could finish this session with you, Ian. We are a little confused about the decommissioning time framework. That was brought home to us at Sizewell B yesterday. Within the next six years there are six nuclear power stations that are going to start their decommissioning programme, that are going to stop producing electricity. What is the length of the decommissioning programme? Perhaps you could put in a note to us on that. What factors are involved in dictating how long and, also, how much it will cost? There seem to be endless time scales for some of these decommissioning programmes and we would like to get a clear handle on that in terms of matching the skills needs to the decommissioning programme.
Dr Hudson: I can write a note to that effect. Generically, what affects time scales is a balance between removing the high hazard part of the plant, which is the fuel, and then making a decision about what the care and maintenance regime might be, what time scales that might be.
Chairman: You indicated earlier, and Fiona picked it up, that you now have clear programmes for decommissioning with proper time lines. It would be really quite useful to the Committee to have those.

Q165 Dr Iddon: I think we should point out, Chairman, that yesterday at Sizewell somebody indicated that the graphite core reactors could be decommissioned in less than 10 years. Nine years was quoted.
Dr Hudson: One of the roles that we fulfil on behalf of government is that the lifetime planner approach that we use for our science we apply to British Energy to get a sense of what the liabilities might be in the future. If you would allow me, I can certainly put a note together to that effect.
Chairman: We would be very grateful for that. On that note, could we thank you very much indeed, Dr Ian Hudson, Fiona Ware, Alex Walsh and Bill Bryce.

Witnesses: **Adrian Bull**, UK Stakeholder Relations Manager, Westinghouse, **Dr Mike Weightman**, HM Chief Inspector, Nuclear Installations Inspectorate, **David Barber**, Head of Technical Training, British Energy, and **Robert Davies**, Marketing Director, Areva, gave evidence.

Chairman: Let me welcome our second panel of expert witnesses this morning: Adrian Bull, the UK Stakeholder Relations Manager for Westinghouse; Dr Mike Weightman, HM Chief Inspector for Nuclear Installations Inspectorate; David Barber, the Head of Technical Training for British Energy, and Robert Davies, the Marketing Director of Areva. Thank you all very much indeed for coming this morning.

Q166 Dr Turner: Part of the torturous timeline for what kilowatt hour is generated in the UK is the Generic Design Assessment of the new nuclear fleet. We have received very little evidence relating to that. Is this because it is a perfect process or are the companies going through the process not wanting to rock the boat?
Dr Weightman: I would never claim any of our processes are perfect. We always seek to improve on them. This is a new process for us that was developed about three years ago. We put it to government after talking to stakeholders and finding out what the issues were. We also took some advantage of an International Atomic Energy Agency peer review of our approach to nuclear regulation in the UK,

especially in relation to new build. We were fortunate to have the chief regulator from Finland, for instance, provide us with some advice on that. We then put that documentation forward to the Energy Minister and I can provide Committee members with copies of that documentation. We put forward more detailed descriptions of it for possible vendors and again I can provide the Committee with copies of that as well. I could even give a note summarising it all, if that helps.

Q167 Dr Turner: Why are we doing this specifically as a UK exercise? After all, reactor design and deployment is a fairly international business. Given our strange history of previous nuclear development whereby we managed to produce something exclusively British and, frankly, worse than anybody else's, are we going to be repeating this? Why are we doing it differently to everybody else?
Dr Weightman: I would not say British reactors are worse than anybody else's.

Q168 Dr Turner: They have not lasted as long for starters!
Dr Weightman: My duty is to protect the people and society of the UK and that means making sure that the laws and the safety standards in the UK that are relevant are applied so they can be protected and feel protected as well. That does not mean to say we try and reinvent the wheel. We looked at our safety standards in the UK, which are called our Safety Assessment Principles, and we compared them with the latest international safety standards, both the International Atomic Energy Agency and the Western European Nuclear Regulatory Association reference levels as well, and we revised them and published them as a basis for us to regulate the industry in all sectors. We have tried to make sure we are up-to-date with the latest safety standards internationally, but there are particular aspects to the UK law and goal setting regime that we have to apply. That is not to say we are not very closely linked with our colleagues who regulate it in other nuclear industries internationally. We have agreements with the NRC, the Nuclear Regulatory Commission in the States. We have been talking to them about seconding people in, getting access to all their information and similarly with the French. In particular, I was talking to André Lacoste the other week about how we could liaise better and how we could get access to their information and we are getting free access.

Q169 Mr Boswell: Given that both in terms of build and to some extent also in operation this is not a national industry, it is an international one, can you give us the assurance that by and large, allowing for differences in, for example, legal structures, the intentions of the major regulators in most of the major countries where there are nuclear installations amount to the same thing, even if the expression of those in terms of GDA or whatever is slightly different?
Dr Weightman: Yes, that is our intention. The goal is the same.

Q170 Mr Boswell: I am not asking you to single out any defaults from that, but broadly that is happening?
Dr Weightman: Yes. Some of the variations will come from what operators want. If you look at the EPR design, some of the requirements that the operators in Finland wanted have made some changes to the cases and bases for the design of the EPR. There are some things coming from operators.

Q171 Mr Boswell: Could there also be some technical constraints, for example, on geological conditions, the likelihood of earthquakes and so forth?
Dr Weightman: The earthquake issue is unlikely to be a large issue in the UK, but there will be variations around there. I am thinking of the AP1000, for instance. When they had to look at that for the US market rather than an overseas market there were some variations they had to do and they put revisions in around that. There is a group called the Multinational Design Evaluation Programme that is put together by all the chief regulators of those countries that do have new nuclear in front of them. What we are seeking to do there is actually work very closely together, not to make use of each other's assessments and some of the assessments are not complete, but also get to a position where I do not have to send my inspectors half-way round the world, for instance, to check out procurement issues on reactor vessels that may be produced in Japan, I can have confidence that the Japanese regulator is looking at that. We are also looking at some of the codes that are used in different countries for pressure vessels and other systems and comparing the use of one in one country with its equivalent in another country. There is quite a bit of work being done around that internationally.

Q172 Dr Turner: Just how much variation is there internationally in standards? The implication is that we are having bespoke systems, if you like, which are likely to add to the cost. Are there any serious questions about international safety standards that mean that we have to do it differently?
Dr Weightman: No. The issue is not that the design may be different, it is a question of how you justify that design. In America they have a very prescriptive nuclear regulatory regime which will mean that the regulator produces detailed prescriptive regulations. We have a very goal setting regime which fits in with our law in the UK. So we ask the question "Why is it safe?" and we expect the vendor to come back to us and say, "It's safe because of these reasons," and give us the rationale for that and then say where the law requires them to reduce risks so far as is reasonably practicable. So we ask the question, "Can you reduce the risks further?" and they will demonstrate to us that they have done the design optimisation, but this is about putting the onus on the operators and on the designers, not on the regulator, to demonstrate safety through a prescriptive regime. It is a different regime. It may be that the design will still meet both requirements.

Q173 Dr Turner: Is there any problem as far as the Nuclear Inspectorate is concerned in getting access to sufficient technical expertise to carry out this process? Can you recruit enough engineers to run this process?
Dr Weightman: I think it is fairly well known that we have struggled with our recruitment campaign and our numbers. We have put out a pretty aggressive recruitment campaign. HSE, my parent body, is looking at that now to try and make sure we can go harder into the market and that is also being supported by government in terms of reviews that they are doing. You may be aware of the Tim Stone Review.

Q174 Dr Turner: How many engineers have you got and how many do you need?
Dr Weightman: I have got 153.25 full-time equivalent inspectors at the moment and in addition to that I have got eight that are being brought up to understand the nuclear industry and nuclear regulation from the rest of HSE where they were specialists. From our first recruitment earlier this year we expect to get another nine in and from just a recent recruitment we expect to get probably around seven in. That will only bring me up into the 170s. For existing predictive business excluding new build I need 192. That is looking at the MoD programme and the decommissioning programme as you go into the future because we regulate MoD facilities as well. Our planning for three designs coming forward eventually -because we have got step-wise in our Generic Design Assessment process—would mean an extra 40 inspectors around that. That is not the whole picture because we have a demographic problem as well. I really look forward to the pills that the Chairman talked about at the start! We have over 10% at the moment that are over 60 and that will grow in another year or so to about 20% and two years after it will grow to 30–40%.
Chairman: You are depressing us now!

Q175 Dr Turner: What effect is this going to have on the timescale for deploying new reactors? Is it going to slow the process down because you simply have not got enough people power to throw at the problem?
Dr Weightman: What we did in the GDA process was we stepped it to resource build up to reduce regulator uncertainty as we went forwards and we also manage the project risk associated with it as well. That means that we did complete step two within the proposed timescale with a lot of work and we put 50 reports out into the public domain about that, so about four designs. We have started step three. Those reports were basically saying, in terms of security and nuclear safety, because I also regulate nuclear security, these designs should be licensable in the UK if they meet their claims. We took their claims on face value. Now we are starting to explore the rationale for those claims and the details behind those claims. So we are starting this step three now. We have said that we are going to have a slow start on that because we do not have the resources in place for that, but some other mitigating factors may be that if we get aggressively into the market now we could then attract some more who are step four of the process to see whether we can recapture the lost time that will come from the step three slow start.

Q176 Dr Turner: So there are delays?
Dr Weightman: At the present time. We might manage to actually increase resourcing over our planned resourcing so that we can recapture some of the delays and perhaps we will get more benefits from our interactions with our overseas regulatory colleagues than perhaps we planned for, and there may be other aspects we can do around that.

Q177 Dr Turner: What about the costs of the process? Presumably your costs are borne by the public purse?
Dr Weightman: No, not at all.

Q178 Dr Turner: Could you tell us about the cost structure?
Dr Weightman: There are two aspects to that. Under the Nuclear Installation Act our normal cost for our work on licensed facilities is all recovered from industry plus all the overheads. Around 95 to 97% of our costs are recovered from industry through the Treasury, et cetera. In terms of new build and Generic Design Assessment they are not licensees so we cannot recover them under the Nuclear Installation Act, but what we did do is we got the Fees Regulations changed to make sure that we can recover our costs on a similar basis from the vendors and that is what is happening now. Our costs are not recovered from the public purse.

Q179 Dr Turner: We still do not know exactly what the size of those costs are and what percentage of the final cost of a new nuclear station they are going to be.
Dr Weightman: I could write to you with some of the figures.

Q180 Dr Turner: Could you give us a rough indication?
Dr Weightman: I think it is around about £5–10 million or so per design.

Q181 Chairman: Could I just have a view from other members of the panel as to the issues that Dr Turner has raised? How do you view the NII, Robert?
Mr Davies: It is under way. We are very pleased that the NII and the EA joined together; it is very joined up. We are concerned about resource. Tim Stone's eight-point proposals seem to be good. We are going to have to resource up and use more of the information from the other international regulators.
Mr Bull: I would agree with a lot of what Robert has said. We recognise that there is nothing more important than making sure that the process is done thoroughly and robustly and openly and transparently, in the way that Dr Weightman and his team are doing it at the moment. The process is absolutely the right process. We are all keen to make

sure that we get to the end of that process as quickly as possible but without any kind of cutting of corners.

Q182 Dr Turner: How soon do you anticipate licensing the designs that are going to be used?
Dr Weightman: The programme is that we should get within three years to near the end of the Generic Design Assessment process. This process is predicated on building a fleet of identical reactors. We hope British engineers do not do their normal thing and try and change things, but we cannot control that, the operators and vendors will do that. Then we would look at site specific aspects before granting a licence and at the operational organisational aspects as well. There are three aspects we look at before we grant a licence to install a facility: the operating organisation, the siting aspects and the design of the facility itself.

Q183 Dr Turner: Can you give a tentative date?
Dr Weightman: After three years it would be six to 12 months to grant a licence. Whether they can apply in between times for a licence to start working in parallel is for others to decide.

Q184 Dr Turner: So we are looking at 2011–12 before anyone can break ground?
Dr Weightman: The date of 2011 is the comparable date that the NRC have got for their final rule making for AP1000. Some of this work is predicated on having some frozen designs rather than changing designs so that you get clarity on all sides. There is not going to be any change to construction and that facilitates and minimises, as far as I understand it, project risk both in terms of costs and timescales.

Q185 Chairman: Rob, I think you sat in on the first session when I made the point that INucE and the Royal Academy of Engineering did not feel there was a sufficient supply of engineers to meet the requirements of new nuclear build as well as decommissioning. Areva has also indicated that there is a shortage of skills. As a company you are reprioritising your efforts by building another EPR plant in France. How on earth are we going to provide the skills base to meet your requirements as a company? Do you worry about it?
Mr Davies: I am not sure worry is the correct word. We look very carefully at each market. This is a very important market for us. It is a European springboard. That is why we are here. We divide this new build programme into three simple phases. The first is where we are today, which is doing the licensing and regulatory stage, getting the design ready and for us then to build up a supply chain and partners to then build, which will then start in 2012–13, and that is over a four or five-year period for what is going to be the first plant and then there is the operation of that. So our interest as a vendor on this is in the first two phases and then supporting the third phase, which is the 60 years of operation. Let us say there are about 100 people being employed full-time on the regulatory and licensing side in the UK, Germany, the United States and France for the UK EPR, it is about that. However many reactors are built in the UK, they are not going to be built at once by whichever vendor, they will be built in a series of waves. There might be two or three reactors being built at any one time, but I cannot really see more than that being built in the UK. It will come in a series of waves. If you are building two reactors on one site then the second reactor might start some 12 months after the first one starts, so trades will then flop across from the first onto the second. From our perspective, looking at the main bulk, which is the focus of today, which is the five-year build period, for example, we have identified partners and the supply chain in this country that are able to provide the people and skills to build that. We do not bring armies of "Jean-Claudes" across the Channel or Germans across to do this. If you take Finland, it is less than 200 or 300 who are our own employees and who are there on the site, who are managing it and the rest are local personnel who are undertaking the work.

Q186 Chairman: Adrian, would you say that is the same for Westinghouse?
Mr Bull: I would say that model is very similar. We have the approach of buying where we build. We would look to use the local supply chain. This is one occasion where the timescales that the nuclear industry works to, which are quite long, actually help us out rather than the other way round. We have already discussed the licensing issue, the GDA process and the resources around that. Those are the resources that we need urgently today. It is probably going to be of the order of five years before somebody puts a spade in the ground to start construction work on the first UK plant, whatever design that might be. Even if somebody were to sign a contract today, they would have to get through all of the licensing and site specific approval processes before they could start construction. There will be a significant lead time when supply chain companies know that there is a project there that they have to resource up to deal with. Like Areva, we are talking to a number of the supply chain companies and we have got a number of arrangements in place at one level or another. People will have that foresight. When we start to look to operation, it is another five years beyond that. When somebody puts the first spade in the ground then the operators of that plant will know that the clock starts ticking and in five years' time they need to have the appropriate number of trained and skilled operators.

Q187 Chairman: So you are confident you can deliver?
Mr Bull: Yes.

Q188 Chairman: We represent the scrutiny of government policy here. The UK is now going to be highly reliant on large global vendors like Westinghouse or Areva to actually supply. If there is suddenly elsewhere in Europe or anywhere else in the world a more lucrative contract to deliver, how does

the UK guarantee that it will get prioritised in terms of the delivery of these systems when we are so reliant on global vendors?
Mr Bull: We are seeing the UK market as being a very important one. It is certainly one where there is a lot of talk about new build going on, far more so than perhaps some of the other European markets at the moment. It is possible to project forward what the likely timing might be for some of those other European markets. We are starting to look at new build and replacement build because our existing stations are already in a programme of closure. We are a little bit late in terms of taking steps now to replace that fleet, but we are looking, first of all, at getting a replacement series of stations in to replace the ones that will have closed over the next 10 to 15 years. If you look elsewhere in Europe, a lot of those countries have got fleets that were built more recently and so their closure dates are slightly further into the future, if you are looking at it from a replacement point of view. We as Westinghouse are not going to make contracts with anybody that we cannot honour[2]. Once we sign up and get customers lined up we will start to focus on ring-fencing our resources, both in terms of human resource and in terms of our ability to source the heavy components and so on to make sure that we deliver. You are absolutely right, if there are delays, if the UK planning and the UK processes drag on and on and on, then it may well be that a lot of global resources will have been diverted on to other markets.

Q189 Chairman: Robert, I presume you would agree with those comments from Adrian?
Mr Davies: Yes, I would. I hope the UK realises that it is perceived as being a very attractive market by all the major European utilities, that is why they are here and it is why they are viewing and eyeing this market. It is the springboard to what would be a European nuclear renaissance and it is the first market.

Q190 Chairman: Is it a reliable customer?
Mr Davies: It has been very reliable to date. There has been a very fast process in the last four years to actually change from a position where nuclear was keeping the nuclear option open into a position now where it is at the heart of the energy policy.

Q191 Chairman: So we are a good customer. This is going to be a very attractive marketplace. What are you doing to invest in the skills base development? What are your links with academia? How are you going to incentivise students to follow careers to give you your supply chain?
Mr Davies: In the past we have sponsored mechanical engineering students through university. We are in the early stages as far as the UK is concerned even though there is potentially a big market. We have no contracts yet at all. We have joined the Nuclear Skills Academy and we intend now to understand how better we can train and upskill the UK to be able to construct and then operate the new plants afterwards.

Q192 Chairman: The same question to you, Adrian.
Mr Bull: Globally we are recruiting about 1,000 people a year at the moment and we are planning to do the same over the next few years and that is mostly on our new build side. In the UK we have recruited staff for our facility at Springfields where we run the nuclear fuel factory. I think it is 230 people over the last two years and again the numbers there are growing.

Q193 Chairman: What are you doing to incentivise the training market so that this becomes a really attractive prospect within our universities, schools and colleges?
Mr Bull: We are actively involved in things like the National Skills Academy for Nuclear that reaches out into schools and universities and is providing training across the piece. We have got some good relationships with a number of the key universities in the sector, eg the Dalton Nuclear Institute who gave evidence to you last week, the University of Central Lancashire and so on. We are putting a lot of effort into those activities. I personally chair the north-west and north-east employers steering group for the National Skills Academy for Nuclear, so we are very actively involved in that and our site head at Springfields has a position on the Board. We are at the heart of all those initiatives that are going on and making sure that we are able to take benefits from that as those skilled resources become available.

Q194 Chairman: Do you regard the development of the new military requirements for nuclear build and nuclear engineering as a threat or is it an opportunity?
Mr Bull: It is probably a mixture of both, but on balance I would say it is more of an opportunity. You heard from BAE Systems earlier about the capability they have to provide services and components to support the nuclear submarine fleet, for instance. Our reactor design is designed in a way that it is modular. The kind of modules that companies like BAE Systems produce to assemble into nuclear submarines are exactly the same kind of technology and the same kind of approach that we use to build a nuclear power station. So there is plenty of scope for cross-fertilisation and synergy between the two sides there. There is the potential that people who enter one side of the sector might divert in their careers to the other, but I think having that diversity is an added attraction to bring people into nuclear per se and a lot of those skills do have an element whereby they are transferable.

Q195 Chairman: David, British Energy is clearly a major player within the nuclear industry at the moment and yet it is being sold or the British

[2] *Note from the witness:* "On more than one occasion Westinghouse has turned down proposals from potential customers (or decided not to bid on a tender when invited) because we could not deliver to the timeframe requested without going back on commitments already made. In addition we have turned down several discussions with countries that we did not feel were yet ready to take forward their first nuclear power plant."

Government stake is being sold. Why is that at a time when we are sort of in this new, wonderful phase of all things nuclear?
Mr Barber: There are a number of options that the company is involved in looking at, but it is probably not appropriate for me to comment given the legal position that we are in.

Q196 Chairman: Nobody is listening. You can be as frank as you like!
Mr Barber: In terms of the skills and the transferability of skills, which was a point just raised, the nuclear engineer is probably a bit of a myth. When you look at the skills that we require to operate our plants, it is 80/90% general engineering. We need good mechanical, electrical, control or instrumentation civil engineer skills. We can do the conversion. The proliferation of bespoke qualifications is probably not helpful to the industry as a whole, it is just the general engineering and then the conversion. As a company we have recognised both in our physical assets but also in our human assets that we needed to increase and improve our investment so over the last three years we have opened new training facilities. We have invested over £20 million in developing new training programmes. We have got international accreditation boards to look at those programmes. We have just let a contract for £10 million for an apprentice programme over seven years and it is utilising the redundant capacity down in Portsmouth, the Royal Navy training capacity. Part of that is to try and get all our apprentices who we will recruit locally but then train in one area as a residential base to be what we call a "nuclear professional". It is about having the personal responsibility. It is about giving people that pride in the quality of what they do so they come out with all the right employability.

Q197 Chairman: Why are those softer skills important to the nuclear engineering industry?
Mr Barber: When you look at the performance of the business there are two components: it is the availability and reliability of the plant and it is the capability and reliability of the people. When you look at the history of events, whether they have been significant events or less significant in the industry, the human being has been the factor in that. There is a lot of emphasis placed on the quality of the person. We have adopted the same approach that they have in the US, but it is a key component of what we believe. It is not just the person, it is the management framework and the culture of the organisation.

Q198 Chairman: Do you think the universities should be doing more to provide you with people who have got those soft skills or our colleges or our schools system?
Mr Barber: What we find is that people that come out of university have got a level of personal responsibility and are professional learners and they come with a lot of the right attributes. The people that come from school on apprenticeships do not have the right attributes. The first programme starts in September this year and it is a life skills team, working skills, personal responsibility. They are able to take part professionally in the environment that we have in the nuclear industry. The technical side of it is the same that you would get anywhere, it is transferable and I would suggest that the behavioural side of it is equally applicable to any major industry.

Q199 Chairman: David will not give us a comment about the British Energy sale and the Committee is equally confused about why Westinghouse was sold in 2006, at the very point at which there were likely to be very significant contracts coming their way and in which Government could be a beneficiary.
Mr Bull: I think I can probably give a better answer given that the Westinghouse sale by BNFL, which is UK Government owned, has now gone through. Government had made it very clear sometime before that that if there was to be any new nuclear programme in the UK then it was going to be down to the market to deliver, the private sector and that there was not going to be any taxpayers' money going into a new build programme. On that basis it was absolutely right that the companies that might participate within that market should be companies which are not owned by or largely controlled by UK Government. It is a slightly strange situation in the first place perhaps for UK Government to own Westinghouse, which is a company headquartered overseas and with most of its activities overseas, albeit at a time when our aspirations were slightly different, but we would find it much more difficult to participate in this market at the moment, given the framework that the Government has set, if we were still under Government ownership. In the case of Westinghouse it was absolutely the right thing to do. The value of Westinghouse grew very significantly under BNFL stewardship and so the taxpayer made a significant profit on its ownership of the company over seven or eight years, and now we are much better positioned to do business not just in the UK but also hopefully in international markets. It would have been a very difficult situation for us globally if we had found, because of those constraints, we were not able to sell our plant in the UK whilst owned by UK Government. That would have created perhaps an unhelpful perception further afield.

Q200 Dr Iddon: The supply chain has been mentioned more than once by this panel. Where are the significant bottlenecks in the supply chain, if there are any that you perceive?
Mr Bull: The most obvious is in the provision of the very heavy forging components. At the moment there is really only one company in the world, Japan Steel Works, that makes those ultra heavy forgings. They are investing in increasing their capacity. There are other companies around the world, including in the UK, that are also looking at whether they might invest significant amounts of money to develop a comparable capacity, but at the moment that is where the major pinch point is. Companies like Westinghouse and other vendors have slots in that order book for many, many years ahead so that we

can assure ourselves that we can provide and source those components to meet the orders that we sign up to.

Q201 Dr Iddon: We cannot gear up in this country for heavy forging, is that it?
Mr Bull: It is possible. It was in the press recently that Sheffield Forgemasters have a capability to produce forgings not quite at that level and they are looking at investing many millions of pounds into whether they want to invest and build the ultra heavy forging capability not just for the UK market but for the global market. I think that is driven by a point that cuts across lots of the discussion we had earlier on about the supply chain of human resources as well as components, which is we are just at the point in that hockey stick curve where the nuclear renaissance that people have talked about for many, many years is starting to take off. We have heard about this renaissance for the best part of a decade, but in terms of hard orders being signed, it has only been in the last two or three years that we have started to see our AP1000 orders. A previous piece of evidence was about the eight that we have sold already and that has been in the last 18 months. We are seriously starting to ramp up that order book. It is only when people see real orders rather than just a lot of talk and speculation that they are going to be much more confident investing in many cases many millions of pounds in supply chain fabrication equipment.

Q202 Dr Iddon: So what will be the key to encouraging companies to invest in manufacture in this sector?
Mr Bull: I think it will be when they see those orders becoming real for the various reactor vendors. We are in discussions with a number of supply chain companies and I am sure Rob and other vendors are in the same position in terms of making agreements with them to source capacity and source what they can produce from that capacity if they were to invest in it. We have the confidence in turn to do that as we see our order book developing. It is as the customers are starting to put pen to paper—

Q203 Dr Iddon: So it is beyond licensing and planning?
Mr Bull: Absolutely. The licensing activity is ongoing. Utilities can put planning applications in, they can get to the end of that process and then they are perfectly at liberty to just stop. It is when somebody actually signs the order, the procurement construction contract, that they have committed to build the thing. With all of the work we are doing now in the UK we have to remember there is not an order yet. We are doing an awful lot of preparatory work and companies like ourselves and others are investing in the GDA process, but we need a customer at some point to translate that into real plant orders. When that starts to happen or when that starts to become much more likely is when I think you will really see those supply chain companies' investment stepping up a gear. I should not imply they are not investing at the moment, but I think their interest will step up a gear.

Q204 Dr Iddon: Robert, does Areva see it that way or do you perceive some other bottlenecks?
Mr Davies: I do not like the word bottlenecks as it gives an impression that if something is not available today then you cannot have the ultimate product tomorrow. Right now that is not the case. I do not know yet of any vendor who is unable to sign the contract to provide a reactor by date X realistically within the licensing regime because there is a bottleneck of component X, Y, Z, whatever it is. We know all of the shortfalls within the global supply chain to feed our reactors. People mentioned forging because it slips off the tongue, but there are a whole range of things which vary from tubing, some of the I and C equipment. Some we might take five years in advance and some two years in advance. If you came to me today and said, "I want a reactor, please, and I would like you to turn the first earth in 2013 to turn on in 2018," then I or any other vendor would then have a list for you and say, "You might now start to buy these items and leave them in the back yard and then we will start building it in 2013." As far as the supply is concerned, I am sure our approach is really very similar to the other vendors and that is a global one. It is not in the interests of a company to invest in this nuclear renaissance just for a local market. That is very dangerous. What happens if the local market goes right? What happens if it goes sour? Then that investment just goes down the pan. Therefore, from our point of view, we see companies who are able to support us in a global view and support local. That is where the opportunity is for the UK, it is an opportunity now to join globally and to support locally.
Dr Iddon: As you know, gentlemen, the Planning Bill is going through the House at the moment. Its plan is to set up a Commission and to speed up planning processes for large capital investment, especially nuclear power stations. It has undergone amendment in the House of Commons because our Members were unhappy about the lack of involvement of local authorities and so on. In general does the new Planning Bill meet with your agreement? Would you be seeking amendments to it yourselves if you were in Parliament?

Q205 Chairman: Could you say whether you think from the regulator's point of view the new planning arrangements will assist you in being able to make decisions within more clear timeframes?
Dr Weightman: I do not think it is in a sense relevant to our decision making. We will do our job on behalf of the people come what may.

Q206 Chairman: Does it help?
Dr Weightman: I do not know whether it helps or not.

Q207 Dr Iddon: Sizewell B had a very long public inquiry.

16 July 2008 Adrian Bull, Dr Mike Weightman, David Barber and Robert Davies

Dr Weightman: That took our resources in terms of having to contribute, quite rightly, in that planning system at that point in time. We are putting a lot of effort in now to being a lot more open with how we regulate new build at the moment. We got the vendors to put their safety cases into the public domain subject to commercial and security considerations and invited comments from the public. We have put all our reports at the end of step two into the public domain, with some 50-odd reports around that. We have been very clear about our safety assessments, our standards and that is very clear in the public domain. We are comfortable with whatever public scrutiny there is of our approach and our standards and our work because we are public servants. At the end of the day our duty is to the public and the UK Government.

Q208 Chairman: Does anybody else want to comment on the planning issue?
Mr Bull: The principles of it we would welcome, that more timely and streamlined confidence in the timescale for decision making in the planning process is something that the industry needs given that we are looking at private sector investors and the comments that you made about their ability to go elsewhere in the world. They need to know what the process is in the UK. So we welcome that. If it does what it says on the tin it will have been very helpful not just to the nuclear industry but to other parts of the energy sector. I think the GDA process and the new planning reforms really go hand in hand because the only way you can get that predictable and more streamline planning process is to take out the safety and technical scrutiny of the reactor designs that, quite rightly, does need to be done and do that upfront in a one-off exercise, which is what the GDA process represents.

Q209 Dr Iddon: This time round we are likely to build a number of these nuclear reactors on existing sites where the local community relies upon this big investment for jobs, especially in the Lake District. We were at Sizewell B yesterday out in Suffolk and a considerable number of local jobs are involved on the Sizewell B site.
Mr Bull: It will be up to the utilities to decide where they put them, but a lot of the sensible comment seems to be that the existing nuclear sites look like a good bet for certainly the first wave of new nuclear stations.

Q210 Mr Marsden: I would like to ask some questions about the recruitment and skills issues. We have had some discussion on this in previous sessions. You were talking about some of your specific shortages in the inspectorate earlier on. Is this a reflection of shortages in engineering generally or is it that much worse in nuclear?
Dr Weightman: I am sure the NIA has got figures on that. I think it is a reflection of the general shortage of engineering skills around. I have heard from David Barber that in terms of general engineering then the skills are transferable. It is a global market as well and that can operate both ways. I was up at Heysham One the other week looking at some items there, the boiler closure unit aspects and it was very interesting to see they had got quite a lot of American engineers over to assist them in that and they were assisting them in quite a lot of work there because there is a large programme of work in looking at some of the ageing phenomena in the existing reactors.

Q211 Mr Marsden: Given the security sensitivities of much of what is going to be done we are going to need to have a home grown workforce, are we not?
Dr Weightman: I do not dispute that. It is still a global work market that will operate both ways. Clearly in one of my other areas of responsibility, nuclear security, we have to look at the vetting of whoever is involved in operating new nuclear power stations and there are issues around that as well.

Q212 Mr Marsden: Adrian, you mentioned the young people you have recruited at Springfields over the last two years. I was at Springfields earlier in the summer and I think what is going on there is very interesting and positive. The reality of it is, with demography as it is going to be over the next 10 to 15 years, you are going to need to re-skill quite a lot of the existing people as well as hoping to bring in people from schools and universities. What strategies have you got for that?
Mr Bull: You are right, there is that issue about the retention and re-skilling of the existing workforce. Our workforce has gone from around about 4,200 at its absolute peak in the mid-Eighties down to about 1,300 and it is up to about 1,400 or 1,500 now and rising at the moment. We are looking at how we attract new people in. We do a lot of work with the schools and the universities in the region around Preston and more widely across Lancashire and the vast majority of our recruits do come to us from local surrounding areas. We are seeing the benefit of that engagement that we do on our doorstep. We offer some particular advantages for young people who come in and want to join the BNES Young Generation Network.

Q213 Mr Marsden: You are talking about young people. I am being ageist on this occasion. I want to hear about older people. What are you doing for older women, for example?
Mr Bull: I am not aware that we have any specifics—

Q214 Mr Marsden: What about adult apprenticeships generally?
Mr Bull: I would have to write to you with the figures on that. I do not have the break down by age profile of our apprentices. I know we have about 70 in the system at the moment.

Q215 Mr Marsden: Does anyone else want to comment on this demographic issue? The point that I have just made to Mr Bull is that even if you get all of the red hot school-leavers and graduates you are still going to have a shortage because you are going to have far fewer graduates and school-leavers in the next 10 to 15 years.

Mr Barber: One of the issues as well generally in the UK is everybody has been competing in the transfer market. Going back to the football analogy earlier and buying players from other teams. What is the balance between growing your own talent and the people you take in the transfer market? We took on 420 people last year and 50 of those were apprentices and 20 graduates. So we are heavily biased to buying people in the transfer market and we feel that we need to move more to the other side to grow our own talent to be more secure going forwards.

Q216 Mr Marsden: Let me ask you about the sector skills council, Cogent, as you are a Board member of that. We heard in the previous session that there were possibly four or five sector skills councils that potentially affect the nuclear industry. Cogent, of course, has "pot pourri" membership of quite a lot of other non-nuclear interests. Does that hamper or assist trying to get skills going in to the nuclear sector?
Mr Barber: It comes back to the earlier point of having general engineering skills. Really what you want is the Cogents, Semta, EU skills to be collaborating together on growing the whole engineering skills population. There are a lot of similarities, even if you just take the Cogent footprint, in the foundation degree apprenticeships on the approach that we take to skills. The efforts that are going in to promoting science and engineering in schools are all common.

Q217 Mr Marsden: So the fact that Cogent is quite a broad umbrella sector skills organisation does not worry you?
Mr Barber: No. To some extent it is helpful. The co-ordination needs to take place within other sector skills councils. I do not think the Government needs to do anything else in terms of the skills structure. What it needs to do is focus on making sure it delivers what it has set out to deliver.

Q218 Mr Marsden: Are you happy you are going to be relicensed by the new UK Commission on Employment and Skills?
Mr Barber: It is a difficult one for me to comment on, but I would hope we are because we have got very good support from industry on that body and it has got clear targets and plans to move forwards. There is quite a large number of organisations trying to do the same things, but where we bump up against them we are very clear on who is doing what. You develop a memorandum of understanding so they are not overlapping. The CEO of the National Skills Academy for Nuclear is also coordinating activities across the whole of the National Skills Academy again for the same reason.

Q219 Mr Marsden: I met her and, if I may say so, she is a very impressive figure.
Mr Barber: That was our concern from an industry point of view, a lot of people tripping over the same things. I think those are positive approaches to try and improve that.

Q220 Dr Blackman-Woods: We have already heard a little bit about what you are doing to attract people into the sector. Is there any evidence that it is becoming easier to attract young people into the nuclear industry now that it appears to have a future or are the environmental obstacles still too big to really get the numbers of young people into the sector that you need?
Mr Barber: At the moment from an operational point of view we are not having problems attracting people. We probably get about 50 applicants per position. We are not having difficulty now. The issue is will we have difficulty in 10 years' time. You can have the most robust training structure in the world but unless you can get people to come in to put through that process it is not going to be helpful in 10 years' time. What we can do is support the efforts that are going in with the STEM agenda, working with Energy Foresight, working with the teachers to try and promote that. It is difficult to speculate how that is going to pan out going forwards, but when you think that in 2018 the first new generation power station is operational in the UK then those people, if you are at apprentice level going through to a degree level, will be somewhere between 12 and 15 now. They are already in the school system and already thinking about their options. Now is the time to start making that work.

Q221 Dr Blackman-Woods: Is industry doing anything to target young women in particular so that they see a future career in the nuclear industry because the numbers are rather low at present, are they not?
Mr Barber: I think one of the things that is helpful is having some role models. At some of the careers fairs we take along some of our recent female graduates and we use those to help talk and act as science and engineering ambassadors supporting the schools. If you have the role models I think that helps to attract more people into the industry. We have just appointed our first female station director and again it becomes a focus point and people can see it can be done.

Q222 Chairman: Any other comments on the gender issue?
Mr Bull: The gender balance in the organisations that we represent, the industry as a whole, probably represents what has been in the science and technology and engineering courses in universities at the time when we have been doing recruitment. I think with that in mind, when you are looking to the universities now and see the far greater proportion of women who are doing science, technology, engineering qualifications, we are seeing that balance reflected through into the nuclear industry. I think the industry's broader level of public perception has changed in the last 10 years or so and has been reflected in people's

willingness and keenness to come and join the industry, whatever gender they may be and that has to be a good thing.

Mr Davies: We recruit about 2,500 people a year from Europe and from the United States. For them actually joining nuclear is seen as being a green option. Many of our graduates come from Germany. The paradigm has moved very quickly. The paradigm has changed. I think we are now in 2008 and not 1998. As far as females are concerned, we have a female chief executive which does our business the world of good!

Chairman: We always like to finish every session on a very positive note. Thank you very much indeed.

Monday 3 November 2008

Members present

Mr Phil Willis, in the Chair

Mr Tim Boswell
Mr Ian Cawsey
Dr Ian Gibson
Dr Brian Iddon
Mr Gordon Marsden

Witnesses: **Mr Mike O'Brien,** MP, Minister of State, **Mr Michael Sugden,** Assistant Director, Nuclear Supply Chain and Skills, and **Dr Nicola Baggley,** Director Nuclear Strategy, Department of Energy and Climate Change, gave evidence.

Q223 Chairman: Could I welcome our witnesses to this, the final session, in one of our case studies which have been looking at nuclear engineering as part of a broader inquiry looking at the future of engineering in the UK. We welcome in particular Mr Mike O'Brien, the Minister of State, and we welcome you to your new post.
Mr O'Brien: Thank you.

Q224 Chairman: It is good to see you, supported by Mr Michael Sugden, the project manager for waste and decommissioning. Welcome to you and Dr Nicola Baggley, the director of nuclear strategy at the Department for Energy and Climate Change. Could we also extend a very warm welcome to the Royal Society Fellows who are part of the pairing scheme this week. We are delighted to have you within our Committee this afternoon and we fully expect to see you here on Wednesday morning as well, otherwise we will regard it as a dereliction of your duty. Minister, nuclear engineering is clearly now very firmly on the Government's agenda with a challenge of building up to eight nuclear power stations by 2023, some as early as 2017–18. What we would like to know from you first of all is where does nuclear engineering fit into the Government's thinking? Is it just your department? How is it approached across Government?
Mr O'Brien: The whole way in which we develop nuclear power is going to be crucial to the country. It deals with some of the issues around climate change, the security of energy supply and the issue of affordability. What we are conscious of is that in terms of building up the capacity to develop nuclear power what we need to have are the skills and the workforce to do it.

Q225 Chairman: But we do not have them.
Mr O'Brien: We have 50,000 of them, so we do have some. At the moment one of the difficulties of course is that the modal age of some of them is now getting on. We also have a significant agenda in terms of decommissioning, clean up, new build, defence and it is a broad agenda. Not only that; we are operating in a global employment economy where we have other countries who will be competing for much of this skilled labour here. The UAE and Jordan recently made some announcements.

Q226 Chairman: We will come on to the issue of where we are going to get the skills from but what I am interested in as a starting point is who discusses this whole issue of nuclear engineering across Government, or is it just purely your department?
Mr O'Brien: It would be ourselves and BERR, Lord Mandelson's department, who would discuss it with us and it is all part of the skills agenda that they are running. We would be involved in that and, of course, the DWP in the sense of work; but also of course the universities and schools are absolutely crucial in this. In terms of where it sits with Government, we would be the lead department to ensure that we get delivery of the nuclear agenda. In terms of who would also be involved, a whole series of other Government departments, particularly education and universities would have a crucial part to play and BERR in terms of developing the broader skills agenda.

Q227 Chairman: Is there a structure within Government that you lead where all the different departments have representatives, where you have a common structure, a common goal, or is nothing formalised?
Mr O'Brien: There is a clear Government strategy in relation to both skills and nuclear. Developing that is part of the Government's objective. Ministers constantly meet to talk through some of these issues both on an *ad hoc* basis and more generally when we are discussing issues around the skills agenda. Within Government there is the capacity for ministers to regularly discuss this.

Q228 Chairman: We would agree with you there is clearly the capacity. The question is does it happen?
Mr O'Brien: It does happen. Indeed, it has happened very recently when ministers have had discussions on this and particularly on the nuclear agenda. Because we have quite a significant policy development that has taken place now over the last few years, certainly with BERR, it has been one of the key priorities that they have had in the last couple of years. There has been a widespread discussion, as you know, across Government on the whole issue. In terms of where would engineering fit and where would the issues around the skills in engineering fit into the wider setup of Government, Cogent and the skills council there has been tasked with drawing up a skills

assessment, a sort of stock and flow assessment, of what there is now, not only in terms of the capacity for new build, the current need, decommissioning and also MoD needs, but also where we are now and how we go forward. That will then become the responsibility of ourselves and other Government departments to implement.

Q229 Chairman: I appreciate that you are very new in this post and perhaps your colleagues will help you out. It is a huge agenda to produce at least one nuclear power station on the ground by 2017. To produce eight of them by 2023 requires more than these loose connections between different departments. It is the engineers who are going to deliver this. It is not going to be politicians. Where is the structure? If it does not exist, then just say it does not exist.
Mr O'Brien: There are a number of structures. One is in terms of policy development. Another is in terms of delivery, so the Office for Nuclear Development has been set up in terms of delivering the whole nuclear agenda. That operates across Government departments. I am not sure I quite understand whether you are asking me if there is a Government policy capability. There clearly is.

Q230 Chairman: We know you have a policy; it is how you deliver it.
Mr O'Brien: In terms of delivery, it sits within the Office for Nuclear Development as a delivery mechanism which is responsible to DECC and answers to me through the department and then to other ministers.

Q231 Mr Boswell: That is very helpful. You will forgive us because we are not familiar with the details of this either. Essentially, from the centre—that can be from Number 10 down, including all ministers—if there is concern about the timing of this or any worry about slippage, it will be the OND who reports on it and does any progress chasing of any of the delinquent departments or other policy areas that may be required.
Mr O'Brien: The straight answer to that is yes.

Q232 Mr Boswell: Somebody is going to crash this through if that is what you need to do.
Mr O'Brien: Yes. The OND has a cross-departmental responsibility for ensuring delivery of the agenda, but in a sense it is not the policy forum. It is the delivery forum.

Q233 Chairman: Nicola, you were nodding your head so vehemently there that I think we will give you the option to say something briefly.
Dr Baggley: The OND was launched formally in the middle of September. It very much sits within DECC. We report up to Mike and it is very much envisaged as the one stop shop for nuclear. One of our key aims is to facilitate new build. We very much see it as a step change from the old nuclear unit which sat within BERR's energy directorate on a number of fronts. One of those which I think is most pertinent to this Committee is a renewed focus on the supply chain and skills agenda. Back when the White Paper first looked at the barriers to bringing on new build in the UK, the skills and supply chains were identified as an issue but were very much felt to be something the market would address. In the last few months I think we have had a step change. Ministers have asked us to focus on what more we should do to make sure it is not an issue. We were only formally launched in September. It is very much a new focus for us alongside the other facilitative actions that were set out in the White Paper. At the same time that the Office was launched the Nuclear Development Forum was also launched and that is a Secretary of State chaired forum of people from industry, but also cross-departmental, so representatives attend from the MoD. There is a number of departments which are interested in the nuclear agenda. The Forum is very much for us to hear directly from senior members of industry what the challenges are to delivering our programme but also for them to hold us to account to ministers for delivery. It is not a formal Forum; it is non-advisory, but it is just useful. We have only had one meeting so far but the skills agenda was very much raised as an issue. We plan to discuss that at the next meeting which we are hoping to schedule in the New Year.

Q234 Mr Boswell: Can you say a bit more about the project management skills of this? It had a background in my own constituency and I am conscious that we took radar from an invention in 1935 to a completely fully fledged home defence system in four years, which required a really prodigious effort to get it done. In this case you are not the contractor, you are not building in-house and you need to see contractors. Can you just say a bit more about what we might almost call business skills that will identify bottlenecks and so forth that we need to address?
Dr Baggley: Certainly. Do you mean within the wider new build programme or the skills?

Q235 Mr Boswell: I meant within the wider programme.
Dr Baggley: The OND is partially modelled on the shareholder executive to the extent that we have brought in secondees from the private sector to complement the existing Civil Service skills. My unit, the strategy unit, is a new unit that did not exist within the old nuclear unit. One of my main areas, aside from sitting over the supply chain and skills arena, is what we call programme integration. Although we have existing project plans and a timetable, we feel now is the time to revisit that and make sure that we know where we are trying to get to, what we are trying to achieve, what we need to do to get there and revisit all our facilitative actions but also look more widely. Is there something else we should be focusing on—for example, the National Grid? We also need to know more clearly what decisions industry needs to take, by when and what we need to have delivered for, for example, the next stage of investment.

3 November 2008 Mr Mike O'Brien, Mr Michael Sugden and Dr Nicola Baggley

Q236 Mr Boswell: It is the critical path?
Dr Baggley: It is the critical path. In doing that, one of the secondees we have brought from the private sector is supporting us in that work. He has had 40[1] years' experience building, operating and decommissioning power stations in the US. We have also the support of our professional, in-house project centre which is an internal project management centre of expertise.

Q237 Dr Gibson: Why eight nuclear power stations? Where does that figure of eight come from? Is it hard and fast?
Mr O'Brien: No. What we are looking at is how we can get a number of nuclear power stations going. Whether we get to the target we are aiming for will depend on a number of factors. You have already seen the significant announcement of EDF and British Energy which suggests we will get some development fairly quickly. By "fairly quickly" we are talking about 2017–18.

Q238 Dr Gibson: It is not in tablets of stone?
Mr O'Brien: It is an objective that the Government has.

Q239 Dr Gibson: Do you think the UK nuclear industry will be able to build these nuclear power stations given that it has its military presence and job and it has a bit of decommissioning to do on the side which is more than five or 10 minutes? How are these wonderful people going to do all that?
Mr O'Brien: We have to make sure we have the skills capacity in order to deliver that. That is why we have set up Cogent. We have the National Skills Academy for Nuclear and that is helping to develop not only the capacity in universities with degrees—Masters degrees in particular—developing some funding for that and bringing in the private sector as well to ensure that is there. I know you have already heard from some academics about it. I have read the evidence. You will know too they took the view that there was the ability to get the levels of skills required but it will not be easy. There is a lot of effort going to be required. That is not just going to be done by Government. It has to be done by the private sector and by universities and schools as well.

Q240 Dr Gibson: The generic design assessment process complicates it further. Will you be on time with that as well?
Mr O'Brien: We believe we can be. There are some issues around skills capacity there. In order to carry out the assessment we need some highly skilled people. We have a number of the people from the Nuclear Inspectorate who have been seconded to that, eight, and we probably need about 20 in all. We have to develop that skills group.

Q241 Dr Gibson: Are you going to hire them in like when you were in immigration? Are we going to have to bring people in from France and Germany? Will you be allowed to?
Mr O'Brien: There are some areas where obviously it would be inadvisable, particularly in terms of defence, to bring in people from abroad, but there are other areas where, if we are looking at new build in particular, we have EDF involved which obviously is not a UK base. We would have to look at who was coming in and what they were able to provide that we needed. We would look carefully at who was involved in what area but the straight answer to the question is yes, there would be circumstances in which we would be prepared to bring in skills.

Q242 Dr Gibson: You will have to scout for them. You will have to find the Chelsea stars.
Mr O'Brien: We would rather build up our domestic capacity. In terms of the skills situation, we currently have 50,000 people who have some skills in the industry as a whole. Because we have the substantial expansion of nuclear, not just civil but also military, we need to ensure that we have the capacity to deal with both of those areas in the future. That does require quite a significant future development and that is why we are putting some Government funding in. We are also looking to the private sector, Cogent and the National Skills Academy for Nuclear to develop that.

Q243 Mr Cawsey: We know there is going to have to be home grown talent and we will need more to meet these targets that are being set. Do you have any feel for what the balance is going to be between what we have in the home grown UK sector at the moment and what we will need to bring in to achieve the Government's aspirations?
Mr O'Brien: There is no reason to believe that we need to bring in any significant levels from abroad. I hesitate very slightly on that because my concern is not so much that we could not produce the levels of skill in this country that we will need going on for the next couple of decades. I think we are quite capable of doing that but there will be other demands from other countries who will be paying quite substantial sums to get exactly those skills. I have already mentioned to the Chairman about the Middle East and other areas of the world and indeed the United States now who are developing their own nuclear programmes. We are likely to see some competition there for skills. My only hesitation there is we may develop the skills here but we will need to make sure that we have the interest and the funding, the salaries and the good conditions, that will keep them here.

Q244 Mr Cawsey: Do you think we have perhaps shot ourselves in the foot slightly in that regard? There has been some criticism of the way that BNFL has been broken up over the years. I think it was the Institute of Physics who said that BNFL provided a strategic view on UK skills and expertise and that the UK has now lost its strategic thought and leadership as well as the source of funding for industrial research. Are you concerned that we have the capability now of ensuring we develop the skills in this sector?

[1] *Note from the witness*: "Actually 30"

Mr O'Brien: We were aware of the need to ensure we kept some of those skills, which is why we are setting up the National Nuclear Laboratory and bringing together some of those old skills from BNFL, but also adding to them with new skills that we hope will help not just that particular group of people but the wider nuclear industry.

The Committee suspended from 4.33pm to 4.43pm for a division in the House

Q245 Mr Cawsey: We were talking about the need to ensure that we have the right skills to meet the Government's aspirations. There is an acceptance that obviously the UK is not the only country going through this process. There is a limited number of people in the international market place. Other countries will be trying to get some of the same people that we would like to get to come to the UK. What are you going to do to ensure we can successfully compete to get those people into the UK so that we can meet our targets?
Mr O'Brien: The first thing is the matter of keeping people who are highly skilled here. In the end, it is going to be to a significant extent up to the private sector to pay the sorts of salaries that will keep those highly skilled people in the country. We can train them. We can create the university courses and the skills training in colleges and so on that will bring these people out in a condition where we have the skills we need, but then we have to keep them in this country. We have to pay them. Therefore there is going to be a demand. There are going to be other countries competing for these skills and they are, to a significant extent, transferable. I think the private sector recognises the need to fund that. We have a particular issue within Government that in a sense illustrates your point, which is that there is a transfer to some extent from the MoD to the private sector at the moment because of salaries. The MoD are looking at that and looking to address it. We are aware that in probably five years to a decade there is going to be quite a push to get this skills cohort. We need to make sure that we are able to fund keeping those people who we train in this country.
Chairman: With respect, you have not said a single thing about what you are actually going to do, other than that you are going to do it.
Mr Cawsey: The market will do it.

Q246 Chairman: Is that it?
Mr O'Brien: The question from Ian was are we going to be able to keep those people essentially in this country. The answer to that is yes, we are, providing we pay them the amount that keeps them in this country.

Q247 Chairman: That is it? We are going to have to pay them more?
Mr O'Brien: Yes. We are going to have to pay those who are of sufficient quality to stay in this country. There is no other way of keeping them. They have transferable skills and there is a free market out there. If you are asking me how do we make sure we have them in this country in the first place, I can set out very clearly for you how we are going to do that, but once they are qualified to some extent, unless they have some sort of honorarium from a particular company that requires them to stay in the UK, they will be able to transfer elsewhere.
Chairman: This is a key issue.

Q248 Mr Marsden: To bring us back to where we are now, we know from the evidence that we have received from Cogent and the Nuclear Skills Academy that we have substantial deficits and skills shortages at NVQ levels two and three now. We also know that over the next 10 to 15 years the demographic changes in this country are going to give you a smaller and smaller cohort of younger people potentially to fill some of those areas. Given that is the case, what are you going to do to address the skills shortages at levels two and three?
Mr O'Brien: The key thing that we need to do is to make sure that we are encouraging people to have interest in science, technology, mathematics and some of the key areas that we need to train them in. That is why the skills sector has already mounted a quite significant project to extend these stem skills in schools. Secondly, we have to make sure that we have the capacity in the colleges and in employment to teach. Thirdly, we have to make sure we have the apprenticeship schemes. As you know, we have set out the community apprenticeship schemes and also the expansion of apprenticeships across the nuclear industry which is being very much co-ordinated by the National Skills Academy for Nuclear. They are trying to develop that whole strategy. They have a clear programme of developing that. In the end, it is going to be about making sure that we have the universities as well that will in due course be able to provide the higher level skills that people will aspire to achieve.

Q249 Mr Marsden: That seems to me to be all very well and good and encouraging as far as it goes, but you have not said a single thing in there about how you might reskill or upskill some of the people in the industry at the moment. I repeat the point that I made earlier: given that you are going to have a much smaller cohort of younger people, should you not be thinking about doing more in that area now?
Mr O'Brien: We are thinking about that through Cogent. Cogent is already examining how we upskill some of those who are already in the industry to make sure that within employers some of the training that they provide and the access they give for further training outside the workplace is given a higher level of priority by the nuclear industry itself. I accept your point that there will be a narrower cohort of young people coming through. All we are doing is giving higher priority to that cohort and ensuring that the STEM issues are given a much greater priority in terms of the delivery, not only in schools but in colleges, and that in due course employers are creating the ability to encourage their employees to go and do the upskilling that we need for the future.

Q250 Mr Marsden: There is also an issue, is there not, Minister, about the diversity within the workforce? I am very encouraged that you have Nicola with you as a concrete demonstration of that diversity within your own department but the fact of the matter remains that out there not only is the workforce, as you said, very old; it is very male dominated and it is not very ethnically diverse.
Mr O'Brien: You are quite right that because of the nature of that employment going back 20 years it recruited people who were predominantly male and are now in their forties and fifties very often. What we are trying to do is encourage employers to recruit more broadly. We need to make sure that not only in terms of recruiting more women but also ethnic minorities it is more diverse. Employers have certainly got the message—that is what they tell us—that developing a wider skill base is important to them because, if they do not, they end up focusing on the group of people that they have recruited up to now and they will not be in a position to get the breadth of skills that they need.

Q251 Mr Marsden: Mr Sugden, could I ask you a quick couple of questions about your particular area which covers decommissioning? That is of particular interest to me because I have just down the road from my constituency the Springfield decommissioning plant. Interestingly, we had a slight conflict of view from two of our witnesses previously. The University of Central Lancashire said they thought there would be competition for talent within the sector between decommissioning and new build. The Royal Academy of Engineering however tended to downplay the problems or issues regarding getting people in to do decommissioning and said, " . . . there is no urgency requiring the diversion of nuclear engineering expertise to the task of decommissioning." Which of them is right?
Mr Sugden: Both of them in a way.
Mr O'Brien: You are virtually asking a political question. I think it is better directed towards me rather than to an official. In terms of decommissioning, we will be seeing the NDA publishing tomorrow how it is going to develop its skills base, what it says it needs, and we are hoping that that will set out in some detail the answer to your question.

Q252 Mr Marsden: Whatever balance is struck, will that again take on board the issue of reskilling within the industry as well as recruiting from outside it in terms of decommissioning?
Mr O'Brien: It will. The whole industry is conscious that it has a major task in that upskilling of its current workforce as well as reskilling, so developing a whole new skill capacity amongst some of the current workforce and bringing in new people will be essential if we are to deal with the gap that we can all see coming. To be fair, of all the areas of energy that I deal with at the moment, the nuclear area is the one area where I think there is a clear understanding of the nature of the problem and an agenda that has been set out to deal with it. If we were talking about some of the other areas, I would have some more concerns but this is an area where the nuclear industry and the academic side of nuclear interest are very conscious of this problem and are ensuring that we put together a clear strategy for dealing with it. We have not really gone into some of the things that are happening, the way Cogent is developing its analysis of what is needed across the whole piece, the way the National Skills Academy for Nuclear is working with employers and Government and others to set out a clear strategy for dealing with this and for delivering it. Broadly, I am content that, yes, there is a problem—no one is complacent about it—but there is a grip on this problem from both the Government and indeed from the wider industry.

Q253 Mr Boswell: My question is about the co-ordination of the different players in pursuing this skills initiative which we are now focusing on. You have the National Nuclear Laboratory whose job as I understand it is to preserve the critical skills needed looking forward, new programmes; yet, its funding is only going to come from the existing customers. Does that create a contradiction?
Mr O'Brien: It is about making sure that we do not lose some of the BNFL skills. That was the initial thing. We have some skills here; and let us not lose them, and then there was the thought: now we have that, can we do more with it? Can we create a National Nuclear Laboratory that everyone can utilise with these skills? We have brought in Government funding and funding from other sources in order to try to create a laboratory with capacity for research and information that can have more general application. It would be wrong to see this as the only source of that sort of knowledge. It is not, and there are other private sector organisations and organisations in the public sector that also have a lot of that knowledge and employ people, including in universities. Am I concerned that those are the only sources of funding? We would like to broaden the funding but at the moment what we also have is a certain number of people that we can bring into this organisation and I think in the future we would be looking for more funding from outside but not at the moment.

Q254 Mr Boswell: To put it more crudely than if I had time to make it diplomatic, is there any question of an entry fee for outside interests that might want to come in to build power stations?
Mr O'Brien: There are always going to be entry fees but not particularly in terms of this.

Q255 Mr Boswell: Just to pursue the various players in this orchestra: the National Skills Academy for Nuclear, the National Nuclear Laboratory, the Nuclear Decommissioning Authority, Cogent, the Royal Academy of Engineering as the professional guardian of standards and of focus, the universities you mentioned and then the new Nuclear Institute which is going to be formed out of the Institution of Nuclear Engineers and the British Nuclear Energy Society. You have added in two new bodies as well which I have not put down this purpose: the Office for Nuclear Development and the Nuclear

Development Forum. How on earth is the Government going to conduct this particular orchestra, make sure it is all playing in tune and gets to the end of the piece at the right time?
Mr O'Brien: Because we have set up the OND, the Office for Nuclear Development, it is their job in a sense to ensure that the conducting of the orchestra is done in a way that produces the tune that we want.

Q256 Mr Boswell: They are in the driving seat?
Mr O'Brien: They are essentially there to make sure everything works effectively. I demur slightly from being in the driving seat, they do not directly control companies or anything like that. It is their job to say, "This is where we are. That is where we want to be. This is how we get there." If somebody is going off at the wrong angle, then we tell ministers and ministers will have the job of pulling them back.

Q257 Mr Boswell: A light touch, I hope.
Mr O'Brien: Yes.

Q258 Mr Boswell: You will know the Committee has just been in China and Japan very interestingly and of course those countries have very different histories and social structures, but they do seem to have the common theme of being relatively more straightforward and simple in all this. Is there anything we can learn from that? Do we have the ideal structure given our personal history or is there a degree of rationalisation which somebody—the OND or ministers—might actually seek to promote to make it easier?
Mr O'Brien: We have looked at this relatively recently and hence we have set up the Nuclear Development Forum to bring together everyone into one body which can hold Ministers and the Office for Nuclear Development to account for the development of the nuclear agenda. In a sense, we have looked at this but if you are asking, "Is there never a capacity for greater rationalisation?" I am sure there is. I think the way to do this would be through discussion with people on the Forum rather than trying to suggest that we need to stop some of the initiatives that are going on at the moment because there is some quite good work going on in terms of developing the skills agenda at the moment in particular and developing academic work in universities. I think we could do more in universities at the moment.

Q259 Mr Boswell: Part of this of course is about the public credibility of these programmes as to whether they are going to happen or not. Are you also giving thought to using the Forum as the vehicle for producing a situation report for lay people and indeed commentators outside Government to have some sense that there is an onward progress, even if perhaps there is not too much to see for it on the ground on day one?
Mr O'Brien: I am not sure the Forum is the right place or organisation to do that report. I think probably the OND is because they have the responsibility of doing that and keeping Parliament updated. The Forum is really an opportunity for the various Government departments and the main outside stakeholders involved to come together and hold to account ministers and the OND for what has happened or what has not happened. It is not really a reporting organisation in that sense. I think probably, in terms of reporting, it would be (a) the OND and (b) ministers.

Q260 Dr Iddon: The Government's hope is for Britain to become again the leading nation in nuclear engineering. Bearing in mind that we are going to be importing French and American designed reactors with the possibility that they will bring in their own engineers who know that plant better than ours, do you think that Government hope will be realised?
Mr O'Brien: Yes, I do. Although it is certainly true that the French will bring in knowledge that they have and no doubt the Americans will in due course and others, we know that they will want to have the ability to use the people and the knowledge that we have as well. We also hope that there will be other players in the market who will be producing nuclear power and therefore I think there will be plenty of demand. There will not be a shortage of demand for the skills in nuclear. Will we be importing some of the knowledge from France and America? Yes, we will import their knowledge and we will use that knowledge to generate power in this country for people here. That is all to the good. I do think that companies like EDF and others will want to have people who are able to run their power stations who have been trained here as well. They are not just going to want to import all the knowledge from abroad.

Q261 Dr Iddon: The Government last week nailed itself to the 80% reduction in CO_2 mast under extreme lobbying of course from Friends of the Earth and others.
Mr O'Brien: The new department took a decision and convinced them to support us.

Q262 Dr Iddon: That is the Government answer.
Mr O'Brien: I congratulate those who also lobbied for it.

Q263 Dr Iddon: That is by 2050 of course. Bearing in mind that we are going to be closing a substantial number of our existing reactors down during the next two decades, do you think that nuclear power is going to play a significant role in getting that 80% target met?
Mr O'Brien: Yes. It must. We have 15% electricity generated from nuclear, a drop from 19% four years ago. We are going to see a number of nuclear power stations coming off production over the next few years. We have to replace those. We have a big renewables programme. That is not capable of itself of replacing the capacity from nuclear. We need to ensure, for environmental reasons, for security of supply reasons as well as affordability reasons, that we have a range of provision of power. That means we have to have it from renewables. We have to have it from oil, gas and other sources. We also have to

ensure that we have nuclear generation of electricity too. That is going to be a key component of ensuring that we get to the very tough targets that we have set ourselves for 80% reduction of emissions by 2050. We were conscious when we agreed that that we were challenging the country. We were also aware that we were giving a clear message to those who say "No nuclear" that they would have to explain how on earth we were going to be able to hit these challenging environmental targets without nuclear. We will not. It is as simple as that. We have to develop nuclear as a serious technology if we are going to hit these targets.

Q264 Dr Iddon: Is eight new reactors an initial target?
Mr O'Brien: That is initially where we are. We do not have a statistical "we want this percentage generation" but we have dropped over the last few years from about 19% to about 15%. We certainly would want to replace that sort of area with nuclear generation of electricity.

Q265 Dr Iddon: Let me turn now to another pressure which Japan is meeting. Japan is going for overcapacity in nuclear energy, not only to provide electricity for its citizens but also to generate the hydrogen economy. As you know, there are various processes—electrolysis of water being just one, reforming of methane as steam being another, and there are other processes—whereby we can generate hydrogen using nuclear power as well. Has the Government considered that option of overcapacity to enjoin the hydrogen economy?
Mr O'Brien: It is not our view at this time that we want to go to overcapacity. We are interested in the development of the hydrogen economy. Indeed, when I was previously in this post, I had some involvement in trying to promote the development of the hydrogen economy in the UK. We need to see how this technology will develop in the future. I hesitate to say it is experimental but it is also quite well-developed and we know a lot about it. At this stage, we will be looking to see how that develops and it is not our aim to create overcapacity by reason of nuclear generation.

Q266 Mr Marsden: Minister, you have talked already about what we are going to have to import in terms of skills and expertise as only part of the process that we are now going down, but there is also surely a requirement on us to have an input into new developments. I am referring specifically to the Generation IV International Forum and to the nuclear systems from which we have, I understand, as a country directly withdrawn ourselves as from 2006. Professor Billowes from the Dalton Institute said to us that our engagement with Europe and America is weak in basic R&D. How are you going to reverse the actuality of that weakness in R&D? Are you going to be prepared to provide the £5 million which would enable us to re-engage with the Generation IV programme or, if not, what else have you got on the agenda?
Mr O'Brien: We have a large agenda in terms of investment into development of knowledge but in terms of the Generation IV it was the case that we had to look at what our priorities would be. There are always going to be competing priorities. We took a view that there were other areas that we wanted to prioritise. As you know, this technology and experimental work is unlikely to produce significant, commercial development until after about 2030. The aim is to ensure that we focus on other areas of research. We are involved in Taurus and we are encouraging university research. Ten years ago there was very little development of nuclear research or courses in British universities. Now we are seeing an increasing involvement in research and building up courses. I think you heard from the academics who were before you that a few years ago they would have had very few PhD students but now they have a significant number, so there are at Imperial, at Warwick, at York, at Lancaster now universities that are doing quite a lot of research. In terms of high level, long-term research we did not feel that our involvement in that particular project was where we wanted to focus our resources. There are always going to be priority choices.

Q267 Mr Marsden: You talked earlier, quite rightly, about how you have to engage more people at graduate level. You are not worried that this sends out a signal to them that there will not be any meaningful international collaboration in this particular area and that will then restrict their own research interests subsequently?
Mr O'Brien: The Nuclear Education Consortium has just put together a project involving £2.6 million from EPSRC and others to generate more academic research and MAs, PhDs. I think most people know now that there is a very clear agenda, shared broadly by the two main parties, with deference to the Chairman on this.

Q268 Chairman: I am totally neutral on these matters.
Mr O'Brien: They have made a very clear, long-term commitment to nuclear. It is very clear to anyone considering whether or not they want to develop a career in research in this area that there is going to be a long-term need for those skills and for that knowledge. I do not believe that our decision in relation to GIF in particular or the Gen IV project is something which is going to cause any serious academics to have any doubt that we are fully committed to nuclear research. It is very clear from what else we have done. John Denham last week pledged £98 million for skills including nuclear. There is plenty of funding behind the development of these skills and this area of education and, for this particular project, whatever signal it might have sent, the signals have been overwhelmed by the other signals that we have sent about development.

Q269 Chairman: Minister, we are very grateful to you for your presence this afternoon. Although the Committee has different views in terms of the nuclear issue, that is not our issue as far as this inquiry is concerned. It is really how we produce the engineering capacity to be able to deliver what the Government has as its programme. It is our job to scrutinise that. It would be very useful if we could have a note from you about specifically those issues to deal with skills because Cogent have clearly set massive targets for the expansion of skills over the next 10 years. We do not have a clear picture from you as to what the Government's involvement in that is going to be and that is at every level from the nuclear scientist right through to the level two and three skills that Gordon Marsden was talking about. In order to present that in our report, it would be useful to have the Government's plans to help deliver those skills so it is not simply a matter of saying, "Pay people more within the private sector."

Mr O'Brien: I think I was making it clear that there was a bit more than that in terms of the Government's commitment, both financially and otherwise, to the development of this agenda. I would hope to publish very shortly the Sector Skills Council report into the need for skills in the energy sector as a whole. When I say "shortly", I mean within a week or so. That will give you not only a view about what the Government is doing and what the wider industry is doing in terms of nuclear but across the whole of the energy sector. If I may say so, this report that you will be doing will be timely and will be able, I hope, to take account of the response from the Sector Skills Council to the Government's Energy White Paper, but I would not want you to go away thinking that my only view about keeping people in this country was that we pay them enough. I think that is a crucial factor but there is also the fact that we provide the interest and the long-term career prospects which they see as being crucial to their future. That is what is going to keep them here too.

Chairman: I think we would agree on that. Minister, Mr Sugden and Dr Baggley, thank you very much indeed.

Written evidence

Memorandum 81

Submission from the Department for Business, Enterprise and Regulatory Reform (BERR) and the Department for Innovation, Universities and Skills (DIUS)

1. This memorandum has been prepared by the BERR Energy Group incorporating contributions from the Department for Innovation, Universities and Skills (DIUS). It sets out our view of engineering skills in the nuclear sector and is submitted as evidence to the Select Committee Enquiry. This paper covers decommissioning, on-going nuclear operations, and new build of civil fission power plant. It does not cover the skills needs of the fusion R&D programme.

Summary of our View

2. The programmes to develop skills within the nuclear industry compare very favourably with what other parts of the energy sector have done so far. That is not to say that all is well. In fact there is a great deal to be done and there will be resource pressure to support new build alongside decommissioning and the MoD programmes. But, overall, the nuclear industry is well advanced in developing its plans and is comparatively well-placed to meet the challenges to come.

Background

3. The 2007 Energy White Paper, the Nuclear Consultation and the 2008 Nuclear White Paper all set out the Government's view on skills in the energy sector. This paper gives the BERR view on skills in the nuclear sector, based on the analyses undertaken for the Nuclear White Paper.

4. The 2007 Energy White Paper asked the Sector Skills Network to report on energy sector skills. BERR is assisting the lead organisations, Cogent, Energy and Utility Skills, the Engineering Construction Industry Training Board plus the National Skills Academy for Nuclear to deliver this report in the second quarter of 2008.

Key Points

The UK's Engineering Capacity

5. The supply of engineering skills from craft worker to chartered engineer is tight across the energy sector. Building nuclear power stations is a challenge but the UK has to make radical changes to de-carbonise its energy infrastructure and the alternatives to nuclear are also challenging. The universities have already responded by creating new capacity to develop a skilled nuclear workforce.

6. The Generic Design Assessment and licensing of the nuclear technologies creates the most immediate demand for engineers and scientists. The Nuclear Directorate of the HSE is the lead organisation for this activity.

7. The UK is pre-eminent at executing major projects for the energy sector worldwide, especially for oil and gas projects in the Middle and Far East. Subject to the global supply and demand situation, some of this capability is transferable to nuclear build.

8. The construction workforce is under most pressure, due to ageing of the workforce plus a big up-turn in demand. The lead time for new nuclear build gives time to plan and to develop the specialist skills required, although the availability of non-specialist skills will be more affected by market conditions.

Training vs Immigration

9. In BERR, we expect the worldwide market for energy sector skills to be difficult for the foreseeable future, with supply running behind demand. While it may be necessary to rely on internationally-mobile skills for short-term specialist activities, or to deal with big peaks in activity, wholesale reliance on the international labour market will expose us to competition from the rest of the world, with the risk of cost escalation and non-availability of resource when needed. Where immigration has been necessary to deal with acute skills shortages in other parts of the energy sector, such as high-voltage transmission line workers, the Borders & Immigration Agency, supported by BERR, has required evidence of a strategy to return the UK towards self-sufficiency.

Role of Engineers

10. Unlike the Magnox and AGR programmes, the UK will not be developing its own design of reactors. A new nuclear programme will require both engineers and scientists to ensure the safety and operability of the designs, translate the design data into a construction programme, design the plant infrastructure, procure equipment & services, manage the project, commission the power station, operate the station, maintain and modify the station throughout its working life and, finally, de-fuel and decommission the station.

Economic Viability of Nuclear Power

11. A cost benefit analysis was given in the 2007 Energy White Paper and the economics of nuclear were discussed at length in the recent Nuclear White Paper. The costs of nuclear electricity are heavily weighted to capex. Fuel is only responsible for 1–2% of the cost of generation from nuclear, compared to around 60% for a CCGT (gas) power station. Thus nuclear has only a small exposure to the cost of uranium, whereas fossil fuel plants have much more exposure to the costs of their fuels. On our analysis, the cost of nuclear generation is favourable on the basis of our current projections for fossil fuel prices. While other technologies (especially renewables and fusion) are being developed, we do not see a new, lower-cost, low-carbon, baseload generating technology achieving global deployment for many decades.

MoD Programmes

12. There will be some overlap of demand between new civil build and, in particular, the submarine propulsion programme. The MoD is best placed to comment.

Supporting Information from the White Paper Analysis

An ageing skills base

13. It is 15 years since the mechanical completion of Sizewell B. Workers with past experience of new build are nearer to retirement. BERR recognises that a programme of new nuclear power stations would have to progress without undue delay, if we are to utilise and transfer existing skills before they are lost. The exact timing is a judgement for the project developers but Government will reduce the uncertainties in the pre-construction period through improvements to the regulatory and planning processes. This includes a process of "Justification"; a Generic Design Assessment by the nuclear regulators and improving the process for granting planning consent for electricity developments, as set out in the 2007 Planning White Paper. Government is also working with the industry to identify suitable sites. These measures should increase investor confidence and encourage the market to invest in training and manufacturing.

14. Across the energy sector in the UK, large numbers of workers will leave for retirement in the next decade. Ensuring a continuity of skills and experience will be a challenge for human resource management. On average, nuclear is slightly better placed than energy as a whole, although there are ageing hot spots. New nuclear build is challenging but, if nuclear power stations are not built, the UK will have to build something else and this will face similar skills issues. For example, clean coal with carbon capture and storage faces competition for process specialists from the oil and gas, refining and petrochemical industries, where the global market, especially the Middle East, is creating high demand for UK expertise.

15. For nuclear overall, we believe that there is time to ensure a skills succession but this must start soon.

The skills deficit

16. We also see growing skills gaps, as workers are faced with technologies and processes with which they are unfamiliar. The overall skills deficit is therefore made up from skills shortages, themselves a combination of natural wastage and increasing demand, skills gaps and the need for a larger workforce to service programmes such as new build.

17. The nuclear sector employs a wide range of skills that can be classified as engineering, from craftsmen and technicians, who trained largely as apprentices, to professionals educated at university. In reviewing skills, it is important not to draw too many distinctions between the various levels of the workforce—they all have the same basic issues.

Open Opportunity

18. Across the energy sector, employers are keen to see a skills and training framework that allows people to reach their potential, something BERR supports fully. However, employer-supported training to degree level is not common and the step up to chartered engineer is not always easy for those with a BEng degree. It was possible for a shipyard apprentice to rise to chartered engineer and managing director in the past and the nuclear sector is keen to offer similar opportunities today.

Construction and competition from other projects

19. Engineering construction activity in the UK and worldwide is growing and new nuclear build will have to compete with other projects. These all need project management expertise and civil engineering, especially for concrete laying and steel erection, while power stations need mechanical and electrical engineering plus construction services for the balance of plant, offsites and utilities. Energy, petrochemical and pharmaceutical sector projects compete directly for these skills, as do Ministry of Defence (MoD) projects, such as the aircraft carriers. At all levels, demand for skills is likely to exceed supply at times and the resulting competition for skilled workers will have to be managed to ensure the best utilisation of the resource. If the energy companies decide on a structured fleet build of identical power stations, whether nuclear of not, that could be easier to manage than one-off projects on an uneven schedule.

The global resource

20. Worldwide, in the developed world, nuclear investment has been subdued for the last 15 years or so. Worldwide demand is now rising, from a low point of starting four reactors per year around 2000 to starting perhaps 15–20 reactors per year by 2020. This is a return to the peak of construction seen around 1980. The world does not currently have the human resources to deliver this programme and strong efforts are being made to re-grow the skills base.

21. Many of the skills and resources needed to build new nuclear power stations are generic to large engineering construction projects. There is an international workforce to service these projects. At present, this is in high demand due to the level of oil and gas activity in the Middle East. In BERR, we expect this to subside in the 2010s and power station construction to increase. We expect the international workforce to be used in the developed world where local labour is unavailable.

22. Given the global demand for more, lower-carbon generation, we expect, therefore, the market to respond by delivering new capacity to build generating plant of all types from clean coal, to nuclear to renewables. We expect UK projects to create opportunities for UK workers but If UK labour cannot be found, overseas labour could be used, subject to safeguards. Overseas workers are already employed, for example, on the LNG terminal projects.

Will nuclear build compete with renewables?

23. Renewables and nuclear power are key components, along with other low-carbon generating technologies, energy efficiency and demand reduction, in the Government's strategy for meeting the 2050 target for carbon emissions. Nuclear power requires specialised skills, both for construction and operation, but in modest numbers compared to the overall energy workforce. For new build, there is some skills overlap with large-scale renewables, such as wind or tidal barrage, especially for large-scale civils and electrical installation. Small-scale renewables are largely dependent on general building trades, where there is little skills overlap with nuclear power. There is no evidence to suggest that building new nuclear power stations would significantly reduce the supply of skills to the renewables sector. In fact, it may well encourage a renaissance in science and engineering, benefiting the entire energy sector.

What is being done about skills in the nuclear industry?

24. The Energy White paper published in May 2007asked the Sector Skills Councils (SSCs) to report on the energy sector, including details of skills shortages, skills gaps and the impact of demographic factors. This will include a forward look that takes account of factors such as retirement and new investment. It will set out the strategies the SSCs and employers are implementing to ensure that the UK can meet future skills needs. It will also consider the actions that can be taken to coordinate recruitment and training across sectors. Government is working with the SSCs to deliver this report in the first half of 2008.

25. Early in this decade, the nuclear industry undertook a strategic review of its skills base, its future needs for skills and the impact of the workforce demographics. The Sector Skills Council, Cogent, was able to build on this in developing its Sector Skills Agreement. This sets out the strategy for future skills development, taking account of both the age profile and the skills gaps that are increasing, as workers are re-deployed from operations to decommissioning. The Sector Skills Agreement sets out a detailed analysis and an action plan to ensure that the industry's skills needs are met.

26. Cogent, with support from the Nuclear Decommissioning Authority and employers from the industry, recognised that a National Skills Academy for Nuclear (NSAN) could play a significant part in recruiting and developing the right skills. Therefore, they submitted a bid in Round 2 of the NSA selection process and were invited in October 2006 to move into the business planning stage. A team seconded from the North West Development Agency, together with a shadow board from employers has subsequently developed a detailed business plan. After appraisal by the Learning and Skills Council, the approval of NSAN as a National Skills Academy was announced by David Lammy, Skills Minister, in September 2007. The Academy was formally launched on 31 January by David Lammy and Malcolm Wicks.

27. NSAN will build on and coordinate existing training provision on a national and regional basis and, with its training partners, aims to deliver 1,200 apprenticeships, 150 foundation degrees and to re-train 4,000 existing workers in its first three years of operation. This will address the decommissioning of existing facilities, the on-going needs of the power generation industry, the Royal Navy propulsion programme and new civil build. NSAN will also develop stronger links with higher education to better integrate technician and graduate training, to improve the supply of graduates into the sector and help to align university teaching with sector need.

28. In parallel, the Nuclear Employer Skills Group (NESG), formed of employers, Government Departments and Cogent, has been taking forward important work on career pathways, up-skilling, competence assurance, passports, qualifications credit frameworks, project management, safety case preparation and foundation degrees.

Graduates and professionals

29. The professional skills set in the nuclear industry includes, for example, physicists, chemists, materials scientists, mathematicians, radiation specialists and health physicists. All of these combine with specialist nuclear and traditional engineering disciplines to design, build, operate and decommission a nuclear power station.

30. The professional workforce is under pressure, with some specialist skills, such as safety case writers, reported to be hard to find. Demand is rising initially for the decommissioning and MoD programmes. New build initially requires skills for the design assessment and licensing of the new reactors, people to support the design and build of the chosen system will be needed later.

31. Retirement will take a toll over the next 10–15 years and it will be necessary to train new professionals to support the forward nuclear programme. Higher education has already responded and 11 institutions now offer masters courses. One university offers a first degree with nuclear engineering specialisms, another will do so soon and two are developing foundation degrees in collaboration with the Academy.

32. Where there is immediate need, such as for professionals to undertake the pre-licensing assessments in the Nuclear Directorate of the HSE, the team can be expanded by competing in the labour market for experienced personnel, by re-training engineers and scientists from other sectors and by training graduate recruits.

33. The Engineering and Physical Sciences Research Council (EPSRC) is contributing £1 million and industry partners £1.6 million towards a "Nuclear Technology Education Consortium" to support masters-level and continuing professional development training for the nuclear industries. Since 2003, EPSRC has contributed £6 million, with contributions from the private sector, towards a research programme to keep the nuclear option open. This brings together seven universities, various Government bodies and the private sector. In 2006 EPSRC also provided support, again in partnership with the industry, for the establishment of an Engineering Doctorate Centre (£4 million) in nuclear engineering, a four year industrially relevant doctoral training programme.

34. EPSRC in partnership with the industry has also provided other support for capacity building initiatives, which include new research Chairs at the University of Manchester in decommissioning engineering and radiation chemistry.

35. EPSRC currently has funding (£4 million) earmarked to support underpinning science and engineering to tackle the challenges associated with decommissioning and waste management in the nuclear industry. Consortia proposals tackling these challenges are currently under review. Research Councils UK (EPSRC) will be submitting a detailed memorandum to the Committee.

36. Outside of the immediate nuclear industry, BERR is assisting Energy and Utility Skills, the sector skills council for electricity, gas, water and waste management, together with its client employers, to develop a skills strategy for the electricity sector. This will ensure the supply of skilled people to operate and maintain the conventional equipment in the nuclear stations and to install the new transmission infrastructure.

37. For new build, engineering construction faces a double challenge of an ageing workforce coupled with a major up-turn in new construction. The Engineering Construction Industry Training Board is working with its employer partners to increase recruitment and training to improve the supply of skills for energy sector and other capital projects.

38. The Secretary of State for BERR announced in October 2006 that, subject to the agreement of contractual terms, a National Nuclear Laboratory (NNL) would be established based around research facilities owned by the NDA, including the Sellafield Technology Centre (BTC), together with Nexia Solutions. This approach is intended to minimise the risk to existing skills within Nexia Solutions and will also help to maintain the research skills base in the UK. A business model for the new organisation is in preparation.

Diversity

39. The nuclear sector is 82% male, overwhelmingly white, with females mostly in stereotypical roles. To a large extent, this is a legacy from past recruitment practice. Employers today are actively seeking to widen their diversity of both gender and ethnicity.

March 2008

Memorandum 82

Submission from Professor Bernard Kelly, University of Manchester

NUCLEAR ENGINEERING CASE STUDY

1. My name is Professor Bernard Kelly and I have held the Chair in Nuclear Decommissioning Engineering at the University of Manchester since 1 May 2007. Prior to that I was employed for 26 years as a senior engineer at BNFL's former site at Sellafield. I am a Chartered Engineer, a Fellow of the Institution of Chemical Engineers and a Fellow of the Royal Academy of Engineering. The views expressed below are mine alone and I speak as a concerned taxpayer and citizen rather than as a representative of any of these institutions. My background is entirely in decommissioning and nuclear waste management and so I am not commenting on any aspect of the new build component of the Committee's remit though Members will of course draw their own analogies as appropriate. I have worked at Aldermaston and Devonport Dockyard on several projects but I do not feel qualified to comment on the overlap between nuclear engineers in the power and military sectors.

2. In stark contrast to the French Government, successive UK administrations have done little to encourage nuclear education in this country. One by one all the nuclear engineering undergraduate courses closed down at our Universities and, as of the end of 2007, not one was left. Now the impact of this myopia is for all to see. Dti estimated that up to 1,000 scientists and engineers will be required at peak to cope with the likely UK nuclear build and cleanup programme. This can be delivered by UK academe given sufficient foresight, planning and Government commitment. In fact Lancaster University has recently announced its intention to launch a brand new Chair in Nuclear Decommissioning Engineering and this will be the first and only undergraduate course available in Britain for many years. My own School is currently offering PhD only education in Nuclear Decommissioning Engineering. Other UK Universities are likely to follow Lancaster's path if a nuclear renaissance begins to materialise in the UK.

3. For many years British Governments (all parties) have encouraged academia and industry to "upskill" in anticipation of a challenge to our traditional strengths in the engineering, chemicals etc sectors from the fast-growing Asian Tiger Economies. Commodity products, chemicals and services will no longer be produced in the UK according to this view. The conclusion is sound and therefore these Governments urged us to move into the higher skill areas based on mastering more advanced science and technology and preferably with high export earnings potential and the promise of self sufficiency in these skills. This exhortation took the view that if progress in industrial success was likely to demand new closer collaborations between our companies and centres of academic excellence, then so much the better. Nuclear engineering fits this description exactly. Worldwide there are over 400 power reactors and over 700 research reactors in operation today. More than half the research reactors are more than 25 years old. The global bill for this cleanup has been estimated at £400 billion. New revolutionary and evolutionary technologies are going to be needed if value-for-money to the taxpayer is to be delivered.

4. I have noticed a real resurgence in interest in nuclear engineering amongst our talented students (and not just the undergraduates in this University). Very promising A level students are keen to learn about a career in nuclear engineering to an extent unprecedented in my professional lifetime. This augurs well for their future and for our economy.

5. Given the content of paragraphs 3. and 4. above, I want to turn now to a specific item within the Committee's Terms of Reference ie . . .. "The value in training a new generation of nuclear engineers versus bringing in expertise from elsewhere". The fact that this question is even raised in Great Britain reveals so much about the attitude towards science and engineering in this country. Many eminent nuclear engineers and scientists have worked in the University of Manchester over the last 100 years—some of them Nobel Laureates. They must be turning in their graves at a question like this. Other submitters of evidence will put forward to you the value to our economy of our nuclear industry—particularly in the North West of England where it all began. In the 1950's, Britain once led the world in nuclear science and engineering—is there no desire within Government for our country to lead once more? I cannot conceive of any circumstance leading to a French Parliamentary Committee being asked this question.

6. Regarding the UK's engineering capacity to carry out the planned decommissioning of existing nuclear power stations, it must be recalled that Britain has already successfully decommissioned many reactors. In addition at Sellafield the Decommissioning Group have already delivered many successful projects. For sure we have to resurrect our nuclear engineering courses and the supplyside in the UK just now is in a distressed

condition but there can be no doubt that sufficient expertise remains to pass on the critical skills to the next generation of nuclear technocrats. Technologies are available to us to achieve this but the key question is "can we develop new technologies to do it faster, safer and more affordably?". That is the challenge.

7. A final word on the interaction between funding and the supply of well-qualified nuclear engineers and scientists in Britain. Paragraphs 2 and 5 above point out the dangers of regarding this as a pipeline of talent that Government can switch on or off at will. For young students to make their commitment, for Universities to invest in new educational facilities, for companies to sponsor graduates etc, there must a steady funding stream to tackle our nuclear legacy.

March 2008

Memorandum 83

Submission from the Dalton Nuclear Institute

1. *Background to Dalton Nuclear Institute*

1.1 The University of Manchester is the UK's largest academic institution with ambitious plans to be ranked in the top 25 universities worldwide by 2015. Nuclear research has been identified as one of the disciplines targeted for significant investment to help the University achieve its aim. The University already has the UK's largest concentration of nuclear research, training and educational activities, and in 2005 formed the Dalton Nuclear Institute to drive forward its ambitions. The University has recently signed a £20 million joint agreement with the Nuclear Decommissioning Authority (NDA) to establish the Dalton Cumbria Facility (DCF), a new research facility and world-leading academic.

1.2 In relation to the nuclear industry, the University has strengths in areas such as:

— Materials performance: Structural Steels, Fuel and graphite.

— Radiochemistry.

— Radiation Sciences.

— Decommissioning Engineering.

— Geology and Geotechnics.

— Thermal Hydraulics and Fluid Simulation.

— Radio-Biological research.

— Dosimetry & Epidemiology.

— Policy and Regulation.

— Stakeholder Issues and Decision Analysis.

— Nuclear Physics.

— Societal Issues / Socio-economics.

1.3 The Dalton Nuclear Institute has facilitated the launch of a new MSc training programme in nuclear and chairs the Nuclear Technology Education Consortium (NTEC) of 11 education and research institutes. Manchester University leads the Nuclear Engineering Doctorate Centre in partnership with Imperial College, has recently been awarded the Nuclear Sustainability Project, and is one of the largest academic institutions that has contributed to the Nirex R&D programme. Manchester has also entered into a £20 million strategic research agreement with the NDA to establish the Dalton Cumbria Facility, which will host radiation sciences and decommissioning engineering capabilities, and to secure 10% access to the state-of-the-art Technology Centre at Sellafield. In addition, Manchester University, through the Dalton Nuclear Institute, has announced plans for the Centre in Nuclear Energy Technology which is a proposed £25 million investment in reactor engineering related capability.

2. *Executive Summary Points*

2.1 There is a recognised skills shortage in nuclear engineering both in the UK and overseas. Such a skill base is essential for continued safe operation of all activities associated with the UK nuclear industry.

2.2 This skills shortage can be overcome with a vibrant and active academic sector that provides (a) a skills pipeline of young individuals, (b) research to support the industrial needs and (c) training and education.

2.3 It is not credible to rely on other countries to fill the skills gap given the need for "an intelligent capability" from a safety regulatory perspective, and the risk that such a capability is mobile and transitory given it is under demand from other countries.

2.4 Investment in research is key to ensure the UK can generate independent and authoritative experts capable of assessing the safety and operational performance of the diverse aspects of the UK interests in nuclear energy.

2.5 A vibrant academic sector and the strong identity of a National Nuclear Laboratory will provide the mechanisms to ensure a coordinated and coherent approach to underpinning the nuclear engineering skill base from basic science to applied technology.

2.6 Despite having a skills gap, the UK still has a significant opportunity to play a leading role internationally in energy, sustainability, non-proliferation, counter-terrorism, etc based on an active nuclear engineering capability.

2.7 The Dalton Nuclear Institute/Manchester University is already making a significant contribution to solving the nuclear skills gap.

3. *Background*

3.1 The UK has historically had a significant capability in nuclear engineering. It is one of the few countries to have fully developed its nuclear fuel cycle capability including reprocessing and re-fabrication of fuel for use in fast reactors. It also has a long track record of pioneering work on different reactor technologies as well as naval propulsion and strategic deterrent capabilities.

3.2 Nuclear Engineering as a discipline in its own right is difficult to define as it tends to be a combination of different capabilities such as civil, mechanical, structural, electrical and chemical engineering in a nuclear environment but there also some specific scientific capabilities such as reactor physics, materials performance, radiochemistry, nuclear data, criticality, thermal hydraulics etc. For the purposes of this assessment we assume nuclear engineering encompasses the capabilities as listed above as well as others that might be specifically applied to support nuclear operations.

3.3 Following the extensive nuclear investment programme from the 1950s onward nuclear engineering was a well established capability in the UK and this was supported by a strong R&D programme and academic partnerships. However during the late 1970s and 1980s with the "dash for gas" nuclear energy received less investment. The UK moved away from fast reactor technology, R&D programmes were cut and consequently academic involvement declined. The teaching of nuclear engineering and related courses in universities subsequently declined—combined with factors such as fewer young people interested in science and engineering degrees, and greater job opportunities in new industries such as service sector, IT, computing, consultancy, accounting etc—and led to a skewed age profile and concern that insufficient trained graduates were entering the industry. This fact has been recognised by many stakeholders associated with nuclear skills such as Cogent and the National Skill Academy for Nuclear.

3.4 Nuclear R&D within academia plays a key role in attracting young people into the industry. Recently there been a number of new initiatives such as EPSRC's investment in "Keeping the Nuclear Option Open", NTEC MSc course, the Engineering Doctorate programme, the "Nuclear Power Sustainability" programme and other initiatives that have helped to plug the gaps. As noted below these R&D activities help to generate scientific capability in nuclear engineering disciplines that is able to make informed and authoritative judgements on the safety, performance and functionality of various nuclear operations (civil nuclear energy to decommissioning to naval propulsion to weapons). Not everyone involved in the nuclear industry needs to follow this path. The industry rightly states it doesn't want undergraduate nuclear engineering degree courses, but instead good quality maths, physics and science courses, and then nuclear expertise added through (i) in-house training, (ii) on-the-job experience and (iii) additional academic qualification (MSc and PhD).

3.5 Thus nuclear engineering covers not only a wide range of disciplines but also different categories of practitioners: those that are engineers-by-training but working in the nuclear industry and those that are authoritative experts having spent their career researching and understanding the fundamental scientific aspects. The industry needs both kinds.The latter are essential for their work on safety cases, for example to ensure a proper understanding on the scientific processes exists. There is however concern that we do not have sufficient capability being generated that can provide a authoritative perspective.

4. *The UK's engineering capacity to build a new generation of nuclear power stations and carry out planned decommissioning of existing nuclear power stations*

4.1 The engineering capability to build new nuclear power plants can be divided into different groups that are very much dependent on the phase of the new build project.

4.2 At the start of the project an intelligent buyer and regulatory capability is needed. These are individuals from a nuclear engineering perspective, who have a deep understanding of how a particular reactor system will work. This capability is only gained through researching and understanding how a system works. It is necessary to make informed decisions about the licensability of a system. The UK only just has the capacity to meet this phase and we are reliant on the historic capability mentioned above being available prior to retirement. We are vulnerable in key areas such as reactor physics, thermal hydraulics, safety assessment, criticality etc.

4.3 Following this phase, the construction phase is very much akin to normal civil construction associated with any major infrastructure projects. Based on a new nuclear build programme being a £2bn per annum commitment, this represents a small fraction of the existing construction industry. Approximately 80% of the list items for a nuclear plant could be sourced in the UK, and the value of these components is approximately 50% as expensive items sourced from overseas.

4.4 Operation is approximately 10 years away although we need to ensure that the future operators of those plants are following the appropriate career path, starting with engineering degree courses, post-graduate training in reactor systems and then into industry. A means of increasing the skills pipeline here is through universities having R&D projects that "hook" young peoples' interest and imagination.

4.5 At the Dalton Nuclear Institute we have been working closely with public and private sector organisations on the need to underpin academic capability to support new build. We have plans for a £25 million investment in a new Centre for Nuclear Energy Technology that will provide academic research, maintain skills, and provide a pipeline of young people to join the industry as well as the independent authoritative perspective that is required. However the UK also needs a strong entity such as the National Nuclear Laboratory to help the transition from basic science through to industrially applied technology.

4.6 With regards to decommissioning plant, the end process may simply be bulldozing an historic building. As for nuclear power plant construction, this doesn't need any significant nuclear expertise. Where the nuclear engineering expertise is required is in understanding how facilities can be decommissioned. Here, given the complexity of the programme, engineers are needed to help characterise, assay, retrieve, separate, segregate and encapsulate waste forms, as well as understand the structural integrity, radionuclide inventory, safety, and functionality of old facilities. This is a significant and complex programme with a great deal of intellectual input before any facility can be demolished, or waste form encapsulated.

4.7 Given the extent of the UK's decommissioning programme at present there is sufficient practising engineering capability, but more needs to be done to support the key expert / authoritative capability that is required. For example the capability that can pass judgement on how and when a building can be demolished or a waste form can be encapsulated. The latter capability is again, obtained through a lifetime of researching specific nuclear aspects. We can't rely on foreign companies providing this expertise indefinitely. Soon, the US decommissioning programme will take off and US companies currently focused on UK opportunities will find work at home.

4.8 The Dalton Nuclear Institute is working closely with the NDA to solve this problem, and we have a joint £20 million to establish new capabilities in Nuclear Decommissioning Engineering and Radiation Sciences, both of which are essential for the legacy waste management programme.

4.9 The UK National Nuclear Laboratory has a key role to play. For both power generation and decommissioning a strong National Nuclear Lab identity will attract people to the industry and also provide a bridge between basic science and industrialisation.

5. *The value in training a new generation of nuclear engineers versus bringing expertise in from elsewhere*

5.1 The extent of the UK nuclear programme means it is vital that the UK develops its own skills pipeline. The alternative approach of bringing in capability from overseas has the following disadvantages:

1. All countries are suffering from a shortage of nuclear engineering capability, therefore a readily available mobile workforce is in very short supply (virtually non-existent) and is being sought after from other countries.
2. There is no guarantee such individuals will head to the UK compared to other countries. We would be fighting for the same resource which would prove expensive and risky (should mobile individuals leave to the next highest bidder).
3. Overseas capability is unfamiliar with the licensing and safety approach in the UK, which is significantly different to other countries such as France, US etc. Individuals from overseas would have to spend a significant amount of time getting up to speed with the safety case approach in the UK.
4. Regulators would express concern if the intelligent capability that understands how to run and operate reactors systems or UK nuclear plant is vested in a transitory mobile workforce.
5. The UK might not be comfortable in a public inquiry for instance concerning the safety of new reactor systems having to call on learned expertise from overseas to present a justification because the UK does not have any indigenous capability?

5.2 In summary it is vital the UK develops its own skills pool to avoid dependency on depleted skills pools from overseas, and also to ensure the appropriate management of safety.

6. *The role that engineers will play in shaping the UK's nuclear future and whether nuclear power proves to be economically viable*

6.1 Nuclear engineering is a critical capability that will be required on an ongoing basis to support the UK's diverse nuclear interests. Such capability is required in the future in private sector commercial companies, and public sector organisations such as regulators and academia. The UK's diverse nuclear interests that require access to nuclear engineering capability include the following:

- Safe operation of the UK existing civil nuclear reactors for electricity generation.
- Assessment and delivery of new nuclear civil build in the UK.
- Support to the legacy waste management and clean-up operations.
- Geological Disposal programme.
- Naval nuclear Propulsion.
- Nuclear Fusion.
- Strategic deterrent capability.
- Homeland security.
- UK involvement in international safeguards and non-proliferation.
- Nuclear medical applications.
- UK involvement in international energy policy and advanced fuel cycle reactors initiatives.

6.2 Nuclear engineering capability to support the interests listed above divides into general engineering capability working in nuclear and specific nuclear expertise. The latter requires dedicated programmes to ensure the UK has access to appropriate expertise that can make authoritative judgements. This ability does not come from reading text books, but from actually hands-on experience. It is supported by an active research programme in the UK, which helps to generate such an informed capability, but it also helps to attract young people into the industry.

6.3 Given the extent of the UK's interests listed above, and also that:

1. The UK has a significant historic track record in nuclear expertise.
2. The UK is no longer a vendor of any system and therefore can act impartially and independently.

there is a significant opportunity for the UK to take a central role on the world stage in important international policy matters relating to energy, sustainability, safeguards, non-proliferation and counter-terrorism.

6.4 With regards to the economics of nuclear energy, engineering is a key aspect to this. Engineering will play a role as follows:

- Capital Cost—Nuclear generation is capital intense and the capital cost drives the economics. Engineering input is essential to reduce cost yet retain high levels of safety and performance. Moreover, development of advanced reactor systems such as High Temperature gas-cooled reactors etc. will require a strong engineering input to achieve capital cost targets.
- Operations—Engineering is required to ensure the plant is operating correctly and safely. Without an engineering capability, plant lifetime load factor and safety would be jeopardised.
- Fuel Cycle—future fuel cycle will be dependent on technology demonstration which will require significant nuclear engineering input.
- Decommissioning—this does not significantly impact the cost of generation, but is heavily dependent on nuclear engineering.
- Geological disposal—as for decommissioning, this will not be a major cost element but it is essential the UK moves forward with implementation of a repository. Again engineering will play a crucial role in this programme.

7. *The overlap between nuclear engineers in the power sector and the military*

7.1 There are a significant number of overlaps in the capabilities listed above between the civil and military sectors. Common aspects include areas such as:

Civil Nuclear Programme	*Military Nuclear Programme*
Reactor technology for electricity generation	Reactor technology for naval propulsion
Fuel recycle technology	Separation technology for plutonium and uranium
Legacy waste management and decommissioning	Legacy waste management and decommissioning
Enrichment technology for civil fuel	Enrichment technology for weapons

7.2 The applications of the technology are different and it doesn't necessarily mean that having a civil nuclear capability means one, by default, has military capability. However there are common capabilities such as:

— Nuclear Materials performance.

— Nuclear Physics and Nuclear Data.

— Thermal hydraulics.

— Control and Instrumentation systems.

— Computational Fluid Dynamics.

— Nuclear Chemical Engineering.

— Safety Assessment.

— Robotics.

— etc.

7.3 In the past, the military programme has been developed very much in isolation from the civil programme. This was due to concerns over classified information. However there is an opportunity for civil and military programmes to work together in developing a skills pool and supporting research, with only the truly classified aspects of the military programme kept separate. The UK is not now in the position of having financial or personnel resources to develop both programmes in isolation. For example, reactor physicists on the military programme can develop their skills and knowledge by researching civil systems, and then only when necessary divert to classified work to follow a specialist career path. This link does however need to be carefully managed to avoid the perception that civil and military nuclear programmes are one and the same.

7.4 As noted earlier, a vibrant academic sector and the strong identity of a National Nuclear Laboratory will provide the mechanisms to ensure a coordinated and coherent approach to underpinning nuclear engineering skill base from basic science to applied technology.

March 2008

Memorandum 84

Submission from the Institution of Mechanical Engineers (IMechE)

The Institution of Mechanical Engineers (IMechE) is a professional body representing 78,000 professional engineers, working in all sectors of industry, including over 3,900 in nuclear engineering. The following evidence is in submission to the Innovation, Universities and Skills Select Committee nuclear engineering case study. The evidence is structured in response to the case study's terms of reference.

1. *The UK's engineering capacity to build a new generation of nuclear power stations and carry out planned decommissioning of existing nuclear power stations*

1.1 The UK's capacity to build a new generation of nuclear power stations is uncertain. Over the past two decades the capacity to fabricate the major components for a nuclear power station (over 1,000MW) has decreased to the extent that they are likely to have to be imported from overseas. Further there are relatively few engineers with experience of pressurised water reactors; at present the only pressurised water reactor in operation in the UK is Sizewell B. In contrast the UK has significant experience in decommissioning existing nuclear facilities, particularly those used in early atomic energy development. British Nuclear Group has also successfully undertaken the decommissioning of early Magnox graphite reactors.

1.2 In general, much of the engineering associated with a nuclear power plant is not nuclear engineering in isolation; broader engineering skills issues have a significant impact on the sector (including mechanical, civil, chemical etc.). Any nuclear new build will require additional engineers, the scale of which depends on the scale of the programme itself.[1] More generally, recent reports[2] indicate that the UK needs to double the number of science, technology, engineering and mathematics graduates it produces if we want to remain competitive, attract high technology inward investment and match the growing countries of the world.

[1] Estimates indicate that the nuclear industry will need to attract between 5,000–9,000 new graduates over the next decade just to meet the existing demands of operation, maintenance and decommissioning.

[2] *Shaping up for the future: The business vision for education and skills* (CBI, April 2007)

2. *The value in training a new generation of nuclear engineers versus bringing expertise in from elsewhere*

2.1 Trained engineers (from a range of disciplines) will be needed to ensure that decommissioning and new build programmes can take place. Historically the UK's approach has been to produce nuclear competent engineers rather than specifically nuclear engineers; graduates and technicians from other engineering disciplines have been trained in the nuclear sector. Although some universities and employers are now investing in courses to provide education and training in areas essential to new build and decommissioning, the demise of development opportunities with BNFL, the Royal Navy and UKAEA is a cause for major concern.

2.2 New build projects will compete globally for available engineering resources. With 300 to 500 engineers needed per operational nuclear site, plus the many more needed during construction and in the supply chain (eg heavy manufacturing, control and instrumentation engineering), it is unlikely that new build projects can be supported by imported expertise alone. In short, it is likely that the scale of the nuclear new-build programme and, in consequence, decommissioning programmes, will be shaped by the availability, or otherwise, of suitably skilled engineers and tradesmen—the exacting standards of the nuclear sector cannot be compromised.

3. *The role that engineers will play in shaping the UK's nuclear future and whether nuclear power proves to be economical viable*

3.1 Engineers will play an absolutely critical role shaping the UK's energy future, of which nuclear is unlikely to provide more than 10% of total energy needs. In terms of the UK's nuclear future—assuming it proves economically viable—engineers will be employed by plant owners to design, specify and manage the construction phase, to operate the plant and ultimately to decommission it, throughout the supply chain and within the various regulatory and licensing authorities.

3.2 No one knows with absolute certainty whether a UK new build programme will be economically viable. Representatives of industry suggest nuclear power will be competitive alongside gas and coal but no plants have yet been built without subsidy in a truly competitive market. Further the cost of building, operating, maintaining and decommissioning nuclear power is subject to significant uncertainty. Engineers have a central role to play in assessing and mitigating this uncertainty and will find innovative and more cost effective solutions, but the fundamentals are unlikely to change in the near to medium term.

4. *The overlap between nuclear engineers in the power sector and the military*

4.1 Civil nuclear engineering is principally focused on power production whereas military covers both nuclear weapons and the nuclear propulsion plants in the UK submarine fleet. In general military engineers working with nuclear weapons stay within that area whereas engineers involved in nuclear power production on submarines do often move to civil power production at some time in their careers.

4.2 There are many parallels between civil and military nuclear decommissioning and there is a strong argument for combining both of these under the Nuclear Decommissioning Agency (NDA).

March 2008

Memorandum 85

Submission from the British Energy Group plc

1. Introduction

1.1 The purpose of this paper is to respond to the invitation extended by the Innovation, Universities, Science and Skills Committee to address the terms of reference associated with the nuclear engineering case study. It is submitted on behalf of British Energy Group plc.

1.2 British Energy is the largest generator of electricity in the UK. We own and operate eight nuclear power stations and one coal-fired power station, and we are a major supplier of electricity to industrial and commercial customers.

2. Executive Summary

2.1 The main areas of focus from British Energy's perspective when considering the terms of reference of this inquiry are the demographic profile of the existing workforce and the issues associated with the ability to resource continued operation, decommissioning and new build. This paper provides information on British Energy's current engineering capacity and our position within the industry as a whole. It highlights areas of activity in the promotion of Science, Technology, Engineering and Mathematics (STEM) subjects as a means of creating engineers for the future. It also outlines specific activity being undertaken by British Energy in support of this objective. The implications of new build are considered in terms of the UK's ability to meet demand for the necessary skills. Finally, British Energy's view on the economic viability of nuclear power is provided.

3. Current Engineering Capacity

3.1 There are currently 10 nuclear power plants operating in the UK—eight of which are owned by British Energy. Closure dates are provided in the table below:

British Energy Power Stations

Station	*Commissioned*	*Current Closure Date*
Hinkley Point B	1976	2016
Hunterston B	1977	2016
Hartlepool	1984	2014
Heysham 1	1984	2014
Dungeness B	1985	2018
Heysham 2	1988	2023
Torness	1989	2023
Sizewell B	1995	2035

3.2 30% of our engineering staff are currently over the age of 50. We need to ensure a supply of suitably qualified and experienced people who can meet the needs of continued operation, decommissioning and potentially the building of new nuclear power stations. British Energy is focused on recruitment of the next generation of engineers and is addressing this through the continued graduate programme and apprenticeships which sees the recruitment of approximately 20 graduates and 50 apprentices each year. The company has also recruited an additional 100 staff during 2007–08 into business critical areas such as Operations, System Health and Design Engineering as a direct means of strengthening internal capability. Whilst the age profile presents British Energy with a challenge, the company is taking proactive measures to ensure the workforce profile continues to meet the needs of the organisation going forward.

3.3 31% of the workforce is directly employed in engineering roles, although the majority of British Energy's needs are not for specialist nuclear engineering. Recruitment, therefore, focuses generally on general engineering/STEM skills with nuclear specific top ups provided internally.

3.4 British Energy's Graduate Programme is a two year scheme aimed at providing graduates with an opportunity to learn about the business through attachments to various functions at different locations within the business. The objective is to give them an overview of the corporate and operational side of the business in advance of final placement in their specialist areas.

3.5 We are reviewing apprentice training with a view to offering a centralised programme of excellence. This national scheme will continue to recruit locally with periods of training undertaken at a residential training centre over a 3 to 4 year period. This revised approach will ensure consistency in the quality and standards, providing the organisation with greater influence on the curriculum. In addition, it provides the opportunity to select high performing apprentices to continue onto higher education and graduate programmes.

3.6 Whilst there is no current shortage in terms of engineering capacity within the organisation at present, there are risks associated with potential skills gaps, for example, control and instrumentation engineers. There is high demand within the industry as a whole in the areas of control and instrumentation, system engineering specialists, project managers, health physics & radiation protection and computational specialists. Specialists in writing safety case documentation are also in short supply and Cogent is considering how to address this issue recognising there is a lack of industry accredited specific qualifications.

3.7 New build presents an additional challenge. According to the CBI, the number of STEM subject graduates leaving university needs to double from 45,000 to 97,000 by 2014 to satisfy existing industry needs irrespective of any demand that will come from building new nuclear power stations. The infrastructure to support the provision of relevant courses requires to be strengthened to meet demand for skills and government support is required in this area. Work is underway and the partnership approach between Cogent and industry is progressing well. The establishment of the National Skills Academy for Nuclear also supports the objective of promoting STEM subjects and interest in the industry. There is evidence that education establishments have recognised the need to encourage uptake of STEM disciplines and are offering relevant courses. For example, Lancaster University is running a Nuclear Engineering BEng/MEng degree course. In addition, Manchester University is providing courses on Radiological Sciences, Decommissioning Engineering, Reactor Technology, Geological Disposal and a Nuclear Technology Computing & Simulation.

3.8 Research Alliances have also been established and British Energy is involved in this process having established partnerships with Strathclyde University Advanced Engineering Centre, Manchester University Materials Performance Engineering Centre, Bristol University Systems Performance Centre and Imperial College where the company will join the non-destructive evaluation centre and jointly fund a chair in high temperature materials with the Royal Academy of Engineering.

4. Train New Engineers or Recruit from Elsewhere

4.1 The education infrastructure needs to promote STEM subjects to provide the engineers of the future. The UK is responsible for only 1%–2% of global output which means, in terms of attractiveness to potential employees, it will be a large but competitive labour market. There are 438 reactors operating around the world, 15 of which are owned by British Energy. As at May 2007, 31 new reactors were under construction around the world, 74 were being planned and 182 proposed. This provides opportunity for engineers to work outside of the UK. It also means there is potential to recruit from abroad although it should be noted the ability to import skills is not straight forward because of the security vetting requirements associated with foreign nationals. The immigration rules and associated point system may be an additional barrier further limiting the potential recruitment pool. Government support in placing a number of electricity generation engineering occupations on the shortage occupation lists is required to ensure the UK can benefit from the international market.

4.2 More needs to be done earlier in the education process to spark pupils' interest in STEM subjects so that the graduate population of science, engineering and technology based disciplines increases sufficiently to meet demand. British Energy has recognised the need to encourage young people to pursue STEM careers and works with organisations such as STEMNET and Energy Foresight to help achieve this goal. STEMNET is the Science, Technology, Engineering and Mathematics Network. It is a regional based organisation that supports employers and students by promoting STEM subjects. It encourages students towards STEM by undertaking classroom activity relating to science, technology, engineering and mathematic subjects and linking companies to schools to give young people a clear idea of potential career opportunities. It has a number of partner organisations such as the Engineering Development Trust. STEMNET supports SETPOINT by distributing core funding allocated by government. They work with partners to arrange industrial visits and work experience opportunities and encourage pupils to do well in STEM subjects and fulfil their aspirations.

4.3 SETPOINT run different projects including Year in Industry, Headstart, Engineering Education Scheme and Go4Set. It also manages a Science and Engineering Ambassadors programme co-ordinated by STEMNET which was set up to help businesses get involved with their local education community. STEMNET and SETPOINT work to create effective links to facilitate this involvement which can include such things as industry visits for students and teachers, industry related projects, workshops and talks. British Energy currently works with SETPOINT and has a number of Engineering Ambassadors at present who act as mentors for the Go4Set scheme. The principal aim of the Science and Engineering Ambassadors programme (SEAs) is to support teaching in delivering the STEM curriculum and to inspire and enthuse young people about STEM. In addition to Go4Set activity, British Energy also has an established Talk Service programme that actively engages with the local community by having trained representatives visit schools and businesses. All new graduates to the business have been trained to provide this service which aims to give people the facts about the industry and potential opportunities. The company has seen a positive response to this initiative so far.

4.4 As well as encouraging interest amongst students, there is also the need to ensure teachers are adequately trained such that they can support their students in making informed career decisions at the appropriate time in their school careers. This is one of the roles of Energy Foresight and British Energy has been engaging with this organisation to ensure support is provided to local schools. We believe that more government support is needed to raise the standard of STEM teaching in schools. The company is also working closely with local communities to promote British Energy in terms of employment options and through the local recruitment of skilled workers.

4.5 To further support the training and development of potential engineers, British Energy is also developing partnerships with universities with links focused on Science and Engineering faculties. The aim of fostering such links is not only to promote British Energy as an employer of choice, but also to provide support in the form of mentors, sponsorship, industrial placements and industry advisors as a means of raising awareness regarding opportunities and potential career paths. This will be achieved by creating partnerships with universities and established nuclear professionals. In addition, work is underway to inform undergraduates about the current Graduate Training and Development Scheme, supported by existing and previous British Energy graduates who visit targeted universities to communicate the benefits not only of British Energy's scheme, but of a career in the nuclear industry in general.

4.6 Apprenticeships are another means by which engineers can be developed. Cogent is currently reviewing apprenticeships for England and Wales and these will cover process working, decommissioning and health physics. The Modern Apprenticeship Scotland covers similar subjects. Cogent is being particularly proactive in providing information regarding apprenticeships and training in general and is targeting training providers to keep them informed on Apprenticeships, Qualification Credit Frameworks and Diplomas.

4.7 Whilst there is general concern about the number of STEM graduates coming through schools and universities, there has been some encouraging data published, specifically by Doosan Babcock who undertook a study in May 2007 which surveyed over 250 engineering students from Imperial College. The study canvassed opinion on, amongst other things, attractive career options. 37% of students said they thought the energy sector which offered the most exciting career opportunities for new engineers was nuclear. Bioenergy was the most attractive option followed by Clean Coal and CO_2 capture and storage. Less attractive options were Wind, Marine, Solar and Oil and Gas. However, it should also be noted the same survey identified that 34% of students said they would be unwilling to be associated with nuclear power with primary concerns relating to environmental factors and perceived limited career opportunities. This highlights a clear need for the nuclear industry to undertake further work to promote the environmental benefits of nuclear power as well as highlighting potential career paths. This is especially important with the prospect of new nuclear power station build.

4.8 If the UK is to capitalise on potential resource for future engineers, the number of females progressing from GCSE to A levels needs to be addressed. More than 50% of those students taking GCSE Double Award Science in 2005 were female. However, this is not reflected in the number of women in the Science, Engineering and Technical workforce. 18% of the total SET workforce and 12% of the nuclear industry workforce is female. The proportion of females in SET job roles within the Nuclear industry is the lowest across the whole Cogent sector.

5. The Role of Engineers in Shaping the UK's Nuclear Future

5.1 The prospect of building new nuclear power stations in the UK creates a great opportunity to attract new talent into the nuclear industry and engineers will have a pivotal role in shaping the UK's nuclear future. Existing facilities need to be sustained and eventually decommissioned and new build supported. Engineering resource is required throughout each stage of the process, although specialities will vary during each phase. Recognising the UK is likely to adopt standardised international designs, this will increase flexibility as a result of transferable skills from overseas.

5.2 Competition from other engineering sectors, and the adverse perception of nuclear power among some graduates (see 4.7 above) shows that there is clearly work to be done in terms of presenting the industry as an attractive option for developing an engineering career. The recent Government announcement should help create certainty and enthusiasm for the industry as a career choice which will be underpinned by British Energy's own new build plans being announced.

6. Is Nuclear Power Economically Viable?

6.1 The economic viability of nuclear is important as is the need to address the pending energy gap that will result from diminishing output as older coal-fired power stations close and the nuclear fleet ages and is decommissioned. By 2010 there will be only eight nuclear power stations in the UK. On current lifetimes, by 2023 only Sizewell B will be operating. In terms of energy supply, we could see an 8% shortfall by 2020, rising to a 15% shortfall by 2030. The energy review acknowledged this gap must be filled by a mixture of renewables, clean coal and nuclear.

6.2 The capital costs associated with new build are a key factor in determining the economic viability. This relies, to a certain extent, on the availability of engineers to support the design and manage the construction of new plants. The UK needs suitably qualified engineers who can provide the right designs and build stations to the highest standards which is why government support in promoting take up of STEM subjects is so important.

6.3 In its White Paper on the Future of Nuclear Power, the government has concluded that uranium supply should not be a constraint on new nuclear build in the UK. The economics of nuclear power are not susceptible to volatile fossil fuel prices, making nuclear an attractive option for the UK as part of a diverse fuel mix including renewables, gas and clean coal.

6.4 Security of supply is another major consideration as the UK's indigenous supplies of oil and gas decline.

6.5 Environmental aspects should also be taken into consideration. Nuclear power is virtually carbon free which will help the government reach its target to cut carbon emissions by 60% by 2050.

7. Overlap Between Nuclear Engineers in the Power Sector and the Military

7.1 There is overlap between nuclear engineers in the power sector and the military. According to an investigation carried out by Cogent in May 2006, there are 2500 Ministry of Defence roles associated with nuclear deterrent and 240 of those roles are specialist in operations and maintenance. It should be recognised the military is experienced in PWR technology which is used in submarine propulsion. This is the same technology used at Sizewell B, and is one of the options for new nuclear build.

8. Conclusion

Training the next generation of engineers is vital for the UK economy to grow and action is needed to meet demand for this skill set. At the moment there are insufficient numbers of STEM students progressing to university and into industry. There are many good initiatives and activities underway to encourage young people to take these subjects and a coordinated approach between government, industry and sector skills councils is essential. There is also a need for action to avoid overlap and improve coordination so that the industry can take advantage of these initiatives to best effect. Many of the sector skills councils are working on similar initiatives and there must be opportunities to work together to achieve greater results. With a more coordinated approach from Sector Skills Councils, Learning Skills Councils and Training Boards, better use could be made of available funding, resources and industry support. Greater government support in the coordination of activities would be of benefit.

March 2008

Memorandum 86

Submission from AMEC Nuclear UK Limited

Introduction & Executive Summary

1. This evidence is being presented by AMEC Nuclear UK Limited to the Innovation, Universities, Science and Skills Committee for their Engineering Case Study in Nuclear Engineering. The evidence covers the four main issues identified in the Terms of Reference, see press notice no 27 (07–08).

2. AMEC is the largest UK-based private sector supplier of programme and asset management and engineering services to the nuclear sector. The business builds on AMEC's 50 years experience in the nuclear market and UK clients include HSE, Sellafield Sites, Magnox, British Energy, UKAEA, AWE Aldermaston, BAe and Rolls Royce. Half of our nuclear business is now international with a wide client base covering nuclear utilities, vendors and regulators in Canada, Europe and the former Soviet Union, South Africa, Japan and Korea. AMEC is committed to maintaining its position as the leading UK engineering company servicing the growing UK and global nuclear market.

3. Nine recommendations arising from this submission are detailed in the final section covering:

— commitment and approaches to inclusion of nuclear technology training in schools and universities;

— promotion of knowledge transfer between academia and industry;

— the importance of facilitating training within industry and not just academia;

— recognition of the value of UK Nuclear Engineering in the growing global market; and

— co-ordination and support to industry involvement in international nuclear programmes and IAEA activities.

UK Engineering Capacity—New Build and Decommissioning

4. New Build Experience—AMEC Nuclear's experience covers most of the large scale power generating reactor designs including Magnox, AGRs, PWR and Candu reactors, as well as Generation IV reactor designs including fast breeder reactors, high temperature reactors (such as the Pebble Bed Modular Reactor being developed in South Africa) and fusion reactors. Consequently AMEC is playing a significant role in the implementation of new build in the UK.

5. International collaboration—As the nuclear industry becomes increasingly global, AMEC's involvement in several international nuclear collaborations indicates a strong willingness for the international nuclear community to engage and value UK nuclear expertise, albeit with little government driven development over the last decade. However it is important for UK companies to continue to play an important part in international activities to maintain and build this position. In this respect, adoption of a more pro-active position by the UK Government to support the benefits derived from these collaborations

would be highly beneficial. The recent addition of the UK to the Global Nuclear Energy Partnership (GNEP) is a welcome step and greater UK industrial participation must be sponsored and promoted by the UK Government to derive future value for the UK economy.

6. Short-term new build technical position and requirements—Western new build applications are likely to be based on existing international reactor designs such as the EPR, AP1000, ESBWR and USAPWR with CANDU6 and ACR in a small number of regions including Canada. Compared with the previous designs, the new designs will make greater use of modular construction techniques with items fabricated in different countries and with new designs aimed at increased safety and lower waste streams. Technical challenges to design and build new reactors with better safety, compliance with new security and safety measures, better cooling capability, lower failure frequencies and better containment integrity are going to be met through international collaboration and sharing of best practice. Companies like Areva and Westinghouse who own new nuclear reactor designs are planning to introduce these to the UK supported by sponsoring licensee utilities. Their requirement is for UK experts with regulatory experience and teams of programme managers with civil, mechanical, electrical and process engineering and construction expertise to help build new stations in the UK to time and budget.

7. New Build engineering capacity—Much work has been undertaken by the Nuclear Industry Association (NIA) to assess the UK capability to support new build as reported in the NIA report "The UK capability to deliver a new nuclear build programme [2006]". AMEC supports the conclusions of this report.

8. Decommissioning engineering challenges—The technology exists to progress the UK's legacy decommissioning programme, but there are some challenges to be faced where benefit would be gained by introducing more innovation in application to secure economic advantages. These include, waste retrieval, characterisation, handling, passivation and storage. This could include short and medium term storage above ground and long term storage in deep repositories. These challenges will only be overcome through the engagement of experienced engineers and scientists in the design of bespoke facilities and innovative technologies and by gaining benefit from overseas advances in related technologies. There is a need to build and develop engineering technology in the following areas:

— Materials characterisation: Techniques to characterise contamination of structures, site, contaminated land and waste properties.

— Waste processing: Sludge handling techniques, remote handling techniques, methodology and techniques for waste, segregation and graphite management.

— Management of strategic nuclear materials.

— Plant termination: Improved decontamination technology and effluent management. Technology to carry out size reduction of large items and remote dismantling technologies.

— Site restoration: Ground remediation technology.

— Waste packaging and storage options.

— Long term waste behaviour in a storage repository.

— Safety and environmental consultancy support to the above.

Research programmes should focus efforts in these areas for legacy wastes under NDA governance through encouraging collaboration between industry and academia to help train and develop the UK engineering pool.

The current BERR consultation on Funded Decommissioning Programme Guidance for New Nuclear Power Stations is welcomed by AMEC as an essential step in framing the financial considerations of decommissioning in support of new build.

9. Future nuclear engineering resource requirements—It is anticipated that both nuclear new build and the decommissioning of existing nuclear facilities will create an increasing demand for qualified engineers and scientists with nuclear experience over at least the next few decades. While at present the available resource within the nuclear industry is just about keeping pace with requirements, there are clear skills gaps in some areas, some of which are unique to nuclear engineering and vital to future nuclear engineering projects. To support the health of this growing sector of the economy, a strong commitment will be required from DIUS to the development of engineers and scientists from early education through to degree and post graduate qualification, with recognition of the opportunities available in the nuclear industry and the benefits that training and working in the nuclear industry bring in terms of standards of excellence and transferable skills. This should include teacher training/careers support into schools and encouragement to and co-ordination of graduate and post-graduate university education courses being offered. Ways of providing financial encouragement to industrial organisations to develop and provide training to help rebuild the skills base should be explored. This could include examining the role of Nuclear training within the ECITB and levy arrangements, tax breaks etc.

10. Age profiles—Although cross-industry comparisons such as the COGENT Sector Skills Council analysis show an even age distribution of Science and Technology skills in the UK, of concern is the age and experience profile to support specific aspects of UK New Build. The last new UK nuclear station was constructed 15 years ago and it will probably be another four to five years before on-site construction of a new UK Station commences. Many of the Senior Nuclear Engineering and Project Managers with relevant construction and commissioning expertise will have retired. International demand is growing for the remaining experience in the industry and skills transfers need to be facilitated, not just between nuclear and non-nuclear projects within the UK, but combined with overseas experience on nuclear new build projects to ensure the demand can be met.

Training versus Imported Expertise

11. The success of the future UK nuclear industry almost certainly depends upon a balance of imported expertise and UK based capability. While the next generation of reactor designs employed for new build are likely to be based on existing international designs, the UK has a long history and extensive experience of reactor design, operation and maintenance including Periodic Safety Reviews, obsolescence management and life extension.

12. It is essential to ensure that this experience and capability is retained and developed within the UK for both the civil and military nuclear sector, not only for security of generation and national security, but also to ensure that the UK remains in a position to innovate and influence world wide nuclear development and to be able to continue to export nuclear skills and experience and set nuclear standards.

13. While the current overall nuclear industry age demographic is looking reasonably healthy, it is important to recognise that some key knowledge and experience is still vested in an older generation of staff involved in previous generations of nuclear new build and operation. Large scale project opportunities have not existed in the UK nuclear industry to transfer this experience to younger engineers. For this reason effective knowledge capture and transfer via training within industry, not just academia, is essential to ensure that this knowledge is not lost.

14. AMEC's objective is to develop sustainable commercial business driven by innovation. UK Science and Engineering will increasingly be undercut by lower priced economies as trading becomes more globally based. UK companies need to invest to secure higher added value services supplied from the UK, supported by lower-cost economy implementation routes. Thus innovation and technical development is key to the long-term future of the UK's Technology platform, not just that of the nuclear industry. Promotion of this through Government commitment to enhancing the attractiveness of the UK as a leading technology innovator is essential. This encompasses promotion of Science and Technology career paths from Primary schooling through to post University industrial placements. This will drive the most able people into the business to encourage innovation as part of a long-term programme. Shorter term developments should be pursued as part of this programme to support academic and industrial collaboration, such as promotion and financial support to technology partnerships in key sectors.

15. AMEC has recognised the need to build UK's engineering and science capacity and proactively participates in several nuclear training initiatives, such as COGENT, National Skills Academy for Nuclear, North West Science Council, Professional Engineering Institute accredited training programmes, Gen2 training initiative, NTEC support, University liaisons etc. Of some concern is the complexity and number of the public sector supported or sponsored training initiatives where there is increasing overlap between the remits of the various bodies, and between academia and industry. We also have concerns relating to potential unfair competition between the academic and industrial sectors over the provision of nuclear development and research services. To maintain nuclear as a non-subsidised sector, we believe that application of nuclear technology should lie within the industrial sector and the remit of academic bodies such as C-NET and the proposed National Nuclear Lab should be confined to academic nuclear training or fundamental research.

16. As a major employer in the Nuclear sector in the UK, AMEC has actively supported the development of the National Skills Academy—Nuclear, which has been created with a vision "To create, develop and promote world class skills and career pathways to support a sustainable future for the UK Nuclear Industry". This is an employer led, and part funded, initiative covering all aspects of the Nuclear Industry from Decommissioning, through Waste management to New Build. It also encompasses propulsion; its tactical position is to assure consistent and accredited high quality training across the industry. AMEC has supported the Academy with a financial contribution, is represented on the Board of the Academy, and is at the forefront of the Academy development in Scotland by providing the Chair of the Scottish Regional Training Cluster.

17. Participation in international collaborative R&D projects has proven to be a valuable training ground in maintaining and developing UK nuclear skills. For example, AMEC has been able to maintain a competent reactor physics capability to assess new reactor designs, rather than just provide ongoing support to existing designs. This has been achieved through participation in Generation IV programmes. The UK Government's withdrawal of support to these programmes is viewed negatively by industry and by our international partners as reducing the UK's standing in the international nuclear community and removing a vital industrial training route. AMEC strongly urges the Government to reconsider its support to these activities.

18. AMEC recognises that due to the shortage of suitably qualified and experienced personnel (SQEP), there may be requirement to bring in expertise from elsewhere or to offshore some of the technical work. There will also be a commercial need to place work overseas where engineering resources are available at lower cost. It will be beneficial if the Home Office's HMSP VISA includes nuclear engineers and those engineers who have suitable qualifications and experience particularly in mechanical, civil and electrical engineering for building nuclear power stations. However it is essential that UK companies maintain high added value skills and the ability to act as an intelligent nuclear client for such support.

19. UK participation in IAEA activities also provides a route for UK industrial companies to maintain an influential position on international standards harmonisation and as an indirect route to promoting UK nuclear capabilities in support of export markets. Many other countries provide funding support towards these activities but none is provided by the UK. AMEC is increasingly participating in IAEA activities as part of its development in training and as a consequence, improving the profile of the UK nuclear industry. It would be beneficial for the Government to support and promote participation and feedback to UK industrials in a more structured way.

Role of Engineers

20. The previous paragraphs have highlighted the important role UK nuclear engineers will play, both in supporting nuclear development and clean-up within the UK, but also as a leading international centre of nuclear expertise providing long-term value to the UK economy.

21. New nuclear power stations will bring with them the requirement to work with and support the UK nuclear regulators and reactor vendors in substantiating reactor designs and anglicising international standards and safety cases against UK requirements.

22. Operational nuclear reactors will continue to require ongoing maintenance, repair, refurbishment and possible life extension, all of which will require experienced engineering input and possible nuclear safety case consideration/justification.

23. The decommissioning of nuclear facilities will require the development of novel, innovative technologies to maximise, efficiency, minimise waste and risk and to ensure that long term arrangements are safe, secure and socially acceptable.

24. Experienced engineers and scientists will continue to play an essential role in bridging the knowledge gap with non-nuclear contractors and suppliers in ensuring that equipment and services are provided to the standards associated with nuclear plant. Engineers and scientists will also continue to perform an essential role in developing and maintaining the UK's strategic nuclear capability and supporting infrastructure.

Nuclear Engineers in Power Sector and Military

25. AMEC Nuclear has played a role of technical partner and programme manager to MoD in a number of nuclear projects such as the Faslane Shiplift, new facilities at AWE and the next generation of Astute nuclear submarines. We believe that there is a strong technical overlap of engineering skills and technologies between the power sector and military.

26. In the UK, the Defence Logistics and Operations is being gradually replaced by the Defence Equipment and Supportability. MoD is moving to "cradle to grave" approach and as a result there is increasing demand for the following:

- Through Life Capability Management (TLCM) involving the CADMID (concept, assess, develop, manufacture, in-service operation and disposal) approach.
- Safety.
- Handling.
- Modelling and Simulation.
- Human factors, training needs analysis and delivery.

27. The requirements by the military/MoD for the above mentioned engineering skills overlap with those needed in the civil nuclear engineering field and AMEC supports cross-sector working which brings engineering and technical benefits in identifying best practice approaches.

28. In addition to the overlap of engineering skills, there is also some commonality in R & D activities which if shared can be of mutual benefit to both civil and defence industry. In this respect, AMEC would encourage the Government to support stronger interfacing between civil Generation IV research programmes and the defence research programmes, again through co-ordinated participation of industry.

RECOMMENDATIONS

AMEC recommends the following:

- UK Government's sponsorship and pro-active direction to UK industrial participation in GNEP activities is defined and facilitated.
- A strong commitment from DIUS to the inclusion of nuclear education as part of an enhanced engineering promotion programme from early education through to post-graduate qualifications.
- Promotion of appropriate knowledge transfer mechanisms within industry and supporting collaborative approaches between academia and industry. The Technology Strategy Board could facilitate this.
- Ensuring training and skills transfer support is provided to industry and not just academia as this is where the main benefits will be realised in the economy.
- Clearer definition of the roles of academia, including the proposed National Nuclear Laboratory, and industrial sector interfaces is required to ensure that Nuclear is not seen as an unfairly subsidised industry.
- UK Government revises its decision not to support Generation IV activities in light of the benefits to be derived by the UK nuclear sector in terms of training and international business development.
- UK Government to support and promote UK industrial participation and feedback on IAEA activities in a more structured way.
- UK Government to support stronger interfacing between civil nuclear and defence research programmes by promoting industrial collaboration.
- Changes in the Home Office HMSP VISA scheme to facilitate the nuclear industry to bring in expertise from elsewhere.
- UK Government's commitment to promoting UK Nuclear Engineering as a priority high added-value service to the international market through a more active UKTI programme.

March 2008

Memorandum 87

Submission from the Nuclear Physics Forum, submitted by Professor R D Herzberger

ENGINEERING CASE STUDY—NUCLEAR ENGINEERING

I write in response to your request for input to the Engineering Case Study: Nuclear Engineering.

On behalf of the Nuclear Physics Forum, which represents Nuclear Physics Groups at universities in the UK I would like you to consider the following points:

> The UK is facing a critical skills shortage in the nuclear technology sector. Topics such as the energy portfolio, nuclear decommissioning, radioactive waste management and new power station build are very much in the public eye and the nation's strategic interest. This is a crucial time to ensure that the vital nuclear skills base is not eroded but built up to meet the long term challenges a continued long-term nuclear power programme holds.
>
> The UK currently has nine University based nuclear physics research groups in Birmingham, Brighton, Edinburgh, Glasgow, Liverpool, Manchester, Paisley (now University of Western Scotland, Paisley Campus), Surrey and York. These groups provide a large part of the nuclear training and education on undergraduate programmes in general physics, specialist MSc programmes and doctoral-level nuclear research. Indeed, even in the engineering areas, key academic staff have their roots in nuclear physics, eg Professor Malcolm Joyce at Lancaster, Dr John Roberts at Sheffield in waste immobilization, Professor Phil Beeley at HMS Sultan, Dr Paul Norman at Birmingham. They bring to the table the unique versatility of the physicist and are best suited to respond to emerging problems outside their immediate area of specialization. Even on the NTEC Nuclear Technology and Nuclear Engineering Doctorate programmes we find amongst the enrolled students a large proportion of physicists rather than engineers.
>
> The importance of a healthy nuclear physics research community cannot be overstated. It is therefore doubly unfortunate that the funding of these university groups is thrown into doubt by the general funding crisis in the Science and Technology Funding Council, under whose remit the groups operate and draw the majority of their funding from. Without adequate support for university based nuclear physics research these groups will decline and eventually disappear once critical mass is lost, leading to a serious reduction in the output of graduates and PhDs. The consequences of such developments can be seen from the experience with the collapse in fission R&D in the 1980s and 1990s. By 2000 there was no nuclear engineering undergraduate programme

in the UK and only a single undergraduate programme with "nuclear in its title (Physics with Nuclear Astrophysics at Surrey). This trend was only reversed in 2008 when Lancaster University opened its Nuclear Engineering course.

Nuclear Physics groups make a very obvious and necessary contribution to UK quality of life and in the nuclear education area and it is important not to neglect this aspect in any discussion of the UK nuclear strategy.

March 2008

Memorandum 88

Submission from the Institute of Materials, Minerals & Mining (IOM3)

1. *Executive Summary*

1.1 In the short term, in order to build and commission new nuclear power stations, it will be necessary for the UK to import technology and engineering skills from those countries which have continued to invest in nuclear power. To be an intelligent customer for these Generation III nuclear power stations, the UK will need to urgently undertake the training of a new generation of nuclear engineers and scientists AND initiate a knowledge capture exercise which would draw on the UK's wealth of expertise in this sector which was world leading for 40 years. This expertise is retained in archives and, more importantly, by those nuclear scientists and engineers who worked in the industry but have now retired.

1.2 In addition, it is vital, if the economic viability of nuclear power generation is to be increased and the costs of de-commissioning and waste disposal reduced, that forensic examinations are conducted on materials recovered from nuclear power stations being de-commissioned.

1.3 It is also necessary to maintain and enhance the engineering skill base in the following topics: improved materials for hostile environments, non- destructive techniques for inspection and monitoring, better understanding of the long term integrity of large plants, especially large welded structures, improved accuracy of plant lifetime prediction and better understanding of the mechanisms of degradation of the materials deployed in the construction of nuclear power plant and waste storage facilities.

2. *The UK's engineering capacity to build a new generation of nuclear power stations and carry out planned de-commissioning of existing nuclear power stations*

2.1 Capacity to build a new generation of nuclear power stations.

The new generation of nuclear power stations will be based on proven technology deployed on existing Generation III designs such as the WestinghouseAP1000 Pressurised Water Reactor (PWR) with its improved passive safety features. In the short term it will be necessary to import this technology in order to design, build and commission new nuclear stations which will replace those scheduled for decommissioning. There is an urgent need to train a new generation of engineers and scientists during the time it will take to build and commission the new nuclear stations.

2.2 Decommissioning of existing nuclear power stations.

The UK has the engineering skills and experience to continue decommissioning existing nuclear power stations. However, current activities could, at a modest extra cost, provide vital information for the design and operation of future nuclear power plants by forensic examination of the materials of the structures being decommissioned. There is no substitute for information obtained on the degradation mechanisms to which materials are subject in nuclear plants than to study materials that have been harvested from real life installations. Ideally this forensic examination would be carried out in a national nuclear laboratory located close to one of the universities that is conducting research on Generation IV Nuclear Power Systems, eg The Dalton Nuclear Institute at The University of Manchester, or the Universities of Oxford and Birmingham.

3. *The value in training a new generation of nuclear engineers versus bringing in expertise from elsewhere*

3.1 It is essential to train a new generation of nuclear engineers if the UK is to be an intelligent customer for the new build nuclear power stations. UK nuclear engineers should also be involved in the research and development of Generation IV nuclear systems such as the Pebble Bed reactor being developed in South Africa and the Fast Breeder reactor where the UK once held a leading position.

3.2 The training of a new generation of nuclear engineers would be assisted by establishing funded secondments/visiting fellowships whereby UK scientists and engineers could work in those countries and companies at the forefront of current and next generation nuclear systems.

3.3 In addition, a Knowledge Capture Programme should be funded to ensure that the explicit and tacit knowledge of those scientists and engineers who worked in the nuclear industry and their research laboratories over the past 40 years is captured and transferred to the new generation of employees. This programme needs to be conducted now. In five years time some of these retired, experienced nuclear engineers may not be with us and their expertise would be lost forever. The Knowledge Capture Programme could be facilitated by a professional institution such as the Institute of Materials, Minerals & Mining (IOM3).

4. *The role that engineers will play in shaping the UK's nuclear future and whether nuclear power proves to be economically viable*

4.1 Engineers will play a major role in shaping the UK's nuclear future and improving the economic viability of nuclear power if they can successfully meet the following challenges:

— Develop materials with enhanced performance in the harsh environment of nuclear installations.

— Improve non-destructive techniques for inspection and monitoring of reactor systems both during construction and operation.

— Understand better the long term integrity of complex plants, particularly large welded structures.

— Improve the accuracy of plant lifetime prediction and management.

— Understand better the materials degradation mechanisms in nuclear plants, in particular corrosion and erosion, environmentally assisted cracking, creep-fatigue interactions, thermal cycling, and irradiation damage effects, especially at the high energies and doses which will occur in future fusion reactors.

— Improve the understanding of the long term degradation of nuclear waste storage facilities.

4.2 It is impossible to accurately predict the long term economics of nuclear power. It is, however, clear that improved engineering can significantly reduce costs. For example, it has been calculated that if all the electricity generated by nuclear power in the UK had been produced by modern PWRs, the amount of waste produced would be one tenth of that from the nuclear power stations currently being de-commissioned.

4.3 The biggest nuclear engineering challenge is the creation of commercially viable nuclear fusion reactors. These would use a virtually inexhaustible supply of fuel (derived from water and lithium, which is abundant), and would not directly generate any radioactive waste (the components would become activated, but with suitable choices of materials, could be recycled within a hundred years, leaving no waste requiring long term storage).

The International Tokamak Experimental Reactor (ITER) to be built in France should go a long way to establishing whether fusion power is feasible, although formidable materials and engineering challenges will have to be tackled in parallel to ITER. The UK has held a prominent position in fusion research thanks, in a large part, to the location of the Joint European Torus (JET) at Culham in Oxfordshire. This facility will be decommissioned in the coming decade and the UK's position will decline unless the UK's fusion programme (which is poorly funded compared to programmes in other major European countries) is expanded to allow the UK to contribute to its full potential in support of ITER and in addressing the engineering and material challenges.

A new UK research and development facility would be highly desirable, either building on the UK's own innovative Spherical Tokamak or in support of work on fusion technology and materials (an obvious candidate is an installation which could expose materials to intense fluxes of energetic neutrons).

5. *The overlap between nuclear engineers in the power sector and the military*

5.1 The main overlap occurs in the engineering disciplines listed in paragraph 4.1 above, ie non-destructive inspection, corrosion, structural integrity, and safety and reliability engineering, remote handling, and waste disposal techniques.

5.2 There will always be concerns that any expansion of civil nuclear power programmes will increase the risk of leakage of the technology that permits the enrichment of fissile materials to weapons grade levels. There is therefore the utmost need to continue to prevent the leakage of technology, and to control the trading and prevent the theft of materials with bomb making potential.

March 2008

Memorandum 89

Submission from the Institute of Physics (IoP)

The UK's engineering capacity to build a new generation of nuclear power stations and carry out planned decommissioning of existing nuclear power stations

The UK is facing a critical skills shortage in the nuclear technology sector. The energy portfolio, nuclear decommissioning, radioactive waste management and new nuclear build are very much in the nation's strategic interest, and this is a crucial time to ensure that the nuclear skills base is not eroded but built up to meet the long-term challenges of a possible new build programme. Even without new build, the entire nuclear industry employs over 18,000[3] graduates and skilled people, with ongoing recruitment required to fill vacancies, particularly for decommissioning. More detailed estimates of the numbers required to allow for new build were made in the Nuclear Task Force's report, *An Essential Programme to Underpin Government Policy on Nuclear Power,*[4] 2003. This report estimated that 355 scientists and engineers were required, including 122 engineers. The engineering sub-groups, in order of size, were: chemical engineers, remote inspection, safety risk assessment, thermal hydraulics, and control and instrumentation.

All of this would be daunting enough if the skills shortages were confined to the nuclear sector, but the UK has a general shortage of science, technology, engineering and mathematics (STEM) skilled graduates. The energy supply sector is undergoing change and rapid expansion in many other fields that also require graduate and technical expertise, examples include clean-coal and renewables technologies. It is essential to see the need for nuclear engineers within the comprehensive need of all energy supplies as development and change occurs in response to climate change.

Currently, many experienced nuclear engineers in the UK are over the age of 50 and thus likely to be retiring within the next decade. All of the engineers involved in the original planning and building of the UK's nuclear power stations (the first of which opened in 1956) have already retired. There is also a possibility that expertise will be lost rather than passed on, particularly given the high proportion of freelancers in the sector. Therefore, there is a need to ensure that a new generation of nuclear engineers are trained while ensuring that existing expertise is used efficiently and properly incentivised.

A survey of Nuclear Employers undertaken by Cogent in 2005[5] found that:

> "The SET workforce has a more ageing profile than the overall industry. 11% are due to retire over the next 10 years, but this could rise as high as 20% if early retirements at age 60 occur. Certain areas were found to have an older workforce, eg 44% of process & machine operatives are aged over 45. While overall demand for this group may be declining this is outstripped by the rate of retirements. Nuclear heat generation has an ageing profile with 18% due to retire over the next 10 years; however this could rise up to 33% if early retirements occur."

Furthermore, the Energy Research Partnership (ERP)[6] found in its investigation into high-level skills shortages in the energy sector that, "The problem is only at its early stages—without intervention this situation is anticipated to worsen to a severe shortage, particularly when the extent of energy innovation and infrastructure replacement that is required is taken into account."[7]

The National Skills Academy for Nuclear (NSAN),[8] launched earlier this year, estimated that 1,500 skilled people need to be replaced each year, with an additional 11,500 over the next 20 years to complete the task of decommissioning, and 6,500 in other civil/defence sectors, which includes new build.[9] New build projects will face competition for staff from other areas of the nuclear technology sector and beyond.

Hence, there is an urgent need to maintain and develop a nuclear skills base, particularly in the core sciences (especially physics), engineering, materials science, project management, and technician level skills. By focusing this Inquiry on "nuclear engineers" it is possible to obtain a misleading impression, both in terms of training and employment. It is important to note that significant areas of nuclear power technology (its full life-cycle including waste-handling and decommissioning) are underpinned by physics, such as reactor technology, nuclear data measurement and evaluation, safety, criticality studies, and materials properties.

The NSAN's remit covers skills at school, in vocational qualifications and further education, up to and including foundation degrees. Its responsibility is focussed on young people at the beginning of the pipeline, but does not extend into higher education. The NSAN has a critical role to play in developing a standardised and coordinated approach to education, training and skills development in the nuclear sector. The

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3 Nuclear Power: Keeping the Option Open, The Institute of Physics; June 2003; www.iop.org/activity/policy/Events/Seminars/file_3514.pdf
4 *An Essential Programme to Underpin Government Policy on Nuclear Power*, Nuclear Task Force, 2003
5 www.cogent-ssc.com/research/Publications/Archived_Publications/Nuclear_Employers_Survey.pdf
6 www.energyresearchpartnership.org.uk/erp.php?sid = 1
7 Investigation into high-level skills shortages in the energy sector, Energy Research Partnership
8 www.nuclear.nsacademy.co.uk/
9 www.cogent-ssc.com/cogent_family/NSAN.php

government and Cogent need to support the academy and encourage more research centres to be developed in order to ensure that the skills base is buoyant, fully trained and equipped to meet the challenges that the nuclear sector will face.

The nuclear industry also currently needs well-trained graduates in physics, chemistry, materials science and mechanical and control engineering who can obtain specialist industrial skills in reactor technology through in-house training and university postgraduate courses. It is therefore important to the sector that sufficient students are recruited on engineering and physical science undergraduate programmes whether or not they are "nuclear" based.

The UK's nuclear engineering capacity is also dependent on the training in ethical issues of its science and engineering students. Nuclear engineers regularly face ethical issues in preparing safety cases, reporting scientific findings with safety-case significance, and dealing with the regulator in a commercial environment. Engineers who have acquired a sound ethical awareness in their education will be better able to handle the pressures associated with these activities. A nuclear-oriented course which puts ethics at the centre of professional practice is also more likely to appeal to young people considering careers in the nuclear industry.

In the last few years there has been an increase in university education and research activity in the nuclear area, which some believe could be a platform for the UK to provide the necessary training for a new generation of nuclear engineers, in order to ease concerns about the skills base.

Undergraduate degrees in physics can contain a good range of nuclear physics, through taught courses, laboratory and project work. The IOP's *Core of Physics*, setting out the requirements for an accredited physics degree, includes a set of requirements for nuclear physics coverage.[10] Physics graduates can move easily across into nuclear engineering areas, and are often considered to be the most versatile graduates. We understand that there are several new nuclear-related undergraduate programmes in the pipeline, planned to be introduced at Lancaster University, Imperial College London and the University of Surrey.

Until recently there was a significant period of time when the only UK graduate course for nuclear power technology was the MSc Physics and Technology of Nuclear Reactors based in the School of Physics and Astronomy at the University of Birmingham.[11] This course provides the necessary background, both in breadth and in depth, for anyone wishing to enter the nuclear industry (in fact, Birmingham has a partnering agreement with the UK nuclear industry for the course). More recently, there are a few other universities, such as Lancaster, Liverpool and Manchester that offer relevant MSc courses. Based at the University of Manchester, the Dalton Nuclear Institute[12] regularly offers MSc project placements within its nuclear research groups, for a three-month duration, which provide an excellent opportunity to get hands-on experience of undertaking research. The University of Surrey offers similar opportunities on its MSc in Radiation and Environmental Protection,[13] which has been running for 30 years with strong support from AWE and others, where graduates are eagerly sought. (Current support for MSc placements from industry is generally offered at the expense of companies, since supplementary projects are generated for placement students, which cannot be employed on actual fee-earning industrial projects because of time, commercial and confidentiality issues.)

Furthermore, both the School of Physics and Astronomy at the University of Birmingham and the Dalton Nuclear Institute are part of the Nuclear Technology Education Consortium (NTEC[14]). This is one of several initiatives funded by the EPSRC to address the immediate skills shortage in the nuclear industry. The NTEC comprises 11 institutions offering postgraduate education in nuclear science and technology for graduates from a general science background. The portfolio of courses has been designed through close consultation with the industry and it covers both reactor technology and nuclear decommissioning areas. The delivery format makes it ideal for use by those already employed in the industry either as a route to a postgraduate award or for CPD purposes. The core modules are also offered in distance-learning format. The number of new UK graduates coming through this programme is limited only by EPSRC-funding (limited to 10 studentships per year, funding only secure until 2008–09). Almost all students coming through this programme have either gone into the nuclear industry or into academic research. More students apply to the NTEC than there are places funded, and the programme has the capacity to expand considerably if funding for fees and stipends were made available. When the Consort reactor closes,[15] the NTEC is the only place in the UK that offers experimental reactor physics training on a working reactor (the TRIGA reactor in Vienna).

10 The Physics Degree; www.iop.org
11 www.ph.bham.ac.uk/prospective/postgrad/pgptnr.htm
12 www.dalton.manchester.ac.uk
13 www.ph.surrey.ac.uk/msc/rep
14 www.ntec.ac.uk/
15 Strategic decision of Imperial College London to close to commercial operations by the end of March 08 and shut down within a few months, although this is being kept under review.

The Nuclear Engineering Doctorate is a programme run by a national consortium of six universities.[16] The scope includes reactor technology, materials and safety systems and is marketed to students from the various backgrounds, such as: aerospace; chemical; chemistry; civil; computer science; materials; mechanical; and physics. This confirms the point that the skills needed are much broader than just "nuclear engineering". The programme provides outstanding students with intensive, broadly-based training in collaboration with industrial companies to prepare them for senior roles in the nuclear industry. Few "research engineers" entering this programme have a standard engineering background. A good fraction start off as physicists and either convert on the NTEC or Birmingham MSc, or join the Nuclear EngD programme directly.

The UK's supply of nuclear engineers is dependent on a healthy nuclear physics research community, which provides a large part of the nuclear training and education at undergraduate, masters and doctorate-level. The UK currently has nine university based nuclear physics research groups at Birmingham, Brighton, Edinburgh, Glasgow, Liverpool, Manchester, Paisley (ie University of the West of Scotland), Surrey, and York. Academic nuclear physics has had limited support from the research councils and has had no direct involvement in any of the major facilities needed for research in this area. This situation compares poorly with other European countries. Moving the funding of nuclear physics to the STFC provides an opportunity to strengthen the academic base, developing a long-term strategy for the subject. This is important in terms of training at postgraduate level and attracting undergraduates to this area.

Research programmes such as "Keeping the Nuclear Option Open"[17] and "Sustainability Assessment of Nuclear Power",[18] funded by the EPSRC, are helping universities to maintain their research groups and recruit new staff which is an important part of addressing the UK's skills issue.

The aforementioned progress being made to address the skills issues is very encouraging, coupled with the planned establishment of the National Nuclear Laboratory, based around the British Technology Centre at Sellafield. But it is vital that this progress continues and gathers momentum, as it will make an important contribution to retaining key nuclear skills in the UK. However, the government needs to monitor the situation, and must encourage more of the same, given the scale of the skills challenge and the fact that many of the key people are close to retirement just as the industry could be embarking on a new build programme.

Before its reorganisation in 2005, BNFL provided a strategic view on UK skills and expertise, responding to any at-risk areas directly by establishing university research alliances. Examples included Radiochemistry (Manchester), Waste Immobilisation (Sheffield: Immobilisation Science Laboratory), Particle and Colloid Science (Leeds), and Materials Performance (UMIST, now Manchester). A small group of BNFL representatives made the case to the EPSRC for the need to support education and research initiatives in well-defined nuclear technology areas. The UK has now lost this strategic thought and leadership, as well as the source of funding for industrial research. Nexia Solutions, BNFL's own R&D organisation, has also been left in a perilous state.

The value in training a new generation of nuclear engineers versus bringing expertise in from elsewhere

The nuclear skills base may need to be supplemented by the international supply chain, but the government's focus should be on a core UK workforce, for reasons of cost, sustainability, and national energy security.

It would be wrong to assume that there is an international pool of staff from which the UK could easily recruit; rather, we are potentially behind the game and will have to compete even to retain scientists and engineers trained in the UK from working overseas. There will be intense international competition for skills. For example, China, Finland, France and India are all planning new build, and it has been suggested that Russia alone is planning 40 new nuclear power stations; other countries are already building up their own staffing accordingly. Companies such as Westinghouse in the US and Areva in France are seeking to recruit very large numbers of nuclear trained personnel. Westinghouse recruited over 800 people globally in 2007 and expect to take on well over 1,000 in 2008. The French INSTN has taken a major step forward by organising the "International School in Nuclear Engineering: Doctoral-level Courses in Advanced Nuclear Science",[19] launched in 2007 to recruit and retain highly qualified staff. Furthermore, the UK's position in the international competition for skills will be exacerbated by the attraction of working for a company which designs as well as builds the reactors, rather than a subsidiary which helps build or decommission them.

In response, it is encouraging to note that the Dalton Nuclear Institute plans to establish a new Centre for Nuclear Energy Technology (C-NET),[20] which will aim to develop professionals with the skills to work in the global nuclear industry and will provide access to high-quality, independent academic research.

16 www.manchester.ac.uk/engd
17 www.epsrc.ac.uk/ResearchFunding/Programmes/Energy/Funding/TSEC/KeepingTheNuclearOptionOpen.htm
18 http://gow.epsrc.ac.uk/ViewGrant.aspx?GrantRef=EP/F001444/1
19 www-instn.cea.fr/rubrique.php3?id_rubrique=176
20 www.manchester.ac.uk/aboutus/news/display/index.htm?id=132502

The ERP found during its private sector interviews that all employers were recruiting abroad for skilled roles. Furthermore, they found that:

> "In four of these [companies] this is a business strategy due to the global nature of the business, in nine it was due to a lack of available skills in the UK. In three of these companies this was a recent (up to three years ago) move due to inability to fill roles in the UK. This was also the experience of two companies in their research involvement; two companies stated that they look abroad due to a shortage in a particular niche area, an example given being boiler engineering."

> "The Henley report . . . concludes that the best UK graduates are probably broadly comparable globally, although it notes the high quality of those engineering graduates from overseas universities that UK firms do encounter. However, . . . this is so far not seen as significantly problematic for retention, and indeed one company recruits a significant number of non-home students and believes this is a sustainable, reliable source of very skilled labour."

It is already certain that the design of any new-build power station will be international, given that all four designs submitted for consideration (AP1000,[21] EPR,[22] ESBWR[23] and Advanced Candu[24]) are owned by non-UK companies. The UK's nuclear industry will need to be an "intelligent" owner of the plant once it has been completed, which will require a body of appropriately qualified staff. Even for a standard international reactor design, continuous demonstration that the plant is meeting all appropriate UK safety and environmental requirements requires detailed knowledge both of the plant itself and of the UK regulatory regimes.

It is essential to exercise skills in areas where the UK is recognised as a world leader, but also necessary to build skills in areas new to the UK. Such a skills base could be fundamental in the future for providing potential licensing and subsequent reactor operating activities within the UK for new reactor types.

As well as international competition for skills, there is competition from other sectors within the UK for the skills required by the nuclear industry. In seeking to ensure a "critical mass" of students are recruited to various programmes in US Universities, the Nuclear Engineering Department Heads Organization (NEDHO) recommended that nuclear engineering departments in universities should ". . . diversify their activities while at the same time continuing to offer nuclear engineering curricula and maintaining their core competencies in nuclear power",[25] in order that courses might survive in the face of declining recruitment at that time. It is not surprising that the broad scope of courses has led to graduates looking beyond the nuclear industry for employment.

Competition for skills is also found, for example, in the application of nuclear techniques for diagnosis and treatment in medicine. In the study of materials, neutron scattering techniques—whether based on reactors or spallation sources—requires staff with a strong understanding of nuclear methods and modelling. Defence and homeland security also call upon the same recruitment pool and there is, finally, the ongoing experience that the financial world finds the skills of nuclear trained students attractive—and the students find the rewards in the financial world attractive too.

The role that engineers will play in shaping the UK's nuclear future and whether nuclear power proves to be economical viable

The nuclear industry currently plays a key role in the UK economy, employing 50,000 directly and supporting many additional jobs. A new build programme will offer opportunities to maintain and grow this work force, while keeping alive the knowledge and expertise that has been built up.

The UK government has concluded that nuclear energy has a part to play in the UK's energy mix and it is clear that a range of other countries are taking similar decisions. In a world where there is increasing competition for dwindling fossil fuel resources and pressure to reduce carbon dioxide emissions, the nuclear technologist has a significant role to play in ensuing that a viable, convenient and affordable source of electricity remains available to the UK population.

A brief summary of the role of engineers and scientists in the UK's nuclear future is as follows:

- Safety, both in (i) the study of safety related issues such as loss-of-coolant accidents (LOCA) or severe reactor accidents, and (ii) case preparation and management, which demands intimate knowledge of facility design.
- Operation of the plant in the most economic, yet safe manner over the longest possible time.
- Life extension assessment and reactor plant evolution to meet future requirements of licensing and operational demands.

[21] Westinghouse: http://ap1000.westinghousenuclear.com/index.html
[22] www.edfenergy.com/html/showPage.do?name=edfenergy.media.news.item.til&cmsPage=/opencms/export/www.edfenergy.com/media/news/20080110.html
[23] GE Energy: www.gepower.com/prod_serv/products/nuclear_energy/en/new_reactors/esbwr.htm
[24] www.aecl.ca
[25] *Manpower Supply and Demand in the Nuclear Industry*, Nuclear Engineering Department Heads Organization (NEDHO), 1999
www-ners.engin.umich.edu/NEDHO/publications/manpower_report/Manpower_report2-17.pdf

— Nuclear data measurement and evaluation, required for understanding of newer materials and concepts.
— Participation in the international programmes of reactor development, such as the Global Nuclear Energy Partnership (GNEP[26]), in order to maintain skills and expertise and be prepared to benefit from future developments.
— Materials science of nuclear fuels and other materials, in order to understand the way that these materials behave under longer burn-up and higher irradiation reactor conditions.
— Waste issues such as fuel cycle chemistry, partitioning and transmutation, in order to reduce the burden on waste disposal; and associated technologies such as accelerator driven systems (ADS).
— Decommissioning.
— Future concepts such as nuclear-generated hydrogen economy, as there will be a need to move to an electricity-based energy economy, which will need substantial change in transport and heating.
— Multi-scale modelling and simulation, which underpins most of the topics above and also demands significant computing skills.

The overlap between nuclear engineers in the power sector and the military

Nuclear power and nuclear weapons share a significant number of fields of interest whether from the experimental or modelling aspects. There is a significant overlap in the skills requirements of the two areas, with traffic of expertise between them.

It is clear that the various companies involved in the UK naval reactor programme are all too aware of the potential for new build to compete with their recruitment needs.

March 2008

Memorandum 90

Submission from the Cogent Sector Skills Council and the National Skills Academy Nuclear

This submission, in support of the Innovation, Universities, Science and Skills Select Committee case study into nuclear engineering, is forwarded on behalf of Cogent Sector Skills Council and the National Skills Academy Nuclear following consultation with representatives from the nuclear industry.

Cogent is the Sector Skills Council (SSC) for the Chemicals and Pharmaceuticals, Offshore Oil and Gas, Nuclear, Downstream Petroleum and Polymer Industries. It is one of 25 SSCs which, together with the Sector Skills Development Agency forms the Skills for Business Network.

The National Skills Academy Nuclear (NSAN) was launched on 31 January 2008 and its vision is to create, develop and promote world class skills and career pathways to support a sustainable future for the UK Nuclear industry. The Academy is the leading body of an employer led strategy to develop a quality standardised and co-ordinated approach to education, training and skills in the Nuclear Sector.

This submission concludes that:

— There are skill gaps within the nuclear industry and the industry average age profile is skewed towards the higher age bracket. In addition there are some specific shortages in defined employment areas (such as HSE inspectors) and in some essential specialist disciplines (such as Safety Case Specialists). Skills initiatives and their associated funding must be maintained to ensure that sufficient qualified and experienced people are available to support all aspects of the nuclear industry.
— The competition from national and international projects has the potential to lead to shortages in nuclear specialists and those conventional skills that are required to support the UK decommissioning and new build programme.
— Positive action is being taken by industry, in conjunction with Cogent Sector Skills Council, the National Skills Academy Nuclear and other bodies, to improve the situation and regularly update the background data on which skills planning and the associated training provision is based.
— The support of Government is vital in sustaining the skills base, through provision of funding and legislative action.

[26] www.gnep.energy.gov

Introduction

1. This submission, in support of the Innovation, Universities and Skills Select Committee case study into nuclear engineering, is forwarded on behalf of Cogent Sector Skills Council and the National Skills Academy Nuclear following consultation with representatives from the nuclear industry.

2. The submission covers all of the elements of the terms of reference for this inquiry, namely:

- the role of engineering and engineers in UK society;
- the role of engineering and engineers in UK's innovation drive;
- the state of the engineering skills base in the UK, including the supply of engineers and issues of diversity (for example, gender and age profile);
- the importance of engineering to R&D and the contribution of R&D to engineering; and
- the roles of industry, universities, professional bodies, Government, unions and others in promoting engineering skills and the formation and development of careers in engineering.

The Role of Engineering and Engineers in UK Society

3. The term "nuclear engineer" covers a range of specialisations (eg mechanical, electrical and civil engineers, chemists, scientists and environmental engineers) who work within the nuclear technical context and regulatory framework, across the various aspects of the operating power generation, defence, decommissioning and maintenance aspects of the nuclear industry. Furthermore, they may be employed in research, design, development, manufacturing, installation, commissioning, contracting, consulting and teaching. Nuclear Engineers are therefore employed across the full range of Science Engineering and Technology (SET) areas of the industry.

4. Many of the graduate nuclear SET employees are registered with the ECUK as Chartered Engineers, with a commitment to achieving the highest professional standards and maintenance of the highest levels of safety, protection of the environment and innovation. They also have a major role in projecting the image of the industry in which they work to ensure that it is attractive to new recruits. However, the take up of registration with ECUK as Incorporated Engineer or Engineer Technician is low and well below the number of people eligible. ECUK is currently promoting the EngTech scheme and this is welcomed.

The Role of Engineers in UK's Innovation Drive

5. Within the short and intermediate term the nuclear industry will require to face up to challenges in keeping existing power generation plants running to ensure a power generation gap does not develop while new build is progress and, face up to the challenges of decommissioning legacy plant. The challenges presented by the establishment of the Nuclear Decommissioning Authority (NDA) to accelerate the clean up of UK's nuclear legacy requires many new innovative processes to be enable these plants to be decommissioned safely and with demonstrable cost and time efficiency gains. Mature processes exist to deal with the decommissioning process and the tail end waste reduction and waste disposal. However, innovative processes could lead to improvements which would assist in accelerating the process and provide these efficiency gains. Innovative engineers will be needed to develop these processes to accelerate the decommissioning process whilst minimising the generation of radioactive waste.

6. Currently any new build nuclear plant will be of a generic design with modular construction on the chosen site. While a high level of skill within the operating company will be required to be the intelligent customer for this process, the level of innovation will be limited. However, in the very long term, UK must continue to ensure the security of energy supply and future nuclear plants will need to have further improvements to reduce waste generation and at the end of life, improved ability to decommission nuclear plant with much reduced radioactive waste generation. Research and Development will be required to enable this innovation.

The State of Engineering Skills Base in the UK, Including the Supply of Engineers and Issues of Diversity

7. The nuclear industry employs approximately 50,000 Science Engineering and Technology (SET) personnel. The age profile of the nuclear industry is skewed towards the higher age bracket with the many of the employees within 10 years of retirement. Furthermore, a number of key "hot spots" do exist—for example, in the Health and Safety Executive/Nuclear Inspectorate, the employees tend to be concentrated in the higher age bands. However, industry experience is needed for these positions, which would explain this pattern. Age is also an issue in the sub-industry areas of Nuclear Heat Generation & Fuel Handling. Among process and machine operatives there is also a higher proportion of older workers. These categories are essential to the viability of all elements of the nuclear industry. The next 10 years will therefore see a large number of retirements from the industry, leading to a high level of replacement and training demand. There is also currently a shortage of other essential skills such as safety case specialists and project mangers with nuclear experience. Uncertainty over the direction the industry was taking before the establishment of the

NDA and the decision on the potential for new build, had led to a reduction in Graduate Development Programmes and Apprenticeships. Graduate Development Programmes are being revived and work has now commenced on development of apprenticeships for the nuclear industry. This action is required to ensure sufficient lead time to educate, train and provide experience to new members of the industry in preparation for those retiring.

8. Competition from other industries (eg petrochemical) or in support of other national major construction programme, such as the Olympics, may also lead to a shortage of skilled personnel in areas where national and international shortages already exist. These include design engineers, particularly mechanical and civil professionals, Construction and Commissioning Engineers and Project and Programme Managers. Furthermore, the UK energy market accounts for less than 2% of the global requirements and many international energy production projects are underway or in planning which could attract skilled people away from the UK nuclear industry.

9. The nuclear SET workforce in the UK is overwhelmingly white and male and women and ethnic minorities are seriously under-represented. This could be related to the attractiveness of the industry and its security requirements where many jobs are only open to UK nationals. The Ethnic and Gender ratios across the industry as a whole are shown in Table 1.

Ethnicity	%
White	96
Non-White	4
Gender	%
Female	18
Male	82

Whilst Table 1 shows 18% of the workforce in the nuclear industry are female, many of these are in administrative posts with only 12% being in SET occupations.

10. The occupation distribution is shown in Table 2 and not surprisingly this shows that the educational level of employees is at the higher S/NVQ level.

Occupation	%
Managers and Senior Officials	4
Professional Occupations	38
Associate Professional and Technical	13
Skilled Trades	24
Process Plant and Machinery Operations	5
Elementary Occupations	5
Occupations other than SET	11

Table 2 Occupations by %

11. A graph of the education level of the personnel in these occupations in the nuclear industry is mapped against the educational requirements in Figure 1.

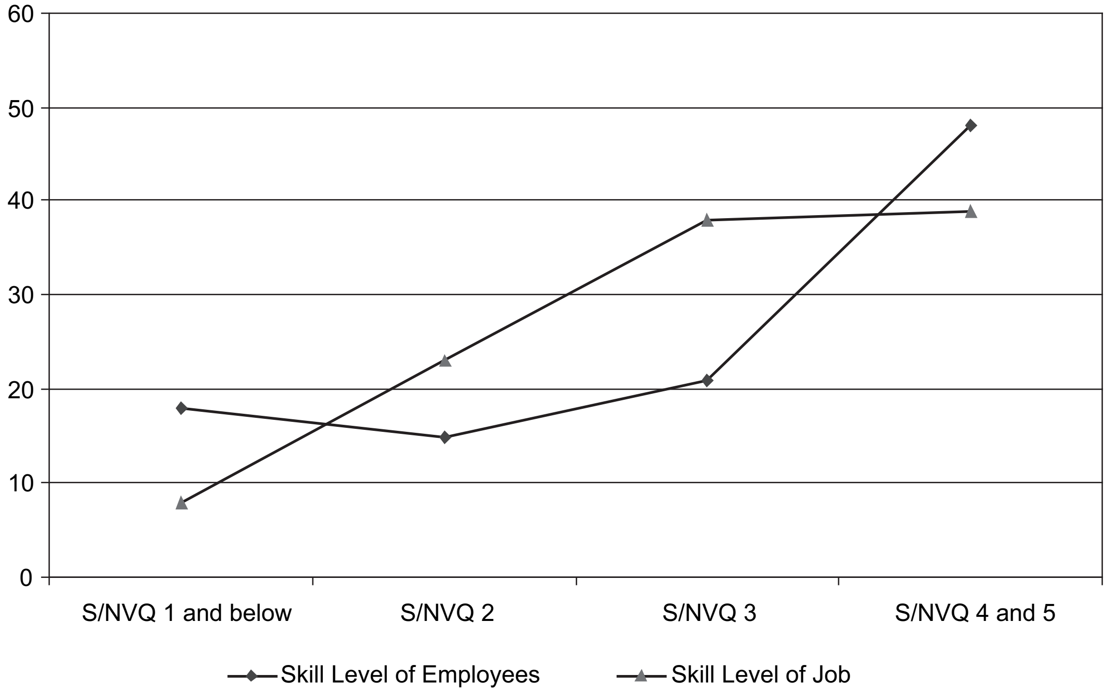

Figure 1 shows that there is an oversupply of people qualified at S/NVQ Level 1 and below although these occupations only account for 5% of the workforce. However, there is a 33% deficit of people qualified to S/NVQ level 2 and 3 which account for 53% of the nuclear industry.

12. The figures above account for the current state of the industry, however, retirements, normal industrial churn and the changing operations of the nuclear industry needs to be taken into account. For example, when a nuclear power plant reaches the end of life, there is a need to re-skill from operating skills to decommissioning skills. Cogent research indicates that around 10,000 people will need to be trained or re-skilled over the next 10 years to cover the skills gap and many of these will be in support of NDA programmes.

13. A new nuclear power station build programme is expected to place a demand on construction skills from around 2011, with specialist electrical and mechanical installation occurring a year later. A few nuclear specialists will be required in the early years to support the licensing and safety case preparations but, with operations expected to commence in 2017, new build will not be expected to place a great demand on new nuclear specialist jobs until around 2015. Further research is being conducted in this area by Cogent to support the Energy White Paper skills review.. There is an excellent opportunity for a pro-active approach to skills development for the new build agenda and the mechanisms are in place via NSAN, Cogent and the Universities to ensure that we have the right skills in place at the right time to address this challenge.

14. The training and re-skilling of the nuclear SET workforce required to close and sustain the skill base of the nuclear industry is not insurmountable and is being worked on by industry, the NDA, Cogent Sector Skills Council, the National Skills Academy Nuclear, Academia and others with Government support. Despite all this effort, public perception is a major feature in recruitment and retention in the nuclear industry. Until recently the image of the nuclear industry has been that of a contaminating process and an industry in decline. The clean-up facilitated by the NDA, the prospect of new build and the impact of "global warming" are now having a positive effect in attracting people into the industry. This preposition is backed up by crude data such as the number of people applying for nuclear MSc courses and the large number of graduates vying for places on industry development programmes.

The Importance of Engineering R&D and the Contribution of R&D to Engineering

15. There is a requirement to manage nuclear waste from previous generations of nuclear plants from both civil and military activities. Whilst these clean up activities generally use mature technology options, there exists opportunities to reduce over costs to UK tax payers through investment in research and development into innovative new options. Even where mature technology options are utilised, the waste management activities also require extensive technical support.

16. Disposal of nuclear waste is a sensitive issue in terms of proposed technology options and particularly location of facilities. The UK Government has established a process for evaluation of options for disposal of higher activity nuclear waste based on learning from historic and international experiences. The

framework used has been to establish an advisory body titled "Committee on Radioactive Waste Management" (CoRWM). The CoRWM committee identified, in its summary review in 2006, the need for "a commitment to an intensified programme of research and development into the long-term safety of geological disposal aimed at reducing uncertainties at generic and site-specific levels, as well as into improved means for storing wastes in the longer term." It is expected, based on these recommendations, that a major research programme will be initiated.

17. Many roles in the nuclear industry require a high level of technical competence, where the traditional entry route is through the completion of postgraduate studies. It is believed that for the industry to maintain a high level of technical competence, a sustained programme of support to University research activities will be required in the areas of nuclear science and engineering.

The Roles of Industry, Universities, Professional Bodies, Government and Others in Promoting Engineering Skills and the Formation and Development of Careers in Engineering

18. Industry—Industry has a major role to play in sustaining the nuclear SET skill base. Cogent Sector Skills Council and the National Skills Academy Nuclear have had extremely good support from the nuclear industry. This has taken the form of funding, personnel secondments and resources in support of skills initiatives. Industry must also play a full role in development of technical staff through apprenticeships and graduate development programmes. Traditionally the nuclear industry has appreciated the need to have a highly skilled and motivated workforce to maintain the high level of safety required and to respond to the high level of safety regulation. The main companies also appreciate the need to sustain the skill levels of their supply chain. However, many of the companies in the Supply Chain have limited their investment in training and skills development in recent years due to uncertainty over future contracts, it is essential to maintain and further developed a skilled and competent Supply Chain. A Nuclear Skills Passport is being developed, to align with the national Qualification Credit Framework, and this will be a key tool in demonstrating the competence levels of staff across the whole industry including the Supply Chain.

19. Schools—A major factor in ensuring the supply of new entrants into the nuclear industry is having an adequate pool of STEM students. This must start in the schools and there have been numerous studies into increasing the level of STEM teaching. One particular initiative relevant to the nuclear industry is the Energy Foresight programme being funded by the National Skills Academy Nuclear (NSAN) and overseen by an NSAN industry steering group. The aim of this programme is to provide a set of education resources, including teacher training, for Keystage 4 that present Radioactivity and related issues in personal and social context, supporting the new science GCSE curriculum. The results of an evaluation by the Open University of the Energy Foresight programme showed that overall more students were being attracted to science subjects and, in particular, there was a positive opinion shift in the attitude of girls about working with radioactive materials. The nuclear industry is also supporting Energy Foresight through provision of school ambassadors.

20. Universities—Universities can assist in the provision of skills through provision of relevant course and providing students with opportunities for placements in the nuclear industry. Traditionally there have not been any specific nuclear engineering first degree courses, although some Universities have provided nuclear related modules. Graduate nuclear education has, in the main been provided through post-graduate courses. In response to increased demand, two Universities have started Nuclear Engineering degrees. Universities also provide a range of related MSc courses and 11 Universities/Higher Education Institute Departments have collaborated to form he Nuclear Technology Education Consortium to deliver MSC courses across the breadth of the nuclear industry. The programmes have been developed in consultation with industry. University research department also conduct some of the essential research work needed by the nuclear industry.

21. Professional Bodies—Engineering Institutions, Learned Societies (such as the British Nuclear Energy Society) and the Engineering Council UK play major role in ensuring that the standards of Chartered and Engineering Technician engineers are maintained. The institutes and Learned Societies also facilitate some of the continuing professional development the nuclear SET workforce through their professional journals and through the organisation of conferences and seminars, which enables the spreading of best practice awareness of changes happening within the nuclear industry and its engineering processes. Accreditation and approval of education and training course by Institutions also ensures the relevance to the nuclear industry is maintained.

22. Sector Skills Councils (SSCs)—SSCs and the Skills for Business Network enables the skills need across the nuclear industry to be articulated to Government, skills agencies, qualification authorities, educational institutions and training providers. Cogent SSC signed a Sector Skills Agreement SSA with the nuclear industry, Government, Trades Unions and other stakeholders in 2006 identifying the skill gaps and solutions for resolution of shortages. Cogent SSC, in conjunction with the National Skills Academy Nuclear, is now implementing the SSA solutions and other to provide the skills required by the nuclear industry. A key problem for SSCs is accurate modelling of the situation. For example, on one side there is the individuals' circumstances and on the other there are strategic decisions on how many nuclear power stations may be built an where they will be sited. An example of the former is that many employees have pension agreements that allows retirement at 60 years of age, while recent age discrimination legislation

allows them to be more flexible in when they will leave the industry. The latter issue will come out of the industries response to the ability to build new nuclear power stations and how this translates to the particular regional skills shortage. Cogent SSC is working with Government to sign a Sector Compact which will articulate the nuclear industry training requirements and get an agreement for funding of specific training activities. As part of the Sector Compact, Cogent SSC, on behalf of the nuclear industry, are making the case to extend the "Train to Gain" scheme to make it more applicable to the higher skills levels required by this science based industry.

23. Trades Unions—As noted in paragraph 20, the Trades Unions have been supportive of the need to train, upskill and reskill the workforce and Cogent SSC is aware of the UnionLearn own initiatives that supplement the employer training programmes. The Unions have a key role in ensuring effective implementation of all the Skills Initiatives developed by both Cogent and the NSAN and are on the Boards of both organisations. They also have a place on all the NSAN working groups, with a lead on the development of the "Worker Trainer" Programme.

24. Government—The skills issue has been recognised across central Government Departments Regional Agencies and there are many examples of studies into either the particular needs of the nuclear industry or the more general provision of STEM capable people through funded initiatives in schools, apprenticeships, Further and Higher Education institutions and research. Government's role is essential to provide the funding necessary to ensure the success of the nuclear industry through the provision of the right level of skills. This includes having a flexible response to funding training and education initiatives required by strategic industries. Some Regional Development Agencies, such as NWDA, have made significant investments into the establishment of the NSAN and there is a need for this support to be continued across the RDA network.

25. With much of the nuclear industry focussed on the decommissioning of legacy plants, the Government also has a role in providing a consistent level of funding to the NDA to enable sites to plan ahead with certainly and thus provide a the platform for succession and career planning for individuals within he industry, including the supply chain. Without this, recruitment, initial training and upskilling will not be possible for the decommissioning sector of the nuclear industry and its supply chain. The power generation sector of the nuclear industry is also readily affected by changes Government policy which can affect their profitability, with consequent impact on short term training programmes for their employees. Reductions in profits can also impact on contractors and reduction in the supply chain skill base.

Conclusion

26. There are skill gaps within the nuclear industry and the industry average age profile is skewed towards the higher age bracket. In addition there are some specific shortages in defined employment areas (such as HSE inspectors) and in some essential specialist disciplines (such as Safety Case Specialists). Skills initiatives and their associated funding must be maintained to ensure that sufficient qualified and experienced people are available to support all aspects of the nuclear industry.

27. The competition from national and international projects has the potential to lead to shortages in nuclear specialists and those conventional skills that are required to support the UK decommissioning and new build programme.

28. Positive action is being taken by industry, in conjunction with Cogent Sector Skills Council, the National Skills Academy for Nuclear and other bodies, to improve the situation and regularly update the background data on which skills planning and the associated training provision is based.

29. The support of Government is vital in sustaining the skills base, through provision of funding and legislative action.

March 2008

Memorandum 91

Submission from Professor R G Faulkner, Loughborough University

Executive Summary

UK Engineering Capacity for New Build

1. The Government's sale of BNFL was an untimely and, in view of recent events, disastrous move from the viewpoint of engineer skill provision for nuclear new build. The nuclear engineer skill base has been reducing by approximately 10% per annum for the past 15 years. There are precious few nuclear engineers with deep experience left in the UK workplace. Many of those who could have helped are either retired or have globalised and gone to work for EDF, Siemens, and Areva in Europe or the Far East. There are small pockets of capability in British Energy, British Nuclear Group, and Nexia Solutions. The latter group have

developed good skills in fuel reprocessing and de-commissioning. A few ageing academics and consultants from the good days with Nuclear Electric, BNFL Magnox are still available to help build the knowledge base for the next generation.

Value of Training a New Generation of Nuclear Engineers

2. The skills base in nuclear engineering is still just above the critical nucleus size to allow training of the UK nuclear engineer skills required for the future. The scale of the difficulty lies in the spread-out nature of existing training facilities. There are some reactor and training facilities at Imperial College. BNFL, before its demise, set pu the Dalton Centre in Manchester, but this urgently needs re-direction since it has lost its focus since the withdrawal of support from BNFL. There are areas of good physics and materials nuclear engineering experience in the Universities at Loughborough, Birmingham, Liverpool, Bristol, and Oxford.

3. We are competing against much greater forces in the US. Currently there are 21 Nuclear Engineering programmes operating in the States. My recommendation is that we get on with it and re-build our University skills base to match the American model as soon as possible.

4. It would be very sad if we abandoned the skills that we still possess in the UK from a training viewpoint, and relied on foreign input. Many of us have built good relationships with nuclear engineers in the USA and France in recent years, and this networking will now begin to pay off if UK based training courses were re-introduced.

Role of Engineers in Shaping UK's Nuclear Future

5. It is important to stress that development of environmentally and economically viable nuclear plant in the UK depends entirely on the skills of engineers. This is one area where having a good business degree will not be an advantage. There are many new technological developments that have to be harnessed by engineers with respect to making nuclear cleaner and cheaper. The Generation IV systems, including high temperature reactors, pebble-bed reactors, AP1000 designs (based on the current PWR at Sizewell "B"), are all requiring more research, development and construction. The goal is worthwhile because all of these designs will improve fuel efficiency and reduced resource and operating costs. The long term solution to electrical energy supply with no resource problem, that of Fusion, is already well-underway with excellent teams of UK engineers in place at UKAEA, Culham and at the ITER site in Cadarache, France.

6. There is no question that the new generation of UK nuclear engineers will be trained to work in the global market: it simply remains for us to create sufficient numbers of these people to maintain the UK's still-leading role in the global nuclear marketplace.

Civil/Military Conflicts

7. In my 40 years of experience of nuclear engineering, there has always been a very large gap kept between the engineering activities in the civil arena and those at Aldermaston. Certainly, there are many potential student nuclear engineers who would be discouraged to enter the Industry if they thought their work was likely to be of military significance.

March 2008

Memorandum 92

Submission from the Institution of Engineers (INucE) and the British Nuclear Energy Society (BNES)

1. Executive Summary

(1) This response is issued by the Institution of Engineers (INucE) and the British Nuclear Energy Society (BNES) in response to The Innovation, Universities and Skills Committee major inquiry into ENGINEERING announced on 29 January 2008. This response relates specifically to the ENGINEERING CASE STUDY; NUCLEAR ENGINEERING. A separate joint response has been made by the societies to ENGINEERING.

(2) In the future the UK nuclear industry will cover design, build, operation, maintenance, decommissioning of plant and design build and operation of waste management facilities. The availability of adequate numbers of suitably qualified and experienced engineers for this industry is a concern to BNES and INucE. Our members, the industry and government have introduced many initiatives but more needs to be done. These initiatives need to address the demographic issues, the specific multidisciplinary needs of the industry, recognition of transfer between industries and internationally and the need to portray the industry as vibrant, important and with a long future.

(3) The resources required need to address both our UK civil and defence requirements in the UK and opportunities abroad. We cannot rely on availability of resources from outside UK. We are in a global market with major nuclear expansion world wide.

(4) The role of engineers is for both innovation and operation. We have liabilities to discharge, existing nuclear plant to operate safely and efficiently, replacement plant to build, waste facilities to build and operate and all the associated infrastructure including regulators.

(5) Civil and defence draw on the same pool of resources with many common skills needed and market conditions will lead to mobility of resources with some security constraints. The two sectors communicate and collaborate through skills agencies such as NSAN and BNES & INucE membership leads to learned society interfaces.

(6) As they develop towards the Nuclear Institute, BNES and INucE will continue to proffer independent and charitably supported networking, advice, debate and qualification for the engineers and scientists necessary to underpin nuclear activities in the UK.

2. About INucE & BNES

(1) The Institution of Nuclear Engineers (INucE) is a professional body representing a broad cross-section of nuclear engineers engaged in various aspects of nuclear technology, predominantly in the UK, but also in the USA, South Africa and Asia. Members are involved in many aspects of the fuel cycle from fabrication, through operation of nuclear power plants, to decommissioning and waste management, as well as regulation. Their mission is to promote the highest professional and safety standards for the nuclear industry.

(2) The British Nuclear Energy Society (BNES) is the leading "Learned Society" for Nuclear Energy. The Society functions almost completely by the contributions of volunteers who make available their experience and dedication to provide information to members UK, worldwide on Nuclear Energy issues, to afford opportunities for members to publish and present papers, meet and debate issues locally, nationally and internationally, to promote nuclear energy specific training in the UK and to further increased public understanding of the issues surrounding the use of nuclear energy.

(3) The two societies have announced their intention to merge and are currently pursuing the necessary charitable processes. This structure will continue our joint continuing encouragement of E&T initiatives to promote and interest specifically in the nuclear energy field but recognising that this field itself is dependent on a base of good science and engineering in general.

3. Response: NUCLEAR ENGINEERING

3.1 *The UK's engineering capacity to build a new generation of nuclear power stations and carry out planned decommissioning of existing nuclear power stations*

(1) The 2008 White paper on Nuclear power has clearly shown that HM government considers that nuclear power has a place in the UK energy portfolio. In addition the UK has a legacy of nuclear facilities, civil and military which must be decommissioned over the next 50 years or so and is in the process of establishing the necessary waste disposal facilities. In order to do this we will need a significant increase in the supply of people with nuclear skills at all levels. The ETB report "Engineering UK 2007" shows a disturbing age profile in the UK with 27% of charted engineers being over 65 and a mean age of 55. Due to the nature of the industry the profile for INucE is even more skewed with 60% of Fellows being over 65.

(2) The problem is not only due to the fact that so many bright young graduates entered the industry in the 1960's when it was growing rapidly and are now retired or approaching retirement but the big cut backs in all forms of energy research in the UK following the privatisation and fragmentation of the industry has meant that opportunities for employment have been significantly reduced. Small employers who do no research and little design are not attractive to our brightest scientists and engineers who are looking for interest and career progression as well as just money.

(3) We have commented in the response to ENGINEERING that the formation of the National Nuclear Laboratory will be an example of reversal of this trend as will the investment of the contracting industry in its own development if clear business opportunities can be seen.

(4) Engineers encouraged in to the contracting industry will not stay if there is considerable uncertainty and a stop-go approach to the use of contractors. The current reorganisation of the nuclear industry has led to much movement around and in and out of the industry and we highlight our comment in the ENGINEERING response that for many types of engineering nuclear is operating in a global, not a country specific isolated market.

(5) The age profile of the work force needs to be addressed if we are to keep the decommissioning plans on schedule let alone consider new build. Fortunately for UK plc there are some signs of improvement already on the horizon. New undergraduate courses are being created and numbers on existing nuclear options are now on the increase. At the moment there is enthusiasm amongst undergraduates for the nuclear industry as they can see good interesting job prospects.

(6) That young people can be motivated by nuclear is demonstrated by BNES Young Generation Network. By encouraging younger members to participate and network, not only in the UK but around the world, society membership has grown from less than 10% to nearly 40% in the under 37 age band.

(7) To maintain momentum it is important help the "new blood" realise their expectations. This will mean a good supply of suitable jobs with prospects and training on graduation which is much more difficult for the nuclear operators now the industry is so fragmented. The new NDA graduate training programme is a step in the right direction and does get over some of the problems caused by the break up of companies such as BNFL who were a big recruiter of graduates.

(8) However, the supply chain also supports nuclear not only in decommissioning, waste management and new build but in operation of the remaining Magnox, AGR, PWR (civil and military). Engineering Contractors working in the industry offer a range of graduate recruitment opportunities including graduate training schemes sometimes accredited for corporate membership of Engineering Institutions. These contractors work not only the civil and defence nuclear industries but also in other industries requiring high skills such as the process, oil & gas, pharmaceutical and power industries. So not only are engineers required who can work in nuclear but transferability is needed between industries. This leads to the need for fundamental skills being obtained in the first place with more specific training when industry specific skills are required. We believe that the recently formed National Skills Academy, Nuclear has recognised these different needs and will address them in future programmes.

(9) Another factor which would be a very big help in encouraging graduates to study nuclear energy would be a rapid start to the new build programme. However technically interesting and challenging decommissioning and waste management may be it does have poor connotations to many young people whereas new build looks very exciting. It is thought better to be in at the beginning than the end, however long the end may last for decommissioning and waste management.

(10) Rather than to encourage full undergraduate courses in nuclear engineering, it may be better simply to encourage a growth in engineering courses in general with provision of more final year options in nuclear power. In this way students can keep their options open and such training may be more appropriate to the current structure of the industry where a very small number of large highly specialised companies such as BNFL are replaced by nuclear divisions of more general companies and NDA is targeting growth in use of the supply chain.

(11) Engineering courses alone are not sufficient; there has to be recognition that engineering and science are complementary and for example the nuclear engineering activity of one university is found in a science (physics) department. It is of serious concern that chemistry and physics departments appear to be under threat due to University funding issues.

(12) However, the balance between "nuclear specific" and "courses with nuclear options" needs to be carefully considered as there is some experience from the USA that courses with some nuclear content being too general has led to loss of graduates to other industries. The perception may be different depending on position in the owner/supply chain. The higher up the chain means the more likely it is to require more speciality nuclear engineers, whilst lower down contractors require cross-industry flexibility. It is unlikely one solution fits all.

(13) One factor that is vital to increase the supply of engineering manpower, not just at graduate level, is better and more rigorous teaching of physics/chemistry and maths in schools. It may be necessary to give these two, and other academically rigorous subjects, some form of weighting in school league tables. At the moment schools are judged almost entirely on such tables and it is well known that it is much easier to get an "A" grade in softer subjects such as Media Studies or Textiles then it is for maths or physics. The temptation for schools to encourage soft subjects is very hard to resist but a way round this most be found if we are to survive as a nation in an increasing high tech world.

(14) The development and launch of NSAN is a clear indication that Government as well as industry is convinced of the need for trained personnel across the nuclear technology field and the requirements exist across the whole breadth of qualification levels.

(15) The work of the OECD Nuclear Energy Agency in the area of Skills is noted:

— OECD Nuclear Energy Agency, "Nuclear Education and Training: Cause for Concern?", July 2000.

— OECD Nuclear Energy Agency, "Nuclear Competence Building", October 2004, (http://www.oecdbookshop.org/oecd/display.asp?sf1 = identifiers&lang = EN&st1 = 92-64-10850-5)

3.2 *The value in training a new generation of nuclear engineers versus bringing expertise in from elsewhere*

(1) Though we will have to procure our new nuclear power stations from overseas we will still need people to manufacture, install, commission and operate them. We will also need regulators to ensure that they are operated safely within UK codes and the Site Licence Conditions require the owners to retain "Intelligent" staff; this is not exportable. The shortage of trained and experienced staff in the Nuclear Installations Inspectorate (NII) is already the cause of delay in a number of areas.

(2) We must also look to the future, with increasing concern over global warming and rapidly diminishing fossil fuel supplies the world wide market for nuclear power is already on the increase. As uranium prices continue to increase it is also likely that there will be resurgence in reprocessing as is currently seen in the USA. UK has a significant background in reprocessing and waste handling and we may be able to establish a significant export market in this area. Several of our major contractors have already had success in the USA and elsewhere. We can only do this if we continue to have a good supply of engineers trained in nuclear specialities.

(3) Many of our members work in the UK nuclear industry whose trade association the Nuclear Industry Association (NIA) has undertaken a review of UK capability indicating that with appropriate commitment and investment, UK could supply up to 70% of the equipment and services required for a "foreign" nuclear power plant and at least some vendors have indicated they will use local supply. This will add to the requirement for engineers, not necessarily "nuclear" engineers, ie mechanical, civil, electrical and others. The level of "nuclear" capability of these engineers will vary as their roles vary from front end design right through to active commissioning, operation and decommissioning of nuclear plant. So like any other discipline "nuclear engineering" requires many different skills. As well as the reactor there are steam generation, fuel handling, waste management, electricity generation and distribution, waste management and control and instrumentation plant and systems to consider.

(4) Many of these contractors may also operate abroad. The world nuclear new build and decommissioning markets are in growth at present and overseas opportunities may prove to be attractive, It is probable that transfer of resource internationally could grow if not be essential in future. Multinational alliances have been established to tackle both the new build and decommissioning activity in the UK and this is already leading to transfer of personnel between countries both for training and "best man for the job" reasons. And there is already considerable movement of engineers in the nuclear industry within the European Community and with the EU promoting nuclear as a low carbon solution to the need for energy this would be expected to continue.

(5) It is very clear that other countries are already building up their own staffing in order to meet their own and international demands of the future. Areva in France in particular is seeking to recruit very large numbers of nuclear trained personnel. The French INSTN organisation has taken a major step forward in organising an "International School in Nuclear Engineering Doctoral-level Courses in Advanced Nuclear Science" It was launched in 2007 [http://www-instn.cea.fr/rubrique.php3?id_rubrique = 176] in order to recruit and retain highly qualified staff. It would therefore be most unwise to assume that there is a pool of staff from which the UK could recruit—rather we are potentially already behind in the game and the scientists and engineers we produce could well be "poached" to work overseas.

(6) We do not feel that this is the right forum to discuss the viability of nuclear power as this is a very complex question with many of the variables outside the control of the engineering profession. It is, however, very clear engineers will play a very big role in shaping the future of nuclear power. Nuclear power is very capital intensive so most of the costs come in the design and construction stage. Engineers worldwide have been working for many years to find ways of reducing the capital costs and at the same time enhancing safety and they will continue to do so. UK effort in those areas has much reduced but UK contribution to activities such as outage management, system upgrade, plant life extension etc. is significant with both operator and contractor engineering personnel maintaining the operation of the existing UK nuclear plant that is crucial until new build comes along. These engineers have to be competed for from the same pool of engineering talent available to support the whole nuclear "market place".

(7) Better design of the new build options will also make the ultimate decommissioning much cheaper and easier. Whilst operating costs are low compared with other energy sources despite the recent rise in uranium prices there is still much engineer's can do to reduce them even further. One key factor in running costs is the down time for re-fuelling and this is an area where great strides have already been made at Sizewell B which is now "world class" in this respect. Another area where engineers and nuclear scientists have contributed to reduce the costs and increase the acceptability of nuclear power is waste reduction, the volumes of waste produced by the latest generation of nuclear power stations is only about 1/10th of earlier designs.

3.3 *The role that engineers will play in shaping the UK's nuclear future and whether nuclear power proves to be economically viable*

(1) A brief summary of the typical areas where nuclear engineers and scientists will play their part are as follows:

1. Safety: both (i) the study of safety related issues such as LOCA, severe reactor accidents etc. and (ii) safety case preparation and management—which demands intimate knowledge of the facility design whether or not that facility is bought in from abroad or not.
2. Operation of the plant in the most economic, yet safe manner over the longest possible time, this includes operation itself and through life maintenance and outage management.
3. Life extension assessment and reactor plant evolution to meet future requirements of licensing and operational demands.

4. Nuclear data measurement and evaluation—required for understanding of newer materials and concepts.
5. Reactor development—participation in the international programmes (such as the Global Nuclear Engineering Programme GNEP which the UK has just joined) in order to maintain skills and expertise and to be prepared to benefit from future developments (with the Keeping the Nuclear Option Open (KNOO) programme being an important mechanism for sustaining R&D involvement in the Universities).
6. Materials science of nuclear fuels and other materials issues in order to understand the way that these materials behave under longer burn-up and higher irradiation reactor conditions.
7. Waste issues such as Fuel cycle chemistry, Partitioning and Transmutation in order to reduce the burden on waste disposal—and associated technologies such as Accelerator Driven Systems (ADS).
8. Future concepts such as nuclear generated hydrogen-economy.
9. In addition, the whole area of multi-scale modelling and simulation, which underpins most of the topics above, also demands a similar high degree of technical knowledge, ability and expertise often combined with significant computing skills.

(2) The recent nuclear review has concluded that nuclear energy has a part to play in the UK's energy mix and it is clear that a range of other countries are taking similar decision. In a world of increasing competition for the reducing fossil fuel resource and pressure to reduce CO_2 emissions, the nuclear technologist has a significant role to play in ensuing that a viable, convenient and affordable source of electricity remains available to the UK population.

3.4 *The overlap between nuclear engineers in the power sector and the military*

(1) The question of overlap between civil and military can be divided into two sections, weapons and nuclear submarine propulsion. There is significant scope for interchange in the latter as the power plant of a nuclear submarine is in general, similar to that of a modern power station. Many former nuclear submariners already occupy positions at all levels in the civil nuclear power and contracting industry and this is likely to continue.

(2) Thus the Royal Navy can be seen as a training ground for supporting the future UK nuclear power sector. By the counter argument, MOD are subject to the same issues of demographics as the rest of the industry and they are part of the pool calling for an adequate supply of engineering skills and providing training for them. There is also an overlap between the nuclear weapons sector and civil in certain specialised engineering fields, decommissioning and waste management area. The nuclear skills agenda for the UK therefore needs special attention to satisfy all parties.

(3) With respect to nuclear engineering education and training, the MOD is fully engaged through the appropriate sector skills council (COGENT), the national Skills Academy Nuclear (NSAN) and higher up the skills pyramid, the Nuclear Technology Education Consortium (NTEC), as well as through its own dedicated education and training programmes at HMS SULTAN.

(4) The UK continues to project manage, develop, design, supply and operate PWR technology for the nuclear submarine programme and this involves RN, MOD Civil Service and contractor resource, the latter led by BAE Systems and Rolls-Royce and supported by their supply chains. This programme includes new build through to waste management and MOD are aligning with industry through its published Industrial Strategy. Waste management and decommissioning are specifically being taken forward through engagement with the NDA.

4. Concluding Remarks

(1) In conclusion BNES and INucE are sure that there will continue to be a demand for highly skilled engineers at all levels in the nuclear industry and that HM Government must do all it can to encourage young people to enter the profession. Recent growth in membership has followed the interest in decommissioning and is likely to be further encouraged by new build opportunities. BNES membership for example has increased by ~30% in the last five years. This has been mirrored by significant increases in students interested in nuclear engineering options, albeit from historic low levels (and the recent re-establishment of nuclear engineering courses at undergraduate level, beginning at Lancaster University).

(2) An important objective of our planned combined society "The Nuclear Institute" will be to continue to encourage the networking of all establishments and individuals concerned with nuclear energy, operation, regulation, engineering, education and waste management in the UK, to continue to offer charitable funds within our capability to encourage this.

(3) Through our Advisory Council we will continue to work and collaborate with all the major Professional Engineering and Scientific Institutions who have members who work in the nuclear industry. A significant role for the Nuclear Institute will be to continue to offer professional qualifications that give opportunity for recognition by the Engineering Council. We shall also encourage initiatives amongst the

public in general so that they are able to better understand the issues surrounding nuclear energy, how it is engineered and how it relates to all the other energy sources and application technologies that are important for the economic and sustainable future of the UK and the world.

(4) Currently BNES operates the Nuclear Academic and Industry Liaison Sub-committee (NAILS) to promote the exchange of knowledge between industry and academia with the aim of bringing closer the mutual understanding of R&D needs. Future plans are to publish this information more widely. This work will continue under the new Nuclear Institute.

(5) We look forward to continuing our close work with Government Agencies to further growth of engineering capability and competence in the UK and to provide an independent learned society viewpoint on these issues.

March 2008

Memorandum 93

Submission from the Nuclear Industry Association (NIA)

The NIA is the trade association and information and representative body for the civil nuclear industry in the UK. It represents over 130 companies operating in all aspects of the nuclear fuel cycle, including the operators of the nuclear power stations, and those engaged in decommissioning, waste management and nuclear liabilities management. Members also include nuclear equipment suppliers, engineering and construction firms, nuclear research organisations, and legal, financial and consultancy companies.

Capability of the UK Industry to Build New Nuclear Stations

The NIA has conducted an extensive study on the capability of the UK industry to deliver a programme of new nuclear power stations. The study concludes that at present the UK industry could itself construct 70% by value of a new pressurised water reactor and if there was further investment this could rise to 80%. The study specifically looked at PWRs but the result will be much the same for a boiling water reactor and perhaps a little higher for a Candu type reactor due to that reactor type's lack of pressure vessel which is a key component of the others which can not be manufactured in the UK.

Independent of the type of reactor constructed, much of the engineering and construction work on a new nuclear power plant is not directly nuclear related but is similar to work being carried out by many companies on major projects throughout the UK and worldwide. The UK has a large engineering capacity in comparison to that which would be required for the construction of new nuclear facilities. The NIA study concluded that a new nuclear power station would require only 2–3% of the national civil engineering capacity and 4–5% of the national capacity in mechanical and electrical engineering.

If one was to assume a programme of new nuclear build which consisted of 10 reactors on five sites built over 15–20 years then it is likely to generate 64,000 man-years of work directly and 22,000 indirectly in the support sector in the local communities where construction takes place. Generally the skills resource is available in the UK but there are some specialist areas where more effort needs to be made in training, in particular in the area of safety and licensing. The NIA has long recommended that industry and government agencies should work together to increase training provision and counteract the decline in young people entering the engineering, manufacturing and construction industries. The UK has made good progress in the nuclear sector over the last few years with the establishment of Cogent the sector skills council for nuclear and the launch this year of the National Skills Academy Nuclear. There has also been a large increase in the number of nuclear courses available through colleges and universities. The University of Manchester has established the Dalton Institute to function as a centre of excellence for nuclear research and training. The institute has jointly funded skills and training with the Nuclear Decommissioning Authority.

This submission has been written to conform to the evidence request in terms of word limits and in not reproducing previously circulated work however we will be happy to provide copies of the full capability report on request.

Training UK Engineers or Importing Skills

The nuclear power industry is a global one and the skills the industry need are sourced globally so the lack of locally trained staff is not necessarily a barrier to further development of the industry. However the UK is not alone in looking to build new nuclear stations and so we will be competing for these people in a global market place. While there is no guarantee that home grown engineers will stay in the UK it does make it more likely so having a sufficient supply of home grown engineers is the best option. Having an established home market and close association with international vendors would provide UK companies with access to significant business opportunities worldwide which will in turn make them more attractive places to work for home grown engineers.

The UK nuclear workforce is a high average age with a large proportion close to retirement so the need to train and recruit more staff is urgent. There are also some specific areas in which there are shortages now such as nuclear inspectors. However it is the generally lower numbers of students studying science, technology and engineering fields which is causing the engineering labour market to be difficult. The government should certainly be looking to take action to encourage more students to study these fields as this would be beneficial not just to the engineering sector but to the economy as a whole.

The Role of Engineers

Engineers are obviously key to the development of the nuclear industry whether new nuclear power stations are built or not as engineers are key to the safe operation and development of existing stations and the decommissioning of former station. While the four prospective reactor vendors are all based overseas so the work done by engineers in designing the plant will not be carried out in the UK some of those engineers are UK trained and the implementation of the projects will be carried out here. The construction of new nuclear stations will require engineers from all disciplines as well as nuclear engineers.

Economic Viability

We believe economic scenarios set out by the Government are sensible and reasonable and support the widespread view among electricity generating companies that nuclear power is an economic option for electricity generation, and one in which they would wish to invest. Those economic calculations that drive investment and the investments themselves will be made by private sector companies, not by Government. These companies will not invest in an uneconomic generating technology and so it is the ultimate test of the economic viability of nuclear energy.

Electricity prices have risen noticeably in the recent past, in part driven by the global rise in gas prices. This has had a severe impact on UK industrial, commercial and domestic consumers, particularly those on low incomes. As the cost of fuel is a small proportion of nuclear costs nuclear energy is relatively insensitive to changes in the price of the raw uranium fuel, and provides an element of cost stability in the generating portfolio, which is helpful in keeping overall prices to consumers low. This contrasts with gas-fired generation, where the cost of raw gas can represent 60% or more of the total generating cost. It has been shown that the overall generating cost of nuclear energy is competitive with fossil-fired generation. Nuclear energy will become even more competitive in the future if gas prices rise further and the costs associated with carbon emissions begin to play a larger role. Nuclear energy's low and predictable running costs provide a valuable hedge against volatile fossil fuel prices.

The Overlap Between Nuclear Engineers in the Power and Military Sectors

The reactors that power the UK's submarine fleet are pressurised water reactors and operate on the same principles as those in nuclear power stations. However the NIA only covers the civil nuclear sector and so it is difficult to comment on this point of the inquiry.

March 2008

Memorandum 94

Submission from the Institution of Civil Engineers (ICE)

Inquiry into Engineering—Nuclear Engineering Case Study

The Institution of Civil Engineers (ICE) was founded in 1818 to ensure professionalism in civil engineering. It represents 80,000 qualified and student civil engineers in the UK and across the globe.

1. *The Role of Nuclear*

1.1 ICE welcomes the government's decision to support the next generation of Nuclear Power Stations. To tackle the twin goals of reducing the carbon impact of energy generation and long term security of supply ICE believes that the large scale deployment of all commercially viable technologies is a priority for the UK. Nuclear power will be an important part of this process.

2. *Capacity Issues*

2.1 Cogent Sector Skills Council and the National Skills Academy for nuclear has identified that over the next 10 years the nuclear sector will need to recruit between 5,900–9,000 graduates and 2,700 to 4,500 skilled trades.[27]

2.2 ICE has been advised that circa 30% of British Energy's staff is due for retirement over the next 10 years, creating a significant loss of knowledge and expertise.

2.3 The nuclear sector's demand for skills comes at a time when demand for engineers with the skills required to deliver major infrastructure projects is high. The Office of Government Commerce predicts annual growth in the UK infrastructure sector of 4.2% between 2005 and 2015,[28] whilst international demand, particularly from emerging economies also remains strong.

2.4 In the short term, much of the capacity gap in the sector is likely to be filled by importing skills from nations such as France which have extensive nuclear programme. Longer term, the UK has an opportunity to grow its own cohort of skilled workers.

2.5 To realise this opportunity the UK will need to:

— Reverse the long term decline in Maths and Physics study in schools and colleges.

— Reverse the stop/start pattern of development, which has afflicted the nuclear sector (and much of UK infrastructure) in recent decades, creating. disincentives for entry to the sector and for investment in the development of high level, specialist skills and innovation.

3. *ICE recommendations*

3.1 A Strategic Infrastructure Planning Body (SIPB) should be created to work with government and industry to co-ordinate major infrastructure investment and create a stable environment conducive to specialist skills development.

3.2 Government should create the post of Chief Infrastructure Advisor. This individual would advise government on all aspects of strategic infrastructure development, and work with individual government departments and help them in the formulation of the National Infrastructure Policy Statements that will be required following the passage of the Planning Bill through parliament.

3.3 Within an SIPB, it will be important to set out a clear, multi decade, framework for the development of nuclear power.

3.4 The need for the next generation of nuclear power has been established at the national level and government must ensure that the planning system is able to deliver consents in a timely and predictable fashion. We therefore support the proposals in the Planning Bill for an independent Infrastructure Planning Commission to handle applications for nationally significant projects.

3.5 Industry and government should co-operate to develop more bursary schemes, such as those currently offered by the National Skills Academy for Nuclear, the Nuclear Decommissioning Authority, Serco and SBB Nuclear, to encourage a steady flow of graduates into the sector.

3.6 Industry should explore the wider use of mentoring schemes, allowing older workers to contribute past retirement age and pass on expertise to the next generation.

March 2008

Memorandum 95

Submission from EDF Energy

1. *Executive summary*

1.1 EDF Energy is one of the UK's largest energy companies. We provide power to a quarter of the UK's population via our electricity distribution networks. We supply gas and electricity to over five million customers and generate about 5GW of energy from our coal and gas power stations, combined heat and power plants and wind farms.

1.2 EDF Energy is part of EDF Group, which is one of the largest energy companies in the world, and also the largest nuclear power generator in the world with a fleet of 58 plants with an installed capacity of 63 Gigawatts.

[27] National Skills Academy Nuclear (2008), http://www.nuclear.nsacademy.co.uk/31jan08%20launch%20press%20release.pdf, accessed 14 March 2008

[28] Office of Government Commerce (2006), *2005–2015 Construction Demand/Capacity Study*, OGC, London

1.3 EDF Energy has long argued for a diverse generation mix in the UK to address the challenges of climate change, energy security and affordability of prices. A diverse mix should include renewables, gas, clean coal and nuclear power, as well as greater efforts on energy efficiency. We are interested in investing in at least four new nuclear plants in the UK using EPR technology.

1.4 To achieve this we anticipate making use of a combination of the skills base which already exists and is expanding in the UK, as well as our own expertise as the world's largest nuclear operator.

1.5 We believe there is strong evidence that the UK skills capacity is already growing following the Government's decision to allow investment in a new generation of nuclear plants and that investment in training and educational facilities will continue to increase as new build progresses.

1.6 We further believe that there is no choice to be made between UK skills and international skills and that a successful new build programme will require a combination of both.

1.7 Our UK nuclear project is already benefiting from this mix. We have a team comprising of engineers with direct experience of operating the fleet in France from EDF Group working alongside experts in the UK nuclear and electricity industries.

1.8 The design we have submitted, jointly with Areva, for generic design assessment in the UK is based on the plant we are building on time and to budget in Normandy. Construction in the UK could benefit from this experience.

1.9 Using international designs, such as the EPR, rather than developing bespoke designs for the UK will mean skills and experience are more easily transferable, rather than just having to be developed here. The generic design assessment process now underway is key to ensuring that new build in the UK can be focussed on a small number of internationally recognised designs.

1.10 In responding to this call for evidence we have addressed the first two questions highlighted by the Committee, as these are the ones on which we feel we have the most direct experience.

2. *The UK's engineering capacity to build a new generation of nuclear power stations and carry out planned decommissioning of existing nuclear power stations*

2.1 Most of the necessary skills and resources needed for nuclear build are general civil engineering skills and not nuclear specific. These skills already exist in the UK.

2.2 A study by the Nuclear Industry Association found the requirement for civil engineering resources to build a new nuclear power station would represent only a small proportion, around 2–3%, of the national capability. Similarly, mechanical and electrical resource requirements are only 4–5% of the national capacity.

2.3 Competition for resources from other major projects should not be a problem (for example, any new nuclear build would occur predominantly after construction for the 2012 Olympics).

2.4 Nuclear expertise has been retained in substantial numbers in the UK in support of the ongoing operations of the reactors and in support of clean up and decommissioning activities. Such capability can be expanded and developed to meet the expected demands of a new build programme in the UK.

2.5 Investors, contractors, universities and others will invest in these resources when they are confident new build will go ahead and the additional resources could be put in place in time.

2.6 There is evidence this is already happening: Nuclear studies are increasing at various universities, including Imperial College London, University of Manchester and University of Central Lancaster.

2.7 Imperial College and the University of Manchester recently jointly launched a Nuclear Engineering Doctorate Centre which will award an Engineering Doctorate (EngDoc) qualification in nuclear engineering.

2.8 The Nuclear EngDoc will be a four-year postgraduate qualification aimed at the UK's best young research engineers. Its aim is to equip them with the skills needed to take on senior roles within the nuclear industry. It will train 50 research engineers in areas such as waste management, reactor technology and safety systems.

2.9 Separately, the University of Manchester and EDF have signed a framework research and development (R&D) agreement, which will pave the way for important new studies into energy networks and generation. Under the initial four-year agreement, the University could receive as much as £2 million funding from EDF for a variety of scientific and technological research projects, including research studies in nuclear energy.

3. *The value in training a new generation of nuclear engineers versus bringing expertise in from elsewhere*

3.1 We believe that it is not a question of one or the other and it is a mistake to think of these two routes as being in opposition.

3.2 In section 1 we set out how the existing UK skills capacity can be further developed for new build. But the nuclear industry is a global one, with significant co-operation between different companies, countries and regulatory bodies. This approach has specifically developed over the previous decades to ensure the highest levels of safety are achieved. It would be unusual if new nuclear in the UK did not therefore reflect international experience and make use of skills developed elsewhere in augmenting the domestic skills base.

3.3 For EDF, we would anticipate that our own experience would be an important element of any project in which we are involved.

3.4 EDF's track record is unrivalled and with 58 units in France our fleet is almost four times the size of the world's next largest nuclear operator. EDF is well placed to optimise the benefits of nuclear through our experience, our technology and our financial strength.

3.5 EDF is looking for new graduates to ensure its development and to update its expertise in nuclear engineering and operation. Over the next 10 years, EDF plans to recruit 5,000 engineers and managers Europe wide, including the United Kingdom, and more or less the same number of university graduates. They will join 25,000 EDF employees who are already pursuing careers in this sector.

3.6 Major infrastructure projects worth billions of pounds, like nuclear new build, need a very large deployment of skills to deliver them. There are many such projects around the world and it is now normal practice to deploy multinational workforces of skilled labour.

3.7 The international return to popularity of nuclear energy effectively offers EDF Group new opportunities for showcasing its expertise, particularly in the operation of nuclear power stations. By 2010, 700 people will be working on projects all over the world.

3.8 Apprenticeships are available in all Group divisions, particularly generation, as well as for all levels of education, from vocational training certificates to postgraduate level. By 2008, 3,000 students will have an apprenticeship contract with the company, representing around 3% of the workforce.

3.9 In the UK, we have submitted the EPR design, jointly with Areva, for generic design assessment. This is the same model EDF is building at Flamanville in France, in a project which is on time and on budget.

3.10 Flamanville 3 is due to be completed in 2012, which is when we would expect to begin construction of a first pant in the UK. We will already have experience of building precisely this design and the experience developed at Flamanville can be transferred to the UK.

3.11 Using international designs, such as the EPR, rather than developing bespoke designs for the UK will mean skills and experience are more easily transferable, rather than just having to be developed here. The generic design assessment process now underway is key to ensuring that new build in the UK can be focussed on a small number of internationally recognised designs.

3.12 Any new build by EDF in this country is expected to be in partnership with UK companies. This is the same approach EDF is taking in the US and in China, where we have entered partnerships with leading energy companies in both countries.

3.13 UK companies are already playing a key role working with EDF and AREVA in the Generic Design Assessment of the EPR.

3.14 For instance, AMEC plc provides technical support to EDF and AREVA relative to the UK context as the EPR will be assessed against UK standards and rules.

March 2008

Memorandum 96

Submission from the University of Central Lancashire

A. Executive Summary

The UK's engineering capacity to build a new generation of nuclear power stations and carry out planned decommissioning of existing nuclear power stations

1. The University assumes a traditional definition of engineering, rather then the broader definition that incorporates all science and technology.

2. When considering the UK's engineering capacity, it is important to consider first the engineering sector as a whole, then the nuclear sector and the major sub divisions of the nuclear sector.

3. UCLan believes that the critical challenges for the industry are:

(a) attractiveness with regard to recruiting talent;

(b) ensuring career paths exist for engineers; and

(c) ensuring that training systems and processes are fit for purpose.

4. As well as competition for talent from outside the industry, there are distinct sectors within the industry which may also compete eg decommissioning vs new build.

5. The role of the Nuclear Decommissioning Authority needs to be re-examined when new commissioning begins to determine if it is best for the Authority to continue to focus solely on decommissioning and waste management.

The value in training a new generation of nuclear engineers versus bringing expertise in from elsewhere

6. UCLan believes the focus should be on the need to train engineers more generally, rather than "nuclear engineers" exclusively, to ensure our engineers can apply their skills through all the "higher reliability industries" eg nuclear, oil and gas.

7. Bringing in expertise from outside the UK represents a short-term fix. The UK needs to "grow its own" engineers if we are to develop a robust skills base that will meet the challenges posed by a globalised market.

8. Training our engineers in behavioural skills, such as leadership development, is as important as the training of technical competences in industries such as nuclear, which are heavily regulated and have a clear health and safety focus.

The role that engineers will play in shaping the UK's nuclear future and whether nuclear power proves to be economical viable

9. The role of engineers represents only one part of shaping the UK's nuclear future. Chemists, physicists, environmental scientists and other professionals are just some of the other roles required.

The overlap between nuclear engineers in the nuclear power sector and the military

10. There is considerable overlap between nuclear engineers in the power sector and the military; someone with the common core skills in one sector should be able to make an easy transition to the other.

B. Introduction to University of Central Lancashire

11. The University of Central Lancashire (UCLan) is based in Preston, Lancashire. We are one of the UK's largest universities with more than 30,000 students, and enjoy long-standing associations and relationships with the nuclear industry.

12. In 2004, Westlakes Research Institute (WRI) invited UCLan to take over the running of its operations and to incorporate the Institute into the University, turning the WRI into a full university campus. The campus is based at the Westlakes Science & Technology Park, home to several businesses and organisations providing support services to the nuclear industry and the Nuclear Decommissioning Authority (NDA).

13. In 2006, UCLan launched the country's first Foundation Degree in Nuclear Decommissioning in direct response to the Government's White Paper on decommissioning in 2002 "Managing the Nuclear Legacy", which pledged to spend £50 billion on the clean-up of the UK's nuclear facilities. Students currently study at the WRI and Lakes College West Cumbria at Lillyhall.

14. In June 2007, UCLan opened The John Tyndall Nuclear Research Institute, which is based within the Department of Physics, Astronomy and Mathematics at the University. The Centre is a first of its kind in the UK, acting as a body for the provision of research, alongside offering undergraduate/postgraduate education in nuclear sciences and engineering disciplines.

15. Furthermore, in January 2008, the National Skills Academy Nuclear (Cogent)—the skills and training body for the nuclear industry—chose the universities of Central Lancashire and Portsmouth to lead on the development and delivery of foundation degrees for school leavers, new entrants and individuals retraining and up-skilling.

16. On top of this, the University recently launched its vision for the next decade, including a commitment to innovation in its teaching, research, knowledge transfer and service delivery. Central to this, is the creation of the new post of Pro Vice-Chancellor (Nuclear Industries), taken up by Dr Graham Baldwin in March 2008. Graham has recently completed a secondment to the NDA and Sellafield Ltd, where he advised both the Authority and national stakeholders on the implications of the emerging skills agenda for the nuclear industry, and will oversee the University's plans for a foundation degree in nuclear-related technologies and a suite of related postgraduate programmes.

C. Further Detail

The UK's engineering capacity to build a new generation of nuclear power stations and carry out planned decommissioning of existing nuclear power stations

17. When considering the UK's engineering capacity, it is useful to consider first the engineering sector as a whole, then the nuclear sector and the major sub divisions of the nuclear sector (most notably the areas of new build and decommissioning).

18. We see that the critical challenges for the industry are:

Attractiveness of the industry with regard to recruiting talent: Engineers are in demand across the UK for major projects. Industry surveys have suggested that students are unaware of the opportunities in nuclear, and are more aware of competing sectors (eg London Olympics). Promoting nuclear engineering as a career needs to be a priority.

Ensuring career paths exist for engineers: Studies show that potential entrants into engineering are put off by the apparent lack of career structure in the sector. The nuclear sector needs to ensure that career paths are mapped out and publicised to show potential entrants there is a future for them in the longer term. Likewise, the sector needs to consider how to recognise senior technical staff, without necessarily transferring them to managerial positions where their expertise can be lost.

Ensuring that training systems and processes are fit for purpose: Within certain specific posts there are staff shortages. One such area is that of trained inspectors who can ensure that work undertaken complies with regulations—a shortage of these trained personnel can lead to delays in programmes. The problem here is not lack of people, but the fact that existing training systems are too prescriptive and inflexible to allow the development of talented people who perhaps have not come through traditional routes, and in a timely fashion.

19. As well as competition for talent from outside the industry, there are distinct sectors within the industry which may also compete. For example, it is likely that decommissioning and new build will compete for talented personnel. There is a common perception in the industry that new build is more attractive than decommissioning, largely in part because the term "nuclear decommissioning" suggests finality, casting doubts over a person's long term future in the industry.

20. The role of the Nuclear Decommissioning Authority needs to be re-examined when new commissioning begins. The Government needs to determine if it is best for the Authority to continue to focus solely on decommissioning and waste management, or whether redefining its scope and title would be more beneficial to the industry as a whole. This would serve to avoid an apparent overlap in areas such as skills, where entrants could be confused by conflicting messages from competing sectors, when in fact many of the skills are common to both.

21. The other element of engineering capacity to consider is manufacturing capacity. Government will obviously have a role to play in determining the degree of manufacturing of plant and equipment that occurs in the UK, and UCLan would be delighted to support the development of skills and technology to enable this.

The value in training a new generation of nuclear engineers versus bringing expertise in from elsewhere

22. We should be careful about focusing on the need to train "nuclear engineers" exclusively, rather than engineers more generally. There is a danger of limiting engineers' skills if we train them in just one discipline: for example, producing nuclear engineers who can only apply their expertise in the nuclear environment. Focusing solely on the training of nuclear engineers risks a surplus supply, due to the unpredictability of future workforce requirements.

23. We have to ensure that we are creating highly trained engineers that can apply their expertise to all the "higher reliability industries"—those industries such as nuclear, oil or gas that need to have a consistent record of reliability against a backdrop of significant safety and environmental issues. UCLan focuses on delivering skills for the nuclear industry, rather than "nuclear skills". We design our courses so that engineering and technology students can translate their skills to all "higher reliability industries". Degrees need to be designed in such a way to include specialised modules to cover all aspects of engineering.

24. Bringing in expertise from outside the UK represents a short-term fix. The UK needs to "grow its own" engineers if we are to develop a robust skills base that will meet the challenges posed by a globalised market. One way to achieve this is the development of science and technology-related courses to make them more attractive to prospective students. For example, UCLan offers a Motor Sports Engineering course. While the primary focus is concerned with the design, development and manufacture of race cars, the course produces fully-qualified engineers who could apply their skills to other industries. Innovative marketing such as this can be a useful method of encouraging engineers into the sector and teaching core skills, by making it more appealing and easier for entrants to see the potential career paths they might follow.

25. When we consider the training of engineers, it is vital that it is not just technical competences that are considered. Behavioural skills, such as leadership development, are vital in every industry, but they are particularly important in the higher reliability industries which are heavily regulated and have a clear health and safety focus. Strong team leaders are essential in these environments, and a balance needs to be struck in the development of training.

The role that engineers will play in shaping the UK's nuclear future and whether nuclear power proves to be economical viable

26. The role of engineers represents only one part of shaping the UK's nuclear future. Chemists, physicists, environmental scientists and other professionals are just some of the other interrelated roles required in the successful delivery of new build, reprocessing and waste management. The Government needs to take a broad, holistic view of the requirements that are needed, and recognise the importance of all industries in delivering nuclear power.

The overlap between nuclear engineers in the power sector and the military

27. There is considerable overlap between nuclear engineers in the power sector and the military. Common knowledge and skills areas include the use, storage and reactivity of nuclear materials; the handling and processing of nuclear wastes; contamination and criticality issues; health physics; and quality assurance. The non-overlapping areas include manufacturing techniques; specific weapons or reactor design; security; and operating facilities' layout and rules.

28. We believe that in practice, someone with the common core skills in one sector should be able to make the transition easily to the other, giving flexibility when required within the industry. Consideration needs to be given to the design and definition of a system to facilitate this.

March 2008

Memorandum 97

Submission from the Royal Academy of Engineering (RAE)

0.0 The following response was prepared in consultation with Fellows of The Royal Academy of Engineering with expertise in the area of Nuclear Engineering. The response argues that there is good evidence that nuclear power is economically viable and thus there is a pressing need to build up the UK skills base in nuclear engineering in order to support the running of a new generation of nuclear power plants.

0.1 Underpinning all of the comments below is the observation that the current crisis of skills in the area of nuclear engineering, and the uncertainty regarding the UK's capacity to forge ahead with a new generation of nuclear new-build, could have been avoided if a nuclear strategy had been put in place 10 years ago. The need is now pressing for a strategic Government policy on nuclear engineering.

(1) *The UK's engineering capacity to build a new generation of nuclear power stations and carry out planned decommissioning of existing nuclear power stations*

1.1 The UK could by no means be self-sufficient in the building of a new generation of nuclear power stations in the timescales required. The bulk of detailed design for the systems being considered for the UK has already taken place in France and North America. Many major components will be sourced from the existing global supply chain. The issues for the UK are the tensions between global demand and supply; the UK's position in the queue; and the extent to which UK industry is mobilized to participate in this marketplace.

1.2 There have been extensive studies carried out on the UK's ability to build new designs of station. The Nuclear Industry Association (NIA) led such a study in 2005.[29] The NIA took an optimistic view of the fraction of the capability that could be sourced from the UK, suggesting that UK industry could satisfy about a half of this requirement without further investment but that this could increase if confidence existed in a continuing need. Two principal reasons underlie this optimism. One is that the initial stages of new build will take several years, providing the UK industry with time to respond. The second lies in the fraction of the resource that is truly nuclear specific. Much of the hardware and engineering associated with a nuclear power plant is not nuclear engineering per se. The so called "nuclear island" only represents a certain percentage of the overall plant. The balance of plant, including the turbine island, will comprise heavy engineering assets in use across the power sector internationally.

[29] http://www.niauk.org/images/stories/pdfs/MAIN_REPORT_12_march.pdf)

1.3 Nevertheless this "balance-of-plant" still requires specialised engineering. Nuclear plants have to be designed not only to deliver high levels of reliability, but also to meet stringent external hazard safety requirements such a seismic loading that other normal structures do not have to meet. Hence, it is still far from "run of the mill" engineering. But this means that it could, with sufficient investor confidence, present significant opportunities for reinvestment in the UK's manufacturing base as part of the supply chain supporting the international reactor vendors. Confidence that the UK will actually embark on a major nuclear programme could provide the opportunity to reinvigorate the UK's engineering industry, eg by entering into partnerships with Japanese, Korean, French or US companies to build high quality steel making, precision forgings and nuclear pressure component factories to supply the UK and other international markets. The pressure on fossil fuels is likely to see a significant world demand for nuclear reactors over the next 30 years. With some imagination the UK could become a major supplier to this market.

1.4 Planned decommissioning represents a quite different situation and requires a different skill set from new build. The UK already has significant experience in decomissioning redundant nuclear facilities, particularly those used in the early atomic energy development by the UK Atomic Energy Authority (UKAEA) and British Nuclear Fuels (BNFL). In addition decomissioning of the early Magnox graphite reactors has been successfully undertaken by British Nuclear Group (previously BNFL) and there is considerable capability and knowledge in this area.

1.5 There is nothing technically difficult in the decommissioning of the UK's graphite reactors. It does not require nuclear engineering because once the reactors have been defuelled there is no fissile material and hence no nuclear or criticality threats. The expertise required to decommission involves instead knowledge of radiation protection and industrial dismantling and demolition. The time period over which decommissioning of existing operating and past power stations will be carried out depends on a number of factors, including the disposal of waste, for which the UK has still to determine a site and repository timescale. There is no fixed or mandated timescale. Accelerating the process increases the radiation hazard and, as a result, increases the costs of the activities. Extending the timescale allows natural radioactive decay to reduce the hazard and allows time for detailed careful planning of the activities. Hence, there is no urgency requiring the diversion of nuclear engineering expertise to the task of decommissioning.

1.6 Arguably of more concern than the capacity for decommissioning is the adequacy of the staffing of the Nuclear Installations Inspectorate (NII) to provide the generic safety assessment of each of the competing designs required by Government. While conducting this urgent task, the NII will also be continuing its regulation of operating nuclear power stations and of decommissioning and waste storage activities throughout the industry. The NII cannot recruit enough inspectors to carry out their statuary duties never mind license new reactor designs. More attention is needed by Government to ensure an adequately resourced nuclear regulator to inspire public confidence.

(2) *The value in training a new generation of nuclear engineers versus bringing expertise in from elsewhere*

2.1 It would be wholly unrealistic to consider the possibility of sustaining a new nuclear power programme in the UK without UK expertise and engineers. Whilst the design of a new build will be procured from overseas vendors, its deployment will be local, requiring UK engineers to complete detailed design and site specific works, regulate, build, commission, operate, maintain and support a fleet of new nuclear power plants over their projected 60 year lifetimes.

2.2 The Royal Academy of Engineering and companies within the sector remain concerned about the projected availability of UK engineers generally—particularly in heavy electrical, mechanical, control and instrumentation and power engineering. Therefore, the training of new nuclear engineers is a part of the wider issue of the need to train more engineers in these sectors. Highly skilled engineers, technicians and practitioners who understand what is required to make nuclear reactors work safely and reliably will be required in significant numbers. Not enough is currently being done to address this issue.

2.3 Nuclear engineers generally have a background in mechanical, chemical or structural engineering and undertake work experience and further development on nuclear engineering specifically. In the past, the sector relied upon scientists and engineers within main-stream engineering courses having some nuclear training as modules within their standard degree courses.[30] The sector also relied heavily upon the then Central Electricity Generating Board and UKAEA providing nuclear-specific training to graduates joining from universities across the UK. At their peak these two organisations employed between them over 8,000 engineers and scientists in multiple labs across the UK and provided significant post graduate training. They also sustained a vibrant academic research base in several of the UK's top universities. However, this declined to almost zero by the end of the 1990s. Only BNFL's technical support organisation Nexia remains; and the bulk of their expertise is in the waste management and disposal area rather than reactor systems. The supply chain serving British Energy including BE's own engineers maintains expertise for the current operations but is already finding it difficult to recruit trained personnel given the overall industry decline over the past two decades.

[30] Recruitment into nuclear science and engineering degree programme in the US is significantly stronger than in the UK with programmes operating alongside mechanical and/or chemical engineering disciplines or as part of a specialised option within the programme. Such choices are no longer offered in the UK.

2.4 The result of this decline and the reductions in the Royal Navy nuclear training programmes is a serious lack of nuclear engineering development opportunities across the sector. Competences such as criticality assessors, reactor physics, reactor transient analysis, reactor fault studies, thermal hydraulics, heat transfer, fracture mechanics, irradiation embrittlement of steel, nuclear chemistry, health physics, human factors, risk analysis, control and instrumentation, computer protection and many more are core to both new build and decommissioning and in short supply across the UK.

2.5 BNFL, EPSRC and key university self investment especially at Manchester have begun to reverse the situation but The Royal Academy of Engineering is of the opinion more needs to be done. There is a need for a more coordinated approach to the provision of nuclear reactor design and operating education and training. It is not sufficient to fund MSc courses; new staff at post doctoral level, and a research culture at PhD level, are also required to sustain internationally competitive research groups and a new knowledge base from which research results can "trickle-down" to MSc and undergraduate teaching.

2.6 In the longer term engineers should be making significant inputs to developing the overall strategy for the electrical and related energy sectors. The next generation of nuclear plant for electrical power generation is available. However, there will be a need to address the future both for fission and, in the longer term, fusion. The engineering knowledge base should be retained and developed to allow the UK to have as a minimum an informed customer base and, beyond this, skills to operate, regulate and, indeed, participate in future international collaborations of research and development.

(3) *The role that engineers will play in shaping the UK's nuclear future and whether nuclear power proves to be economically viable*

3.1 Whilst the size of the nuclear component of the UK's electricity generating mix is open for debate, the Government has already indicated nuclear energy has a key role in sustaining security of supply of low carbon electricity at affordable cost. And evidence suggests that nuclear power is economically viable—nuclear power is comparable in cost with fossil fuel generation and generates electricity at roughly half of the cost of wind turbines.[31]

3.2 There is mounting evidence that declining global oil and gas production, coupled with increasing global demands and the inevitable impact this will have on cost, will mean that the success of the UK economy and our standard of living will become increasingly dependent on secure electricity generation. The requirement for the UK to have secure electricity supplies, at affordable cost, will inevitably mean that the UK will become increasingly reliant on nuclear generated electricity.

3.3 Increased global use of nuclear power means that the pressures to increase uranium utilization will lead to the use of the "Generation IV" nuclear reactors. This will require nuclear fuel recycling. The UK will need to maintain its capability in this area and should be participating fully in international R&D efforts in this area. This will enable UK engineers to inform policy options and to develop a skills base in this area.

3.4 The financial viability of nuclear power, or any other part of the power sector, depends to a great extent on the availability of skilled engineers and technicians to ensure plants are regulated, built and commissioned to time and cost, and run safely, reliably and efficiently. Hence, ensuring that there is an indigenous supply of trained nuclear engineers will help to ensure that nuclear power in the UK is economically viable and matches modern global norms.

(4) *The overlap between nuclear engineers in the power sector and the military*

4.1 In the early days of the UKAEA there was an element of flow of talented personnel between the civil and military sectors, especially Aldermaston, Harwell and Winrith being geographically close. However, the civil and military programmes have diverged since the 1960s and for a long time they have effectively been different industries.

4.2 Historically, there was some interchange between the Central Electricity Generating Board/British Energy/Magnox employment and the MoD's nuclear propulsion programme. Similarly, Royal Navy engineers and technicians experienced in nuclear submarine plant acquisition, construction, operation and maintenance have been attracted into the civil nuclear power programme particularly in time of expansion of the latter.

4.3 The potential for two way flow is greater within the nuclear propulsion/nuclear power fields. Historically, there was some interchange between the Central Electricity Generating Board/British Energy/Magnox employment and the MoD's nuclear propulsion programme. Similarly Royal Navy engineers and technicians experienced in nuclear submarine plant acquisition, construction, operation and maintenance have been attracted into the civil nuclear power programme particularly in time of expansion of the latter. In this regard, it should be remembered that the nuclear submarine programme continues to represent the largest body of UK experience with with Pressurised Water reactors (PWRs) the type of reactor most likely to be built in the UK.

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[31] See pages 8 and 9 of The Royal Academy of Engineering report, "The Costs of Generating Electricity": http://www.raeng.org.uk/news/publications/list/reports/Cost_of_Generating_Electricity.pdf

4.4 Today there is untapped synergy between the civil and military missions. As the UK seeks to embark on a post-Trident era, and to maintain its capability in the years running up to this, there is much it could learn from practice in the civil sector in efficient 21st century project management, systems engineering and manufacturing in a contained environment. There are also significant synergies in the area of radioactive waste management and residue processing and recovery.

4.5 The basic engineering requirements in both of these industries are the same and there would be obvious benefits in having a national education and skills programme that supported both industries. There is a need to ensure that the necessary engineering skills for both sectors are available. The further development of university undergraduate and post graduate courses in both core and specialist engineering and science should be encouraged, as it will provide a pool of graduates who are able to choose which part of the industry they wish to develop their careers.

March 2008

Memorandum 98

Submission from Research Councils UK (RCUK)

Executive Summary

The Research Councils work together in energy through the Energy Programme, which brings together all facets of energy research and training across the Councils in a comprehensive, multi-disciplinary programme which includes nuclear power and fusion.

Through the Energy Programme the Councils have actively encouraged and invested in research and trained people in nuclear engineering and related disciplines in order to help keep the nuclear power option open. This followed the Government policy set out in the 2003 Government Energy White Paper. Funding for fission related research and training has increased and begun to reverse the downward trend in university based fission related research and training over the past 10–15 years. The Councils also provide support for the UK Fusion Programme.

Research Council funded activities underway in nuclear engineering include consortia in "Keeping the Nuclear Option Open" and "Sustainability Aspects of Nuclear Power". Two training centres have been supported—an Engineering Doctorate Centre and a Masters level and continuing professional development training centre. Other research capacity building projects have also been supported.

EPSRC, the Ministry of Defence, the Atomic Weapons Establishment, British Nuclear Fuels plc (now Nexia Solutions) and British Energy plc work together under a formal agreement in areas of common interest in research and training to sustain critical nuclear related capabilities. Future developments are discussed and areas highlighted for Research Council activity, addressing stakeholder need. The Health and Safety Executive and the Nuclear Decommissioning Authority are expected to formally sign soon. As a result of this activity proposals are currently being considered for a consortium in nuclear waste management and decommissioning, and the Engineering Doctorate training Centre has been established.

In addition to their actively encouraged activities the Councils support some projects through their responsive mode schemes. In particular the Councils fund a wide range of fundamental research and training which may eventually have longer term applications in nuclear engineering.

Current grants of relevance to nuclear engineering (including fusion) led by EPSRC total £72 million.

Introduction

1. Research Councils UK is a strategic partnership set up to champion the research supported by the seven UK Research Councils. RCUK was established in 2002 to enable the Councils to work together more effectively to enhance the overall impact and effectiveness of their research, training and innovation activities, contributing to the delivery of the Government's objectives for science and innovation. Further details are available at www.rcuk.ac.uk.

2. This evidence is submitted by RCUK on behalf of all Research Councils and represents their independent views. It does not include or necessarily reflect the views of the Science and Innovation Group in the Department for Innovation, Universities and Skills. The submission is made on behalf of the following Councils:

Biotechnology and Biological Sciences Research Council (BBSRC)

Engineering and Physical Sciences Research Council (EPSRC)—Annex A

Economic and Social Research Council (ESRC)

Natural Environment Research Council (NERC)

Science and Technology Facilities Council (STFC)

3. All Research Councils have contributed to the main text of this response; some Councils have provided additional specific information about their research in separate Annexes, as detailed above.

4. In this response nuclear engineering is taken to cover the branch of engineering concerned with the design and construction and operation of nuclear reactors. Fusion is included in this response.

RCUK Overview

5. The Research Councils recognise the importance of conducting technology-based research in the context of a thorough understanding of markets, consumer demand, environmental impacts and public acceptability. Within this context, cross-Council initiatives, in collaboration with stakeholders, play a crucial role. NERC, EPSRC and ESRC received additional funding in the 2002 Spending Review to launch the "Towards a Sustainable Energy Economy" Programme. This Programme was designed to adopt a multidisciplinary, whole systems approach to energy research, including nuclear power.

6. In April 2005 the Research Councils established a new Energy Programme, led by EPSRC, in partnership with BBSRC, ESRC, NERC and STFC. The Energy Programme brings together all facets of energy research and training across the Research Councils in a comprehensive, multi-disciplinary programme which includes nuclear power and fusion. The total investment in energy research has increased to approximately £90 million per annum by 2007–08. Much of the increased expenditure was in the engineering and technology research areas supported by EPSRC, but also encompassed the range of energy research issues including social, economic, environmental and biological contributions that were developed in conjunction with other Research Councils.

7. The Energy Programme will be investing a further £334 million over the CSR period (2008–11) in:

— Work to realise the potential of Energy Technologies Institute (ETI) for a step-change in energy research, development & demonstration in the UK and internationally.

— Ensuring the Research Councils' Energy Programme plays a key part of the UK energy innovation landscape. The aims are to support a full spectrum of energy research meeting the government's long term policy goals, to work in partnership to meet the research and postgraduate training needs of business, to develop research capacity, and to increase the level and impact of international collaboration.

— Increase support for research in demand-reduction and transport, whilst maintaining research in power generation.

— Support for the fusion programme at Culham, using the internationally leading facility, Joint European Torus (JET).

8. As detailed above the Energy Programme is intended to support a full spectrum of energy research, and so activities in nuclear power have been actively encouraged: further details on these activities are given below. The Councils work closely with the Technology Strategy Board, ETI and other stakeholders. In addition to support through the Energy Programme the Councils support some projects through their responsive mode schemes. In particular the Councils fund a wide range of fundamental research and training which may eventually have longer term applications in nuclear engineering.

The UK's engineering capacity to build a new generation of nuclear power stations and carry out planned decommissioning of existing nuclear power stations

9. Through the Towards a Sustainable Energy Programme and the more recent Energy Programme the Councils have actively encouraged and invested in research and trained people that will help keep the nuclear option open. This followed the Government policy set out in the 2003 Government Energy White Paper. New commitments in fission related research and training have begun to reverse the downward trend in university based fission related research and training over the past 10–15 years. The Councils also support fusion research, based at Culham. Further details of these activities are given below.

10. Current grants of relevance to nuclear engineering (including fusion) led by EPSRC total £72 million. This has risen substantially recently due to the Councils taking on responsibility for the UK Fusion Programme and the new activities detailed below designed to maintain nuclear energy as an option.

11. EPSRC has taken the lead in enabling the establishment of the £6 million "Keeping the Nuclear Option Open" (KNOO) initiative, scoped in collaboration with Government and industry stakeholders. The KNOO consortium, led by Imperial College and involving six other universities, commenced work in October 2005 and is due to run for four years. KNOO is addressing issues such as fuel cycles and fuel management, future reactor systems including Gen IV technologies, waste management, storage and decommissioning and extending existing plant lifetime through materials science and technology. BNFL made an additional input of £0.5 million. Other key stakeholders include AWE, BNFL, British Energy, Defra, the Environment Agency, the Health and Safety Executive, DTI, Mitsui Babcock, MoD, Nirex, NNC, Rolls-Royce PLC, and UKAEA.

12. A Letter of Arrangement (LoA) has been agreed between EPSRC, the Ministry of Defence, the Atomic Weapons Establishment, British Nuclear Fuels plc (now Nexia Solutions) and British Energy PLC. Partners in this group work together in areas of common interest and collaborative working in research and training to sustain critical nuclear related capabilities. The partners meet regularly through the LoA Advisory Board which also includes members from the Health and Safety Executive and the Nuclear Decommissioning Authority who are expected to formally sign soon. At the meetings future developments are discussed and areas highlighted for Research Council activity, addressing stakeholder need. The first activity under this LoA was to establish a Nuclear Engineering Doctorate Centre (see paragraph 17).

13. The second activity under the LoA has been a call for multidisciplinary, multi-institutional consortia to carry out underpinning science and engineering to tackle existing and future nuclear waste management challenges. Sustainable nuclear waste management solutions are one of the corner stones of the industry, and are one of the key areas that the UK is focusing its research efforts. Whilst much effort has been made to encourage the strength of the UK research base it was felt that more could be done to foster new ideas and links across the various disciplines relevant to nuclear waste management and also to increase research capacity in nuclear waste management in the UK. Hence consortia bids were invited to target some key issues now facing the industry and solutions that could be appropriate for the future. Stakeholder involvement in these bids is mandatory. Proposals are currently under review and £4 million is available to fund the successful proposal(s).

14. On waste management, NERC's British Geological Survey (BGS) maintains expertise relevant to providing advice on the location of burial sites according to geological conditions. Also relevant to environmental considerations, NERC funds, jointly with the European Commission, the UKAS[32]-accredited radioecology labs at the Centre for Ecology and Hydrology (CEH) Lancaster. The Science Budget expenditure of approximately £200k (in 2007–08) supports the laboratory and underpinning science on the transfer of radionuclides to man and wildlife. As plans are considered for a new generation of nuclear reactors, NERC's capability in climate change prediction, in particular its impact on sea levels, could help to inform decisions regarding the sites of new plants.

15. There is synergy between nuclear engineering and fusion research in specific areas. EPSRC provides support for the UK Fusion Programme, the Joint European Torus (JET) facility and the UK contribution to diagnostic systems for the international fusion programme centred around ITER based in Caderache, France. Fusion is the energy-releasing process that powers the sun and other stars. If it can be harnessed economically on earth it would be an essentially limitless source of safe, environmentally responsible energy. The most promising method uses strong magnetic fields in a "tokamak" configuration to allow a high temperature deuterium-tritium plasma to be generated while minimising contact with the surrounding material surfaces. In the UK Fusion Programme a strong theory and modelling group supports the experimental programmes and contributes to the research and development of fusion materials (which have similar issues to materials in the nuclear industry) and to studies of conceptual fusion power stations (which have relevance to nuclear power plants). Remote handling technology and decommissioning are also relevant to both nuclear engineering and fusion. The skills and expertise of the scientists and engineers working on fusion may also have relevance to nuclear engineering. Support in this activity has recently been reviewed and for the next phase the Programme will receive £47 million over two years from 1 April 2008.

16. In the longer-term STFC is seeking to investigate the possibility of building HiPER, a high-power laser designed to demonstrate practical energy generation from nuclear fusion via the advent of a revolutionary laser driven technique known as fast ignition. The UK is leading on this long-term European science project and STFC is pursuing the opportunity for the facility to be built in the UK.

17. In addition to this targeted support, focused on the nuclear energy option and including research capacity building the Councils support a very wide range of fundamental research which could have longer term applications in nuclear engineering. Examples include plasma physics, radiation chemistry, and structural materials. Some projects are also supported through the responsive mode schemes of the Councils.

18. The Research Councils believe that this increased support for fission together with fusion programmes such as ITER and future science projects such as HiPER have the potential to attract many young people into a career in nuclear engineering.

The value in training a new generation of nuclear engineers versus bringing expertise in from elsewhere

19. Similar to activities in the research area (which also increase the capacity of trained manpower) the Councils have actively encouraged and supported training and research capacity activities in nuclear energy to ensure that they were providing trained manpower to keep the nuclear option open and help ensure security of supply. Consultation with the nuclear industry and key Government stakeholders demonstrated that provision of postgraduate nuclear skills training is a critical issue.

20. The first activity taken forward under the Letter of Arrangement was the establishment of an Engineering Doctorate Centre in nuclear engineering. The Engineering Doctorate is a four year, industrially relevant doctoral training programme which offers a radical alternative to the PhD, geared to training

[32] http://www.ukas.com/

research managers of the future. The Nuclear Engineering Centre is a partnership between the University of Manchester and Imperial College London with participation from four additional universities. Ten students are recruited each year, with this Centre taking students from October 2006.

21. The Nuclear Technology Education Consortium (NTEC), a collaborative training account to provide masters level and continuing professional development training in nuclear energy related skills has been funded with £1 million from EPSRC and £1.6 million from various stakeholders such as Government bodies (NDA, MoD, Cogent), regulators (HSE/NII) and leading industrial employers (BNFL (including Nexia Solutions, Energy Unit, British Nuclear Group), UKAEA, AWE, Rolls-Royce Naval Marine, Serco, British Energy, Nirex, NIS, NNC, NPL, Mitsui Babcock, Atkins Nuclear, INucE and BNES). NTEC includes eleven universities and will cover decommissioning and clean-up, reactor technology and fuel cycles, environment and safety, policy and regulation, project management, fusion and medical use.

22. Other capacity building activities have included the support, in partnership with industrial sponsors, of new research Chairs at the University of Manchester in decommissioning engineering and radiation chemistry. A Science and Innovation Award to the University of Strathclyde has included support to enhance their academic capacity in nuclear engineering.

23. Current support for students and research assistants has risen with the above initiatives both through training awards and research projects. There are currently 59 studentships and 80 research assistant posts supported under research projects relevant to nuclear engineering, over and above the support at the training centres detailed above.

24. Although STFC does not directly support training of nuclear engineers STFC does support fundamental research which underpins the skills required for nuclear engineering. At present STFC supports nine UK institutions with active programmes in experimental nuclear physics and two in theoretical nuclear physics—the fundamental study of how the nucleus of an atom works. This academic expertise in the underlying physics of the nucleus is needed in order to provide training on undergraduate and graduate courses in the applications of nuclear physics—including nuclear engineering, reactor physics, radiation protection, radiation detection and nuclear medicine. Training in these areas will be a vital element of any future nuclear industry. STFC invests around £8m per annum on nuclear physics research and supports approximately 20 PhD studentships in nuclear physics per annum.

The role that engineers will play in shaping the UK's nuclear future and whether nuclear power proves to be economical viable

25. The Councils support an amount of research that considers the economic viability of nuclear power and its relationship to other potential power sources and demand reduction options. The UK Energy Research Centre (UKERC), supported under Towards a Sustainable Energy Economy, provides a holistic focus for energy research in the UK and for collaborative international energy research. UKERC's research is organised around six themes that address clearly defined problems and areas within the energy sector, and nuclear power appears within these as appropriate. Three themes reflect the structure of energy markets: demand reduction, future sources of energy, and energy infrastructure and supply. The three remaining themes are cross-cutting: energy systems and modelling, environmental sustainability, and materials for advanced energy systems. Other activities include research road-mapping activity to inform funding decisions, technology and policy assessment, an interdisciplinary doctoral training programme, and a research portal which maps out the UK energy research landscape.

26. A consortium (Sustainability Assessment of Nuclear Power) led by the University of Manchester carries out research targeted at the societal aspects of nuclear energy. The overall aim of the project is to develop an integrated decision-support framework for assessing the sustainability of nuclear power taking into account relevant technical, economic, environmental, social and governance-related criteria as well as the associated uncertainties. The decision-support framework will enable sustainability comparisons of nuclear power relative to other energy options (fossil fuels and renewables), considering both energy supply and demand. The project began in September 2007, involving four universities with a grant of £2.1 million. The consortium has close links with KNOO.

27. The Sussex Energy Group, supported under Towards a Sustainable Energy Economy, is considering the governance of nuclear power. Their research compares nuclear power and other investment options. They are surveying relevant actors in the area, such as financial institutions, industry sources and environmental organisations. A significant element of their work involves an international comparison of economic and institutional contexts in the UK with another country that has made a clear decision to build a new reactor.

The overlap between nuclear engineers in the power sector and the military

28. We consider it more appropriate for companies and the military sector to provide input on this point.

29. Partners under the Letter of Arrangement include the Ministry of Defence and the Atomic Weapons Establishment.

30. There is currently one project relevant to nuclear engineering supported under the joint Research Council and Ministry of Defence Joint Grants Scheme.

March 2008

Annex A

All relevant current projects led by EPSRC in nuclear engineering (including fusion)

Grant Number	*Title*	*Principal Investigator*	*Value (£)*
EP/C013360/1	An exploration of transuranic electronic structure through actinyl coordination to polyoxometalates	Winpenny, Professor RE	269,282.59
EP/C543300/1	An exploration of transuranic electronic structure through actinyl coordination to polyoxometalates	Kaltsoyannis, Professor N	101,400.07
EP/F011008/1	Caesium Mobility and Phase Separation Processes in Borosilicate Glasses	Farnan, Dr I	35,429.89
EP/F013922/1	Chair in Decommissioning Engineering	Kelly, Professor TB	275,577.07
EP/F013809/1	Chair in Radiation Chemistry	Pimblott, Professor SM	270,054.45
EP/F028121/1	Innovative Accelerator Technology for Accelerator Driven Subcritical Reactors	Barlow, Professor RJ	142,340.56
EP/E017266/1	In-Situ TEM Studies of Ion-Irradiated Materials	Donnelly, Professor SE	642,771.76
EP/D002133/1	Integrated Energy Initiative: Innovative Power Networks, Demand/Supply side Integration and Nuclear Engineering	McDonald, Professor J	2,742,414.70
EP/C549465/1	Keeping the Nuclear Option Open	Grimes, Professor RW	6,114,714.76
EP/F012047/1	Multiscale modelling and experimental investigation of radiation effects in oxides and heavy metals	Smith, Professor R	53,512.86
EP/E043151/1	Selection and Optimization of Radiation Detector Materials	Grimes, Professor RW	96,370.67
EP/F001444/1	Sustainability Assessment of Nuclear Power: An Integrated Approach (SPRIng)	Azapagic, Professor A	2,123,000.01
EP/C540603/1	Understanding the physics of the disordered state: universality of phenomena in glasses and resistance to amorphization by radiation damage	Trachenko, Dr K	231,092.56
EP/E036384/1	Zirconium alloys for high burn-up fuel in current and advanced light water-cooled reactors	Grovenor, Professor C	626,741.98
EP/E036481/1	Zirconium alloys for high burn-up fuel in current and advanced light water-cooled reactors	Edwards, Professor L	267,814.94
EP/E036171/1	Zirconium alloys for high burn-up fuel in current and advanced light water-cooled reactors	Preuss, Dr M	670,819.34
EP/D062837/1	A New UK Fusion Plasma Physics Programme at Warwick University	Chapman, Professor S	5,056,202.32
EP/C008359/1	Coupled multi-scale modelling of magnetic reconnection	Arber, Dr TD	86,277.84
EP/C510828/1	Development of Reduced Activation Ferritic Steels for Fusion Applications	Faulkner, Professor RG	277,216.82
EP/D079578/1	Investigating energy transport and equilibration under non-equilibrium conditions	Duffy, Dr DM	189,647.04
EP/F004451/1	Ion irradiations of fusion reactor materials	Jenkins, Dr M	48,791.70
GR/S81186/01	Predictive Modelling of Mechanical Properties of Materials for Fusion Power Plants	Ackland, Professor GJ	95,231.81
GR/S81179/01	Predictive Modelling of Mechanical Properties of Materials for Fusion Power Plants	Finnis, Professor MW	165,916.98
GR/S81193/01	Predictive Modelling of Mechanical Properties of Materials for Fusion Power Plants	Bhadeshia, Professor H	103,747.36
GR/S81162/01	Predictive Modelling of Mechanical Properties of Materials for Fusion Power Plants	Bacon, Professor DJ	322,795.16
GR/S81155/01	Predictive Modelling of Mechanical Properties of Materials for Fusion Power Plants	Roberts, Professor SG	482,628.79
EP/E035671/1	Putting next generation fusion materials on the fast track	Duffy, Dr DM	117,780.56
EP/E035868/1	Putting next generation fusion materials on the fast track	Wilson, Professor JIB	743,777.82
EP/D065399/1	Theory of Explosive Plasma Instabilities	Wilson, Professor H	657,560.50

Grant Number	*Title*	*Principal Investigator*	*Value (£)*
EP/D059836/1	Travel to collaborate on experiments and analysis of data for the JET and MAST fusion devices	Hender, Dr T	9,661.85
EP/E034438/1	UK Fusion Programme	Llewellyn-Smith, Professor Sir C	46,433,000.00
EP/D06337X/1	Queen's University Belfast Plasma Physics	Graham, Professor WG	2,520,872.55
EP/F031629/1	Theory and simulation of dust transport in Tokamaks	Coppins, Dr M	378,080.47

Memorandum 99

Submission from the Institution of Engineering and Technology (IET)

This document is submitted by the IET in response to the inquiry announced by the Innovation, Universities and Skills Committee on 29 January 2008.

The IET welcomes this opportunity to provide evidence to the Committee and would be pleased to provide further elaboration and clarification if required.

Executive Summary

1. Skills and supply chain issues will be key factors determining whether a new fleet of nuclear power stations can be built to time and budget in the UK.

2. The nuclear industry specifically and the power industry generally has a rapidly ageing skills profile in most developed countries. The situation is worse for nuclear than other segments of the industry because nuclear has been seen as a sunset industry for many years.

3. All types of engineering, construction and project management skills will be in short supply because the expansion of nuclear stations in the UK coincides with:

- the decommissioning of previous generations of reactors;
- life extension of existing UK nuclear;
- the expansion of renewable energy technologies;
- construction of further gas and coal fired power plant;
- the renovation of the power supply and distribution infrastructure;
- upgrade of the rail, water and sewerage infrastructures; and
- an actual global boom in infrastructure and a probable global boom in new nuclear.

4. The most urgent need is for engineers able to contribute to the development and appraisal of the safety justification for new-build reactors, environmental impact statements and similar work. These will be needed from now with a peak around 2013–15 when the major work on the detailed safety cases will be undertaken.

5. Even though it is inevitable that nuclear stations will be made and largely designed abroad, it is vital that the UK has the skills required to act as an intelligent customer. Highly skilled UK nuclear engineers will be required particularly for safety engineering and interface with the Regulator.

6. The IET welcomes the formation of the National Skills Academy for Nuclear and is pleased to see the cooperation between the Power Sector Skills Steering Group (P3SG) to ensure a standard approach towards the provision of a possible Power National Skills Academy. This cooperation has already highlighted the problem of different sectors effectively counting on the same "pool" of possible entrants to the engineering profession.

IET Evidence

The UK's engineering capacity

7. In the 1970s, when much of the existing power generation infrastructure was built, there were at least half a dozen major industrial groups in Britain involved in power engineering—GEC, Reyrolle Parsons, Ferranti, Westinghouse, AEI, Metropolitan Vickers, and more. The industry was also supported by major national labs, such as those operated by the CEGB.

8. The current situation is that no British company is capable on its own of supplying and building a major power station, using nuclear or indeed any other technology. This is the result of a combination of factors including the long hiatus in new-build, "the dash for gas", privatisation, international mergers and a more aggressive opening of markets than in our industrial competitors.

9. The loss of manufacturing, research, development and deployment skills has further contributed to the steady decline in interest in engineering in general. The facilities and teaching staff are not easily replaced.

10. The numbers of pupils studying science, technology engineering and mathematics (STEM) subjects is beginning to increase but those opting to go into engineering are still much too low. Thus the pressing need is to get good people into engineering and science and train them well. Specific focus on nuclear engineering is probably less important provided the industry momentum is there to encourage well trained graduate engineers and scientist to join UK based companies involved in nuclear engineering.

11. It will be 10–15 years minimum before pupils attracted to study engineering subjects now develop into the experienced specialists capable of contributing at a significant level to nuclear licensing or safety work.

The value in training a new generation of nuclear engineers

12. Because of the inter-disciplinary nature of the nuclear industry, we believe it will be useful first to explain the term “nuclear engineer”. We recognise four broad categories:

(a) engineers who understand the fundamental physics and design of nuclear reactor and system technology. These are the specialist engineers required for licensing of new designs. Although the numbers required are relatively small the need for these is urgent. The Nuclear Installations Inspectorate (NII) is recruiting now;

(b) those qualified in a range of engineering disciplines (eg electrical, control, mechanical or civil) but who need in addition to have the specialist knowledge together with post graduate training on the job to equip them to work to the very exacting and particular safety and regulatory standards required in the nuclear field;

(c) a still larger number who can support project engineering, design adaptation, subsystem procurement, construction, commissioning, operations and maintenance activities, rather than the fundamental physics or design of nuclear plant. The need is for all-round electrical/mechanical engineers with a good background understanding of nuclear processes, rather than specialists in a particular field; and

(d) a large number of engineers who are generalists but work on nuclear for part of their career, eg by designing the cooling water system for a nuclear power station.

Skills shortages

13. During 2007, members of the IET involved in the HE sector have held meetings with senior personnel from power station operators, manufacturers of nuclear plant, companies involved in decommissioning and national regulatory bodies to identify the education and training needs for professional staff in the nuclear industry. These contacts have given a consistent message regarding the needs of UK industry: All nuclear operators and associated organisations report shortages in suitably qualified staff.

14. An authoritative study of Nuclear and Radiological Skills by the DTI in 2002,[33] reported that the power, fuel, defence and clean-up sub-sectors of the nuclear industry would require approximately 1,000 graduates a year for the next 15 years, ie until 2017. Of these, about 700 would be replacements for retirements and 300 in response to the growth in nuclear clean-up. In 2001, the year preceding the report, these sub-sectors were estimated as recruiting about 560 graduates a year.

15. However in that year HSE-NII studies on the state of nuclear education in British Universities[34] showed that there was not one university undergraduate course with any significant nuclear content to it. At the post graduate level (PgD, PgC and MSc) there were only about 160 students a year graduating from courses with > 5% nuclear content. From courses with 100% nuclear content the number was 82 a year.

16. These reports are now five years old but evidence shows that the demand for professional staff continues to grow—and will grow further if nuclear new-build goes ahead as expected. Although Manchester and Lancaster Universities, in particular, have recently made a step change in the provision of nuclear engineering and decommissioning courses, the higher education output is still well below the needs of industry.

17. The last time the UK nuclear industry recruited large numbers of engineers was in the 1960s and 70s when the current generation of power stations was being built. The age profile reflects this history and, even if there is no new build, the industry and its regulatory authority face recruitment problems to maintain existing facilities and commitments.

Skills requirements for new build

18. The staffing needs for new build are for engineers who can support project engineering, design adaptation, subsystem procurement, construction, commissioning, operations and maintenance activities, rather than the fundamental physics or design of nuclear plant. The need is for all-round electrical/mechanical engineers with a good background understanding of nuclear processes, rather than specialists in a particular field.

[33] Nuclear and Radiological Skills Study (DTI December 2002).

[34] Nuclear Education and Research in British Universities, HSE-NII, Oct 2000 and Nuclear Education in British Universities, HSE-NII, February 2002.

Skills requirements for decommissioning

19. The decommissioning of existing plant and construction of new stations will require substantial numbers of professional staff with expertise in safety engineering and risk assessment in the contracting companies as well as additional resources in the regulatory body. Increasingly, safety regulation and the associated public involvement in risk acceptance and decision-making is seen as a crucial aspect of any programme of new build. The skills shortage at this level is both significant and near term and poses a threat to timely deployment of new build.

20. Decommissioning nuclear facilities requires innovative engineers who can design special purpose equipment for particular tasks as well as adopt industry best-practice for recurring activities. Because of the nature of the risks associated with the industry, it is important that engineers working in this field have a broad view of nuclear physics and chemistry and the safety issues involved in working with the residues of nuclear processes.

Technician skills

21. In addition to engineering level skills there will be a large requirement and skilled technicians during operation. These are likely to emerge through the National Skills Academy (NSA) for Nuclear. The NSA is providing a defined route for both academic qualifications and industry "passports". It has brought industry stakeholders together to ensure a consistent training achievement is achieved via a "Hub-and-Spoke" model with regional universities providing the same qualification and training levels.

22. The IET welcomes the formation of the National Skills Academy for Nuclear and is pleased to see the cooperation between the Power Sector Skills Steering Group (P3SG) to ensure a standard approach towards the provision of a possible Power National Skills Academy. This cooperation has already highlighted the problem of different sectors effectively counting on the same "pool" of possible entrants to the engineering profession.

23. The need for fabrication skills during construction is an industry-wide problem that is particularly acute for nuclear with its onerous certification requirements.

Impact of the UK Safety and regulatory framework

24. Because of the risk-based UK legislative structure introduced by the 1972 H&SW Act and subsequent regulations and guidance, safety regulation of the nuclear industry is more stringent than in most other industries. The regulatory procedures are different to those in mainland Europe or in the USA where a more deterministic safety approval process operates.

25. The Committee may wish to consider whether the prescriptive approach by the Nuclear Installations Inspectorate, which stipulates changes to manufacturers' standard designs for application in the UK, is likely to cause suppliers to focus on markets other than the UK in a world of considerable supplier power. It would also increase nervousness amongst investors. Lack of sufficient engineering appraisal capability within NII could lead to this outcome which would arguably be perceived by them as prudent. This would potentially affect not only the time to license designs but also whether plant will get built in the UK at all.

Not all skills can be imported—the UK needs to be an "informed customer

26. Whilst reactors, turbines or alternators of future UK stations will use imported equipment, largely designed overseas, there are many other engineering tasks that cannot be outsourced: site specific engineering, such as cooling systems, substations, auxiliary power systems and the design of pipework and structures will have to be undertaken by people who at least make regular visits to site and are in regular communication with local subcontractors, planning authorities and other bodies.

27. Probably the area where most local knowledge is necessary is in safety engineering and the interface with the regulator. Continuity and confidence in relationships at this interface is an important factor. Also, relationships extend beyond the construction period through the operating life and the decommissioning phase of an installation. It is an important strategic precaution to ensure that access is secured for the long term to detailed knowledge and understanding of nuclear plant design and the rationale behind what was done.

28. The extent to which a plant promoter is or is not an "informed customer" in respect of nuclear power plant operation is likely to be important for safety regulation.

29. Whether the operator is also the owner of the assets or whether the plant is leased from a financial institution will affect the industry structure as will the decision on whether maintenance is handled by the operator or bought-in from the suppliers. The situation is made more complicated by the number of different Government agencies involved in power station construction and operation (the economic regulator, safety regulator, environmental regulator and planning authorities) and by the ownership structure of the nuclear sites—a situation closely parallel the rail industry.

30. Migrating from a monolithic public-sector organisation to a complicated and disaggregated private-sector is likely to lead to complexity in the contract and regulatory structure for a nuclear new build. Given the risk profile of the nuclear industry and the greater public concern, it is inevitable that obtaining safety and planning approvals will be a major workload. It is inconceivable that this could be managed effectively by staff from an overseas contractor with no experience of the unique British safety legislation.

The role that engineers will play in shaping the UK's nuclear future and whether nuclear power proves to be economically viable

31. The power engineering industry is entering a challenging era—particularly if the mandatory renewables target is to be met. In place of a centrally-managed network using a limited range of large generators there will be a wide range of different types of renewable generation (wind, waves, tidal power, photo-voltaic and biomass) as well as a diversity of major generating plant and micro-generation. To date, most of the public debate has been around the financial models that might be used to integrate the industry—but the technical issues are probably more challenging.

32. Without engineers, new power stations will not be built. Even though the core technology for new nuclear will be imported as finished designs from international manufacturers, a vast engineering effort will be needed to apply the core technology to form a working power station. Much of this will need to be led from and preferably delivered from the UK.

33. Engineers will be needed in the following areas:

(a) nuclear technology licensing—an urgent need as the core designs are being assessed by the NII now;

(b) power system planning—an urgent requirement due to the complexity of modelling the impact of new nuclear plant on the overall transmission grid;

(c) design review and assessment—high level nuclear, civil, mechanical, electrical and control/instrument engineering skills to allow proper technology selection;

(d) civil and structural engineering—very large inputs on site specific issues of foundation design, seismics, coastal protection, marine engineering, nuclear buildings;

(e) integration engineering—design integration for the complete power plant;

(f) project and programme management;

(g) cost engineering; and

(h) construction management.

34. Most of these skills are not specific to nuclear, but imply a significant requirement for already scarce engineering skills.

35. The connection of new nuclear power stations to the Grid is a key engineering challenge. Whilst it is pragmatic to consider building new nuclear stations on existing sites, not all of these have adequate infrastructure for new generation nuclear plant. Those scheduled for closure first are the Magnox stations which are modest in size and typically only have 132kV grid connections. New build would require 400kV connections. This will require power system planning, overhead line design, substation design and construction management skills, mainly by specialist electrical and civil engineers who are currently very scarce.

36. New nuclear also creates an opportunity for the gradual re-development of UK industrial skills over time. This is likely to require engineering skills in specialist mechanical design, mechanical handling, robotics, precision and specialist manufacture. These skills are also needed extensively for the decommissioning programme.

Timescale

37. Our best forecast for the construction of a new fleet of nuclear power stations is that the nuclear regulatory authorities will evaluate generic reactor designs (already submitted) between now and 2011. In parallel the NDA has signalled its intent to sell existing nuclear facilities that are likely to provide sites for new power plants. It is not known how long this process will take but it is unlikely to be complete before 2010.

38. It therefore seems likely that, starting around 2010, there will be a commercial negotiation involving potential generators, potential reactor suppliers and site owners. Inevitably the government will be involved as the price of carbon, operation of the electricity trading arrangements and similar issues will be important to all parties. Following this will be the design phase, in parallel with planning enquiries, environmental impact assessments, preparation of the safety case and similar activities, and work on site will start around 2015, leading to the start of commissioning of the first station in 2020. (It is possible this could be accelerated to meet the Government's stated position of power by 2017–18, and desirable to maintain pressure to deliver this, but we foresee the schedule slipping.)

39. This implies that the most urgent need is for engineers able to contribute to the development and appraisal of the safety justification for new-build reactors, the preparation of environmental impact statements and similar work. These will be needed from now with a peak around 2013–15 when the major work on the detailed safety cases will be undertaken.

40. The need for design engineers with knowledge of nuclear engineering for the detailed design phase will occur later and will peak from about 2010–20. Work on site will start around 2013–15, by which time project management teams will have to be in place.

The overlap between the power sector and the military

41. The military sector has two main applications of nuclear technology—propulsion of submarines and large warships and the nuclear deterrent.

42. In the public mind these are often confused with nuclear power generation—not least because facilities like Sellafield were originally developed to extract weapons grade material for the military as a by-product of power generation. Governments, over the years, have been ambiguous of the linkages between the two industries.

43. Plans for a new generation of nuclear power stations are likely to move the two industries further apart and there will be greater demarcation between power generation and nuclear decommissioning on the one hand, and nuclear deterrent work on the other. Those working on nuclear deterrent design probably have more in common with those working in nuclear physics than power engineering. However those involved in the manufacturing process for the deterrent (as opposed to the design itself) do deploy skills that are directly transferable into civilian work.

44. There is a greater degree of commonality between engineers working on civilian nuclear power and those involved in propulsion systems for boats. There are fundamental differences, such as the degree of enrichment of the fuel and the radioactivity of the high-level waste, but many of the skills are the same. (As an example, Lancaster University runs postgraduate courses in safety engineering and decommissioning attended by engineers from both sectors.)

About the IET

45. The Institution of Engineering and Technology (The IET) is one of the world's leading professional bodies for the engineering and technology community. The IET has more than 150,000 members in 127 countries and has offices in Europe, North America and Asia-Pacific. The Institution provides a global knowledge network to facilitate the exchange of knowledge and to promote the positive role of science, engineering and technology in the world.

March 2008

Memorandum 100

Submission by Westinghouse Electric Company

1. *The UK's engineering capacity to build a new generation of nuclear power stations and carry out planned decommissioning of existing nuclear power stations*

The nuclear industry is facing a growing demand for skilled and semi-skilled labour, just at the time that many employees are set to retire. The demand comes from both the continuing need to address the challenges of cleaning up the nuclear waste legacy (including decommissioning of the UK's Magnox fleet) and from the skills requirements related to a prospective new generation of nuclear plants. This latter prospect was given a strong boost by the Government's January 2008 Nuclear White Paper, which concluded that such new nuclear plants would be in the public interest, although it is left to the private sector to fund and deliver them.

There are a number of strands to the "engineering capability" needed to ensure that a new generation of nuclear plants can be built and operated safely successfully. However—one area where significant numbers of skilled professionals is NOT required is that of reactor design. The global nuclear industry is moving towards the deployment of standard internationally-recognised designs, and the requirement in the UK that new nuclear build be funded in full by the private sector strengthens that driver still further. Four designs are currently going through a rigorous assessment of their safety and environmental acceptability, together with a careful review of security and other considerations. Each of these is a design developed for the global market, rather than a plant customised for the UK.

In terms of the engineering and technical skills to deliver a new nuclear build programme, these can be broadly split into three areas:

> Firstly, in the immediate near -term, there is a need for regulatory expertise to carry out the safety, environmental and other assessments of the candidate reactor designs. Already the number of designs which can be assessed on a realistic timescale has been limited to three by the scarcity of resource. The current list of four is to be scaled back over the coming weeks. Although the regulators have initiated an active campaign of recruitment, there remain significant concerns over whether enough of the right calibre of staff can be identified and brought on board quickly enough. We are pleased to see that Government have committed to keep this issue under review.
>
> Secondly, there is a need to ensure that the skills are in place within the UK supply chain and construction industry to deliver any new nuclear plants to time and cost. It is likely that—if new nuclear build does go ahead—the construction of the first plant would start around 2013. This timing means that construction workers from the 2012 London Olympics programme can be expected to be available for such a project, so with careful planning this should not be an issue. Likewise, this timing allows the UK supply chain to "gear up" ready to play a significant role in any new reactor construction.
>
> Finally, the question arises of operating staff to work at a new power station once it is ready to produce electricity. On the timescale noted above, operation would be likely to commence around 2018, which is ample time for the industry to identify and retrain individuals with relevant skills from the existing nuclear plants scheduled to have closed down by that date.

In short, therefore, the industry should be able to plan to resource the building and operation of new nuclear plants, provided that the licensing effort can be found to take the leading designs through the Generic Design Assessment process on time.

In addition, it should be noted that there are a number of recent initiatives, aimed at helping to ensure the availability of nuclear skills for both new build and legacy cleanup programmes. These include:

- The National Skills Academy for Nuclear, launched in January 2008. Westinghouse plays a key role in this development, with a seat on the Board, and the Chairmanship of the NW/NE Employer Steering Group.
- The Dalton Nuclear Institute at Manchester University, and the new Centre in Nuclear Energy Technology (CNET) based there. Westinghouse has close links with both the Dalton institute and CNET.
- The University of Central Lancashire's (UCLan's) John Tyndall Centre for Nuclear Research.
- The Lancaster University Chair in Nuclear Engineering and Decommissioning, launched recently in association with Lloyd's Register Educational Trust.

All of these are important initiatives, and are most welcome, but it is important that the momentum is maintained to replenish retiring workers from the nuclear industry (of whom there will be many over the coming few years) and to build up new and strengthened capabilities to address the two missions of new build and legacy cleanup. Continuing Government scrutiny and encouragement is likely to be needed to ensure that the necessary progress is maintained.

2. *The value in training a new generation of nuclear engineers versus bringing expertise in from elsewhere*

In addressing this point, it is important to recognise that the UK is not the only country contemplating a revival of nuclear energy. The.same issues are driving countries all around the world, from China to the US, from Finland to South Africa, to consider the benefits of new nuclear plants.

The UK therefore competes in a global market for skills—not just as a potential beneficiary of skilled workers moving into the UK, but as a potential source of such skills for other nations. We cannot assume either that we will be able to attract skilled nuclear engineers to the UK from overseas in great numbers, any more than we can expect to retain all of the engineers who are trained up in the UK.

That said, there are also reasons why it is important to have our own capability, trained within the UK to serve the UK market. Whilst it is clear that any new reactor built in the UK will be a standard global design, with an international pedigree, it is also clear that such designs must be shown to meet all relevant UK legislation in respect of nuclear safety, environmental performance, and so on. Such assessment—which Westinghouse and other vendors are already engaged in—requires both the detailed technical knowledge of the design (which can, at least to an extent, be brought in from overseas) coupled with the detailed understanding of UK practices and requirements, which is only likely to be found in this country.

The same principle applies when reactors have passed through design assessment and into construction, commissioning and operation.

3. *The role that engineers will play in shaping the UK's nuclear future and whether nuclear power proves to be economical viable*

Many of the points related to this question have been addressed earlier in this response. Without a much greater supply of nuclear technicians, scientists and engineers, at all levels, it will be very difficult for the UK to deliver the planned cleanup programmes and simultaneously to bring new nuclear build onto operation on schedule.

The economic viability of nuclear energy will be determined by a whole range of factors, but it is clear that the private sector will not wish to invest in an industry where the skillbase needed to build plants to timescale, and then to ensure safe and efficient operation of those facilities, cannot be assured with confidence over the plant's operating lifetime.

4. *The overlap between nuclear engineers in the power sector and the military*

We recognise that some of the basis skills and capabilities relating to nuclear energy are common to both the civil generation and military sectors (in particular in relation to nuclear propulsion units in Naval applications). Neither sector however has an overcapacity of skills which can be used to offset a shortage elsewhere.

Equally—whilst the basic technologies might be similar in many respects, and whilst skills such as safety assessment and reactor operation might be common, the operating environments are totally different and the different considerations to be balanced are not necessarily transferable with ease.

The operation of a civil power reactor in a commercial environment is vastly different from the operation of, for example, a nuclear powered submarine in a military situation. The transfer of skills between the two sectors must always be done with careful regard to the cultural issues and with appropriate re-training.

March 2008

Memorandum 101

Submission from Babcock International Group plc

Executive Summary

The UK commitment to a new generation of civil nuclear power plants and a parallel programme of decommissioning and site clean up will produce demand levels for qualified and experienced resource that significantly exceeds the existing national capacity. A coherent national training plan to deliver sufficient skills to support both streams of activity in the long term is essential to provide adequate confidence in the ability to deliver the strategically important outputs from the revitalised civil nuclear programme, in which engineers play a key part. There are clear overlaps between the power sector and the military nuclear programme elements and these overlaps are likely to increase if both programmes proceed as currently planned.

Context

1. Babcock International Group has two principal centres of nuclear engineering expertise and activity:

- BNS Nuclear Services, comprising the Alstec Nuclear and the INS businesses, supplying services and equipment across the complete life cycle of civil nuclear power generation and process plants.
- Babcock Marine, the MoD's strategic support partner for the nuclear-powered submarine force, which is a Nuclear Site Licensee and operator and has experience in the design, safety justification, build and commissioning of major nuclear infrastructure as well as facility decommissioning.

2. These two Divisions represent a total directly nuclear-related manpower resource of all types of more than 2,000 personnel.

3. In addition, its Frazer-Nash engineering consultancy business works in both the civilian and military nuclear sectors.

UK Engineering Capacity for New Build and Decommissioning of Civil Power Stations

4. The existing civil sector nuclear workforce will be required to support the construction, commissioning and operation of the new generation of overseas-designed plants as well as the decommissioning programme.

5. With the UK new build programme limited to Sizewell B in recent years and with the structural changes that have occurred with the privatisation and fragmentation of large parts of the UK nuclear sector, there are likely be shortages of qualified and experienced personnel in most disciplines. Safety analysis and justification is a particularly difficult aspect to resource, affecting the total programme and also spanning both the industrial and the independent regulatory domains.

6. The resource shortfalls and the training lead times mean that overseas sources of skills will be important for a considerable period, although the use of overseas contractors for programme management in areas such as decommissioning can represent a costly approach.

7. The use of a common, generically justified power station design would help to reduce demand levels for certain types of critical engineering and analysis resource. However, the decommissioning and clean up programme requires mostly project-specific solutions and these activities are therefore likely to be a major driver of demand for skills.

8. Skill shortages are already causing retention problems, cost escalation and programme disruption. It is also worth noting that the nature of the UK civil nuclear programme over the last two decades has led to a workforce that generally has a high average age.

Training versus Buying-in Skills

9. The range of industrial and professional skills required across the total civil programme is already considerable. The demand level will grow and the relevant skills are a long term requirement to support areas such as plant operation, outage management, revalidation and life extension as well as decommissioning of legacy sites.

10. The delivery of many of the required outputs, ranging from power generation through to decommissioned and remediated sites, represent significant national priorities for the UK. A proactive approach to generating the skills to deliver these outputs from within the UK is therefore a sensible strategic approach, given the need for confidence in the ability to deliver, cost effectively and within the required timescales.

11. The resurgence of international interest in nuclear power means that the arguments for a coherent, holistic national training programme to serve this sector are strengthened. Such an approach should increase certainty in cost-effective programme delivery and may in the longer term represent a source of high-added value export potential.

12. There is a need to debate the merits of adding post-graduate nuclear-specific training to, say, graduate engineers with traditional degrees versus the provision of degrees with sector-specific academic content. Babcock Marine has tended to favour the former approach in many instances.

Role of Engineers in Shaping the UK's Nuclear Future & its Viability

13. The viability of the UK's future nuclear industry will depend upon:

- a cost effective/timely planning and safety justification cycle for new civil power capacity;
- basing the new civil power programme on a proven, reliable plant design;
- competent management of the construction and commissioning projects at each site; and
- a demonstrated, correctly prioritised, commitment to address the legacy clean up challenge—cost effectively and safely, in parallel with the new build campaign.

14. Project managers, engineers of all types, technicians and scientists with the right skills to span the entire life cycle challenge (new build plus legacy) will be essential to ensure these requirements are met. The overall economic viability of nuclear power is, however, influenced by many factors, the role of nuclear engineers being only one aspect of this complex issue.

Civil Power Sector & Military Nuclear Skills Overlap

15. The civil sector has for 25 years largely been dominated by the operation, maintenance and re-justification of legacy plants, although decommissioning and remediation has latterly increased in importance. As previously indicated, the policies of successive Governments has radically changed the structure of this part of the industrial base, through privatisation and break up of the generating and reprocessing organisations.

16. For its part, the military sector has been more heavily involved in design and build in addition to O&M and re-justification of legacy designs and equipment, design and build examples being:

— PWR2 (the second generation naval nuclear reactor plant).

— A90 plant at AWE (the Trident warhead plant).

— Faslane/Coulport facilities associated with the Trident programme.

— D154 at Devonport, a major part of which generated the Trident submarine refit facilities.

17. The degree of overlap between the civil and military programmes in terms of their respective focus on common life cycle stage activity is now increasing, examples being:

— the civil power plant replacement programme;

— the potential new submarine reactor plant;

— NDA activity at Dounreay and Sellafield;

— environmental remediation at AWE; and

— submarine disposal.

18. The main areas of skills overlap are in areas such as safety case engineering and plant/system justification, process facility and plant design (mechanical, electrical, etc), civil structural design justification and environmental impact assessment. The nature of this overlap will change considerably as the civil programme accelerates and as the imbalance between engineering capacity and demand worsens. The civil programme represents a potential threat to the military programme in terms of its possible impact on skills availability and the cost of key engineering resources.

19. Babcock will be exploring the opportunity to use "reach back" in both directions between its civil and military activities to increase effectiveness and delivery capability o the benefit of both parts of the market sector.

March 2008

Memorandum 102

Submission from Rolls-Royce

Background

1. Since the late 1950's, Rolls-Royce has been involved in the UK submarine programme as the Design Authority and procurement agent for the nuclear propulsion plant. This began with a technology transfer from the USA, and over the last 50 years Rolls-Royce has had continuing responsibility for development of the reactor system.

2. Current plants in service show major improvements compared with early plant: the sailing distance without refuel has improved by several factors; safety and reliability has increased and plant is much quieter. These factors are all achieved in the challenging environment of an operational submarine subject to shock, extreme manoeuvring, tight space and weight constraints.

3. These improvements have been achieved by Rolls-Royce engineers working closely with the MoD. Rolls-Royce employs around 940 specialist engineers in support of this programme, covering a wide range of skills. The team also manages the support of around 250 full-time-equivalent engineers from partner companies providing managed services.

4. The age demographics of the engineering population is reasonably healthy and recent recruitment has brought down the mean age to about 40 years. A knowledge management process has been introduced to help manage the risk of loss of experience through retirement. Recruitment has been reasonably successful but is growing more difficult and made more so because of the required reliance on UK nationals.

5. Rolls-Royce also recruits engineers from the Royal Navy—ie retired operators. This provides a balance between design and operational skills. It means that there is always good feedback of operational issues into the design process and has contributed to the success of naval reactors.

6. Rolls-Royce is supported by a range of suppliers and technical experts. Our supply chain has required considerable support through low production periods but is now strong with sustainability a top priority. It is capable of tackling the full range of design, manufacture and operational issues.

7. The Company has been involved in manufacture of nuclear equipment since the outset of the military programme and this has necessarily grown through the above-mentioned infrastructure rebuilding. The capability includes manufacture of the reactor core, heavy pressure vessels, major valves and control rod drives. This has required the company to become a nuclear site licensee, bringing with it the experience of dealing with the civil nuclear regulator as well as the relationship with the naval counterpart associated with our military plant work.

8. The Company has managed and operated the land-based submarine reactor prototype site at Dounreay, known as Vulcan, since its inception in the late 1950s. This has seen the building of two prototype reactors and the testing of five core design developments as well as the site providing more general nuclear facilities such as large pump refurbishment and inspection capability.

9. The Company has designed, procured, manufactured and built more nuclear reactors than any other company in Western Europe except Areva. The safety record of these plants is exceptional with experience of over 400 plant-years of operation. Design and development continues with the aim of achieving even greater improvements in performance, reliability and safety.

10. For civil nuclear, we also have overseas units that contribute significantly to the industry. A French subsidiary supplies the Reactor Control and Instrumentation for many European reactors. A US subsidiary is involved in providing reactor management software that has played an important role in improving the availability of nuclear stations. We have also been involved with the global civil industry supplying pressure vessels and inspection services to Sizewell B and inspection, repair and sampling services internationally.

Could These Skills Be Applied To Civil Nuclear Development?

11. Skills are considered to be transferable between military propulsion and civil programmes. This is made all the more possible by civil new build adopting water reactor technology reactors similar to the most recent civil station—Sizewell B, with the Westinghouse AP 1000 and the Areva EPR as likely candidates.

12. New reactors built in the UK will be largely standardised but undoubtedly require local engineering skills to cope with site specific issues. These can include flood defence or environmental impact, implementing safety regulations, safety justification using techniques and design approaches that are recognised by the UK regulator, procurement of local components, management of the build process, maintenance of quality, staff training, operating procedures and ownership of the design after handover. A lesson from the current programme to build a large reactor (an EPR) in Finland is that it is vital to deploy experienced staff to reduce the risk of emergent design and quality issues.

13. The adaptability of the military resource to civil applications has encouraged Rolls-Royce to establish a Civil Nuclear business. A larger involvement in the broader industry will also have a spillover benefit to military capability through skill development and experience exchange.

14. Looking further into the future, there is likely to be considerable activity worldwide in the design of reactors with improved safety features and relevant features for new markets—eg grid appropriateness. This is an important opportunity for the UK and for a new engineering generation.

Does The UK Have The Engineering Capacity For New Civil Nuclear Build?

15. Although the nation is currently suffering from a lack of recent direct nuclear engineering education and training, this was also a problem when the nuclear industry first burgeoned in the 60s and 70s. The rapid deployment of nuclear reactors during that period required the fast generation of capable resource in the existing generation of engineers. We had more general engineers then and the task was less complex given the prevailing standards and regulatory requirements.

16. While the UK today is no longer involved in the design of commercial reactors, we do have substantial expertise but limited resource. It is our view that the required engineering capacity can be achieved to support new civil nuclear build, but this will not be easy, especially with the parallel challenge of the military programme. This will involve consideration of how to harness the experience of current resources to help develop the larger resource pool that will be required.

17. A major increase in education and training opportunities will be needed, particularly at first degree level where they are currently non-existent. Although post-graduate opportunities have increased in recent times, these need expansion and flexible implementation. Having a core resource that has nuclear engineering as its first subject will be essential because nuclear engineering involves the integration of a wide range of sciences and the understanding of complex bodies of standards and legislative requirements. Safety assessments involve a broad understanding of the implications of safety concerns. Priority will be needed to providing first degree nuclear engineering opportunities to establish a solid core of future resource.

18. It should also be recognised, however, that nuclear engineering is also about mechanical engineering, electrical engineering, materials engineering, physics and other generic skills. Recruitment from these pools must be addressed and availability of suitable specific discipline nuclear education "on-the-job" opportunities established. The recent nuclear engineering MSc courses, either full-time or part-time, will be suitable for some of these engineers but less intensive, more focussed opportunities are required.

What are the longer term National benefits of increasing Nuclear Engineering capability?

19. A rapid change in energy technologies is taking place but it is difficult to predict which technologies will emerge as winners. There is a significant probability that nuclear power will expand significantly over the next few years and the UK is well placed to benefit from this business.

20. A second benefit is that UK nuclear stations will be important strategically, and involve significant safety issues. It would therefore be inappropriate to rely entirely on foreign expertise. Furthermore, the aspiration for the next generation Propulsion Plant for the successor to the Vanguard class series, will require a long programme (15 years +) and this will be reliant on the engineering capability of UK nationals.

21. Given the likely international nuclear programme growth, it may not be possible to bring in engineering skills required for the civil programme from abroad. For example, the USA is likely to be a net importer of nuclear skills, and there will be a worldwide demand for these skills.

The Engineer's Role in Shaping the UK's Nuclear Future and Viable Nuclear Power economics

22. Nuclear power will be an essential part of the nation's energy portfolio if we are to achieve environment and energy supply goals. However, renewable sources are also an essential part of this portfolio. Innovative engineering is required to develop the effectiveness and efficiency of all these sources and how they are balanced in the infrastructure.

23. New nuclear reactor designs have the potential for lower equipment costs, shorter build times through such initiatives as modularisation, reducing the period of capitalisation, reducing through life costs through simpler systems and optimised maintenance planning, and driving improvements in plant efficiency. The potential for engineering to progress these developments is high.

24. These issues again throw the focus on a general shortage of engineers nationally and the need to take action to rectify this to provide the transferable skill requirements across a range of industrial sectors.

March 2008

Memorandum 103

Submission from David Lindsley

Executive Summary

This submission is from a Chartered Engineer with over 50 years' experience of power-station operations. It identifies certain concerns over the ability of our current engineering community to support the design, construction, operation and maintenance of future nuclear plant. The question of economic viability of nuclear power stations is dismissed because there is no option but to build these plants. The submission draws particular attention to the critical importance of control and instrumentation technology, and points out that equipment and systems that have operated safely in overseas plant should not be assumed to be readily applicable to a new generation of power station, even if that plant is identical to those operating in other countries. The critical need for the highest possible level of supervision throughout the design, construction and operational phases by properly-qualified engineering personnel is stressed, but the difficulties of finding suitable personnel in the available timeframe make this problematical. Five essential measures are outlined, ranging from increased emphasis on the teaching of physics and mathematics at secondary-school level, media projects to raise the profile of the engineering profession, canvassing the views of existing nuclear staff and increased funding at University level. Finally, the need for compliance with established international standards is stressed.

Submission

1. My background. I am a Chartered Engineer who has worked with Conventional and Nuclear Power stations in the UK and overseas since 1957. I was for 20 years employed by a company in the (then) Babcock and Wilcox Group, and for seven of those years (1975–82) I was engineering Director for that company. I then set up my own consultancy practice, which for 20 years served the power and water industries in the UK and overseas.

2. My specialist experience with power stations. I have now retired, but during my working life my speciality was control and instrumentation—a field that requires a good understanding of how the plant works and the ability to apply control technologies that enable it to be operated safely, efficiently and reliably. I have published two books on the subject.[35] I should however stress that my experience does not extend to the details of nuclear reactor control systems.

[35] *Boiler Control Systems*, Published by McGraw Hill in 1991, ISBN 978-0077073749 and *Power Plant Control and Instrumentation*, Published by the IET in 1999, ISBN 978-0852967652.

3. Relevant concerns. Over the years, I have become increasingly concerned by the gradual erosion of engineering skills in the UK generally and in the power-station environment in particular. In the field of control the requirement for high-level engineering training and competence is particularly important, firstly because errors and failures can contribute to, or even cause, accidents and secondly because computer systems are subject to software malfunctions that are very difficult indeed to predict.[36]

4. The critical importance of control technology. The control systems for nuclear plant demand great skill and care—from the initial design, throughout the entire process of construction and commissioning, and into the day-to-day operation and maintenance. Supervision must be meticulous and stringent, and has to be carried out by engineers who thoroughly understand the plant and the full complexity of whatever technology is employed in its control.

5. The disparate lifetimes of main plant and electronic technologies. It should also be remembered that, although the main plant is designed to last for decades, computer technologies evolve on a two to five year cycle. After they've stopped laughing at it, tomorrow's experts may well have great difficulty in understanding yesterday's technology. They will also have problems in sourcing obsolete components. Manufacturers of computers and electronic components naturally prefer to serve the biggest markets (washing machines, TVs, personal electronic devices and so on), and tend to avoid customers who buy in small quantities, yet demand extreme standards of safety and reliability.

6. A relevant example. In the 1980s, the attitude of computer suppliers to safety-critical applications was brought into sharp focus by the incident at Three Mile Island (TMI). After that incident a major supplier of computers, Digital Equipment Corporation (DEC), became extremely concerned at the risk of possible litigation and issued a decree that no DEC machines were to be used in nuclear power-plant applications. This was a great problem to me because my company was at that stage well advanced in manufacturing the control systems for two nuclear plants—Heysham and Sizewell A. The systems we were providing were for Datalogging only—not control—and so there was no risk of a malfunction causing a critical reactor failure. There was little option but to proceed with the engineering and delivery of the systems. However, bearing in mind one of the TMI findings that the flood of information following the incident confused the operators and contributed to the problems, I was concerned that no item in the complex electronic make-up of a nuclear power stations' electronic systems should be exempted from very close and critical scrutiny by people who are experienced and qualified in all the relevant areas.

7. The risks we face. I am concerned that, with a severe lack of trained and experienced engineers to design and supervise the control systems of any proposed new nuclear plant, there will be a tendency to buy "off-the-shelf" systems from countries such as the USA, France or Canada. However, these countries are themselves experiencing difficulties of recruiting and/or retaining experienced engineers and there is a risk that any systems supplied by them will be hastily cobbled together and that latent weaknesses or faults may jeopardise safety in the long term. We also run the risk of assuming that technologies that have worked successfully on foreign power stations for decades would still be available today, although Paragraph 5 above explains the faults in such arguments.

8. Another example. It is worthwhile seeing how even apparently fault-tolerant systems can be flawed. I have personally seen a situation where are extremely safety-critical application was (quite rightly) provided with a triple-redundant, fault-tolerant control system, yet by a simple lack of understanding this concept was completely negated. In the original design, all critical functions were simultaneously performed by three sub-systems, which acted together under a "voting" system, whereby any failure in one would be detected and out-voted by the other two. This was an excellent concept and should have assured an almost impregnable level of safety. Unfortunately, the decision to apply triple-redundancy was taken at a late stage, when construction of the plant had already reached an advanced stage. Faced with having to provide three separate pressure tappings into expensive—and by then already complete—high-pressure pipework, the constructors found two existing ones and simply "teed off" two detectors from one. This negated the entire voting system since, for example, an obstruction at the tapping point feeding the two devices would cause them to operate erroneously. But—more crucially—they would agree with each other and out-vote the single remaining one, which was in fact providing the only correct reading!

9. Measures to be taken. I propose that five important steps should be taken as a matter of extreme urgency:

(a) The teaching of Maths and Physics in Secondary schools should be stepped up by a significant degree.

(b) Media projects should be initiated, aimed at raising the profile of the engineering profession.

(c) Staff of existing nuclear power stations should be interviewed, to get their views, particularly on issues of maintenance, training and the availability of spares.

[36] I have personally tried to address these concerns by writing a novel in which the hero is a power-plant engineer and the plot revolves round the control systems of power stations! In doing this, I hoped to encourage young people to see engineering as a worthwhile career, and to show everybody the risks of facile control solutions.

(d) The level of funding to support relevant courses at Tertiary Colleges and Universities should be increased. These should expand from the core maths/physics areas (which should themselves be taken to a higher level at this stage) into subjects such as metallurgy, thermodynamics, instrumentation technology and computer science.

(e) The design of any control system of a nuclear plant must comply with IEC 61508 "Functional safety of electrical/electronic/programmable electronic safety-related systems". Moreover, engineers responsible for the supervision of design, construction, commissioning, operation and maintenance of such systems should be fully conversant with this standard, and must ensure compliance throughout the chain. This will require a great deal of intense work by highly-qualified engineers.

10. Is there a non-nuclear option? The terms of reference for the Nuclear Case Study include a question of whether nuclear power can prove to be economically viable. There are compelling engineering arguments that there is no viable option but to build nuclear power stations. This is not the place for presenting these arguments, but a detailed statement can be provided if required.

11. Too late? In many ways, we are already too late in proposing to take action now: the suggested measures should have been implemented at least a decade ago. This is water under the bridge however, and all we can try to do is to retrieve something from the mess. But we must act quickly, positively and decisively.

March 2008

Memorandum 104

Submission from The Royal Society

Key Points

— A wide range of nuclear skills and expertise, and substantially increased numbers of individuals with these skills, are required if future nuclear activity undertaken by the UK (including decommissioning, expansion, etc) is to be successful.

— A lack of these skills may also mean that the UK does not have the expertise needed to design new nuclear facilities.

— A lack of indigenous nuclear technical skills would diminish the UK's ability to be an intelligent customer since economic, technical, and security judgements might be flawed.

— There is a growing recognition of the importance of nuclear security. Maintaining the expertise to deliver nuclear security should be included in assessments of the UK's requirement for nuclear skills.

Nuclear Engineering Case Study

1. In 2007, the Royal Society published Strategy options for the UK's separated plutonium. One of the recommendations of this policy report was that the Government should ensure that its strategic thinking about UK energy needs and the safe disposal of nuclear waste is informed by a review of the staff and training needs in nuclear science and technology. The Government needs to know what future options could be missed through skills shortages and whether it would be desirable economically to import these skills from overseas. The Society therefore welcomes this review of the UK's engineering capacity to build a new generation of nuclear power stations and carry out planned decommissioning of existing nuclear power stations.

2. If a new nuclear power station is built in the UK, much of the technology will have to be imported as the UK no longer has the capacity to deliver it. The UK may also have to import much of the expertise to deliver and install it as the number of nuclear engineers in the UK has been in decline for many years. The recently launched National Skills Academy may go some way to address this, but a new nuclear plant will put additional demands on the need for nuclear engineers who are already required for the decommissioning and disposal of radioactive waste.

3. Design work has now started on new Generation IV reactors optimised to further minimise waste, improve safety and proliferation resistance, and decrease the building and running costs of nuclear energy systems. The Generation IV International Forum (GIF) is currently considering six reactor types. GIF membership comprises: Argentina, Brazil, Canada, China, EU via the European Atomic Energy Community (EURATOM), France, Japan, Russia, South Africa, South Korea, Switzerland, UK and USA. In October 2006, the former Department of Trade and Industry (DTI) withdrew from active membership of the GIF charter, although it still retains "non active" status. This action reflected a refocusing of DTI's priorities following the Energy Review towards near term objectives, and means that the new Department for Business, Enterprise and Regulatory Reform (BERR) will no longer provide the annual funding of up to £5 million for UK researchers to participate in GIF. The European Atomic Energy Community

(EURATOM) is an active member of GIF, so UK researchers could participate through the EU Framework Programme 7. This will require researchers to find up to 50% of the required funding for the research either from their own resources or by obtaining a customer that is willing to provide these funds (RS 2007).

4. The change in the UK's GIF status and the loss of direct involvement with these developing technologies will affect the UK's capacity and willingness to implement Generation IV reactors, as the necessary nuclear engineering skills would have to be imported. A concern is therefore that a lack of indigenous technical skills in the future will mean that the UK would not be an intelligent consumer as economic, technical and security judgements might be flawed. It would also make any assessment whether Generation IV fast reactors should be used in future to dispose of the UK's stockpile of separated plutonium much harder to undertake. New nuclear build that redevelops the UK nuclear power capacity and nuclear engineering skills base would increase the possibility of Generation IV reactors being introduced in the UK in the long term.

5. There is a growing recognition of the importance of nuclear security. In December 2007, the Society held a two day workshop that explored innovative ways to detect the illicit trafficking of nuclear and other radiological materials. It brought together 70 leading scientific and policy experts from the UK, USA, Russia, Israel and several other European countries. Workshop participants were concerned that there may not be sufficient skills and expertise available to sustain nuclear and radiological detection research and development activities in the future, and so more people need to be trained in the area of nuclear security. Some participants felt that a possible global revival in nuclear power would help create new job opportunities and university places for relevant nuclear scientists and engineers. Maintaining the expertise to deliver nuclear security should be included in assessments of the UK's requirement for nuclear skills.

References

Royal Society (2007) Strategy options for the UK's separated plutonium. Royal Society: London.

Royal Society (2008) Detecting nuclear and radiological materials. Royal Society: London.

March 2008

Memorandum 105

Submission from BAE Systems

1. Introduction

1.1 This paper has been produced in response to the Innovation, Universities and Skills Committee major inquiry into engineering. The Select Committee has agreed that one of the case studies will be Nuclear Engineering; the study's terms of reference encompass issues which are relevant to BAE Systems Submarine Solutions ongoing operations.

2. Executive Summary

2.1 BAE Systems Submarines Solutions has a proud history of nuclear engineering in support of the submarine programme. Barrow is the UK's only site integrating the detailed design and commissioning of nuclear reactors since 1995. A considerable effort has been required to rebuild and retain the nuclear engineering skill base at Barrow and its supply chain since the start of the Astute project.

2.2 The international civil nuclear industry is undergoing a renaissance and this will have an impact on the defence programme through increased demand for nuclear engineering skills and key components in the supply chain.

2.3 The Nuclear Industry is facing skill shortages which are rooted in the long decline of the industry over more than two decades, public perception and the post cold war reduction in the nuclear navy.

2.4 Since 2003 the UK Government's commitment to the submarine programme has enabled a vibrant investment in nuclear capability at Barrow. There are similar opportunities in the decommissioning market which could help UK engineering industry build the capacity to meet the civil new build programme.

2.5 Help is required to ensure UK industry investment is coordinated, with key elements of the supply chain cooperating in a more strategic way. A programme to place high calibre individuals in new build projects around the world will help the UK gain the necessary experience and capture lessons for the imminent UK build programme.

3. BAE Systems Nuclear Engineering Credentials

3.1 *50 years experience of new nuclear submarine programme management*

3.1.1 BAE Systems Submarines Solutions' Barrow Shipyard has been managing the design, construction and commissioning of Nuclear Submarines since 1958 (50 years). Astute, the first of a new class of submarine will contain the 26th nuclear power plant to be constructed and commissioned at Barrow.

3.2 *Significant nuclear engineering programme over next 20 years*

3.2.1 Four Astute submarines have been ordered of an anticipated seven. This construction programme will continue until 2019.

3.2.2 The concept phase for the Vanguard successor submarines commenced in 2007; detailed design work will commence in 2009 in preparation for construction in parallel with the last Astute class submarine.

3.3 *Centre of nuclear engineering, construction and commissioning excellence*

3.3.1 Barrow, since the mid nineties, is the only site engineering, constructing, fuelling and commissioning nuclear reactors in the UK (Sizewell B achieved its rating certificate in September 1995); at least three new naval reactors will commission before the first UK civil nuclear power construction starts. These activities require the Barrow site to maintain a nuclear safety case and site licence in accordance with the Nuclear Installation Act.

4. Impact on BAE Systems Submarines of the Changing Nuclear Industry Environment

4.1 *The end of the previous Civil Nuclear Build Programme and Cold War produced a nuclear resource glut*

4.1.1 The end of the Cold War in the early 1990's gave opportunities for a reduction in the submarine flotilla. Old submarines were retired early and new orders deferred releasing a significant number of nuclear qualified naval personnel. This resource was eagerly recruited by industry. The need to train and develop new people was further reduced by the imminent completion of Sizewell B (1995) and the Vanguard Programme (1999). The deferral of orders forced Barrow into redundancies and surface ship work to survive. The Barrow workforce was reduced from 13,000 to 2,900 between 1992 and 2002.

4.2 *The Astute construction programme suffered key skill and knowledge shortfalls*

4.2.1 The nuclear reactor construction for Astute began to highlight problems with the skill and knowledge levels in the Barrow Shipyard and key suppliers in 2002. It became increasingly apparent that a lot of intrinsic knowledge resided in experienced staff and could not be easily documented in procedures and training packages.

4.2.2 The skill and knowledge shortfall was also prevalent in the Ministry of Defence (BAE Systems' customer) and the Regulators (Nuclear Installation Inspectorate and Defence Nuclear Safety Regulator).

4.3 *A negative public perception of the nuclear industry further skewed the age profile*

4.3.1 The UK public's perception of the Nuclear Industry, post Three Mile Island and Chernobyl, reduced the number of young engineers willing to train in nuclear engineering. In addition, the workforce in Barrow had aged, with little new recruitment during the 1990's. The nature of the submarine technology restricts recruitment to UK nationals, further exacerbating the problem of attracting new blood.

4.4 *A reduced Nuclear Navy trains fewer engineers*

4.4.1 Ex-navy nuclear personnel have always been valued by the Barrow shipyard in engineering, safety engineering and commissioning roles. Many have second careers in engineering consultancies supporting the civil and defence programmes. This valuable resource has been reduced in line with the nuclear fleet.

4.5 *Nuclear Decommissioning and Atomic Weapons Establishment projects are already driving new thinking in recruitment and retention strategy*

4.5.1 The new projects in progress at Sellafield and AWE have increased the competition for nuclear engineering resource. Attracting and retaining resource has required a combination of structured development, flexible and home working, increased remuneration and targeting retired engineers back into the workplace.

5. Defence Nuclear Engineering Cannot be Isolated from the Civil Nuclear Programme

5.1 *Civil Nuclear economics will drive Nuclear Engineering remuneration*

5.1.1 The skills being maintained and developed in the defence industry are highly valued in the civil nuclear industry; demand will increase in the run up to the start of new build in 2012.

5.1.2 The economics of civil nuclear power, with its high capital costs, make schedule adherence and quality (reliability and safety) the dominant measures of a project's success. These projects can afford to ring-fence pools of the best nuclear resource as a contingency against problems on the programme critical path. The submarine programme does not have the same economic drivers and needs other strategies to retain resource.

5.2 *Key skills were in short supply during the last Civil Nuclear Construction Programme*

5.2.1 The Sizewell B nuclear commissioning team comprised 50% foreign nationals (American, Spanish, South African and Slovakian). American engineers (the majority) came from the completed nuclear build programme in the USA.

5.2.2 The USA had not ordered a new reactor since 1979; in 2007 the USA nuclear utilities announced a new build programme and are projected to need more than 30 new reactors before 2020. The UK new build programme will need to compete internationally for key skills; the remuneration for nuclear engineers will reflect this competition.

5.3 *Demand for nuclear manufacturing will stress the submarines supply chain*

5.3.1 The international demand for components to support civil nuclear build will overwhelm key areas of the supply chain which support submarines. For example:

- There is a worldwide shortage of nuclear capable forging capacity (75% shortfall against projected civil nuclear demand alone). Submarines require the same capabilities for their nuclear plants.
- Heavy machining capability in the UK is based on old infrastructure and this capacity is running at a high utilisation in support of, amongst other projects, the Chinese market for conventional power plants. The projected UK civil nuclear build will further stress machining capability in the UK.

6. Each Nuclear Engineering Market Sector has a Different Environment

6.1 *A stable Submarine Programme*

6.1.1 The UK Government has shown a clear commitment to maintaining the current nuclear submarine fleet strength. This stable, long term workload, with one submarine build every 22 months and design work already starting on the successor submarines to Vanguard, is enabling BAE Systems to make significant investments in people, facilities and processes.

6.1.2 Barrow has now entered a sustained recruiting period in 2007 59 graduates and 97 apprentices were recruited. During 2008 the Barrow shipyard plans to recruit 85 new graduates, 50–100 experienced engineers, 134 apprentices and 300 tradesmen.

6.1.3 The nature of submarine work restricts recruitment to UK nationals only. The security requirements take over three months to achieve clearance of personnel. As BAE Systems Submarines is currently focused on the defence programme, it cannot make firm offers for employment until security clearance is received. Many staff are lost in this period to competitors with business which has less onerous security restrictions.

6.2 *The Decommissioning Programme's Reliance on Agency staff*

6.2.1 The headline figure for the Nuclear Decommissioning Authority's (NDA) budget of £2.5 billion/annum appears attractive, but the underlying cost of ongoing operations reduces the new money for decommissioning operations to less than £500 million per annum.

6.2.2 Many companies attracted by the headline figures, are finding the decommissioning market highly competitive. To reduce risk regarding the delays to Project approvals that continue to be experienced, companies engaged on these projects use flexible (agency) resource. Agency staff do not receive the same investment in professional development and, typically, do not gain man management experience. The headline rates paid to agency staff make it difficult for them to transition back to the core workforce where they would need greater management experience to justify their salary. Over-reliance on agency staff is undermining an opportunity to develop valuable nuclear engineering resource.

6.2.3 The Barrow Shipyard has lost nuclear qualified personnel to projects at Sellafield. Individuals are attracted by the headline rates paid for agency personnel. A number of these staff have recently returned to BAE Systems when the uncertainties of agency engineering in decommissioning have materialised but the turbulence is disruptive to production and personnel development.

6.3 *New Civil Nuclear New Build is an Opportunity for Regeneration of Nuclear Engineering Capacity and a Springboard to the International Market*

6.3.1 The Government's commitment to enable the replacement and increase in civil nuclear generating capacity offers a challenge to the UK nuclear engineering industry. After such a long period of inactivity, the UK nuclear engineering base has contracted. There is an opportunity for companies to enter the UK market to fill the gap. If UK companies do not step up to this challenge, foreign competition will. UK engineering companies need to co-operate, playing to their strengths, to develop the new engineers and integrated capabilities required.

6.3.2 If this UK integrated capability can be achieved it will be well positioned to exploit international opportunities.

7. The UK has the Engineering Capability; Recommendations to help Build the Capacity

7.1 *Newer Modularised Reactors—offers project and UK industry advantage*

7.1.1 The more advanced reactors offered for the UK market (Westinghouse's AP1000 and GE's ESBWR) both feature a high degree of modularisation. This modularisation maximises the work at factory locations; reducing the work content at the power station construction sites, cutting programme time and risk.

7.1.2 Reducing the work content at site will reduce the number of engineers who are required "on the road". This will ease the problem of retention for companies in this market and help ensure valuable experience is transferred from project-to-project.

7.1.3 BAE Systems has gained significant experience in design for modularisation in the submarine programme. The level of module outfit routinely used at Barrow is higher than the aspirations of the reactor vendors. Extensive experience has shown that this allows significant pre-commissioning; the risk reduction to the programme is significant. Increased focus on higher levels of outfit and pre-commissioning by the reactor vendors would further reduce the number of engineers required "on the road".

7.1.4 Increased complexity in modules and their pre-commissioning requires a more highly skilled workforce for their design, construction and commission. A reinvigorated UK industry supporting modular designed reactors will have competitive advantage in future international projects.

7.2 *An integrated Supply Chain approach is required*

7.2.1 Internationally the demand for new nuclear reactors outstrips the available supply chain capacity; a major opportunity for UK Engineering industries exists. Significant areas of the UK engineering supply chain have been run down or lost since Sizewell B was constructed. With the exception of the defence industry, very few UK companies have recently managed major projects with such a large high quality engineering content since.

7.2.2 The UK nuclear engineering manufacturing base needs to work co-operatively to maximise the value it delivers. Key capabilities such as forgings, machining, manufacturing engineering and commissioning already exist in the UK, but they have limited capacity. The timescales before the new power stations are required do not allow free competition and market forces alone to generate this capacity. There is a need for an integrated UK approach to development of facilities and people to establish a world class UK nuclear engineering supply chain.

7.3 *Ensure the UK becomes an attractive location for nuclear reactors*

7.3.1 The UK Government's intention to streamline planning and licensing for nuclear reactors will help establish the certainty required for these large projects.

7.3.2 The UK will have to attract nuclear skilled people into its workforce. Hopefully many of them will be home grown, but it is likely that some will need to come from abroad. Enabling this mobility will be essential to feed these projects and prevent delays.

7.4 *Develop Engineers and Technicians on existing nuclear projects*

7.4.1 During the preparation for Sizewell B, the CEGB seconded many engineers onto the international nuclear construction and commissioning teams. Engineers were seconded for the duration of construction and commissioning (2–3 years). This was an expensive investment but it repaid many times during Sizewell B's progress.

7.4.2 Government assistance in placing UK engineers at current projects such as Flammaville (France), the Watts Bar Completion (USA) or the AP1000 build in China would greatly increase the UK knowledge and skill bank.

7.4.3 Another option would be to use the existing UK nuclear projects (eg. the submarines and decommissioning programmes) to develop resource; possibly by increasing the scale of the current NDA graduate development programme.

7.4.4 Barrow, as the only UK licensed site integrating, constructing and commissioning nuclear reactors, is uniquely placed to train and develop the nuclear design, manufacturing, construction and commissioning engineers and programme management capability to meet the UK new build market need. This strategic resource will become increasingly valuable over the next four years.

7.5 *Stabilise and accelerate decommissioning activity*

7.5.1 The decommissioning programme could be used to produce a ramp-up in nuclear engineering activity. Decommissioning could then be curtailed to release resource to meet the demands of the new build programme.

7.5.2 By accelerating the early spend, and providing certainty to the decommissioning projects, UK engineering industry would be motivated to invest in core staff and facilities. This would help UK industry to ramp up to the levels of activity required to support a new build programme.

7.6 *Learn lessons from the programmes which are restarting*

7.6.1 The hiatus in the nuclear submarine build programme resulted in a huge loss of intrinsic knowledge in BAE Systems and its Supply Chain; this hurt the programme schedule and increased costs. A significant programme of investment and development has been required to recover competence and capability.

7.6.2 The supply chain supporting the first EPR reactor construction in Finland has suffered similar problems with major nuclear related components.

7.6.3 As the USA restarts the Watts Bar project and moves into new construction, there will be many more lessons to learn. Placing UK project managers, quality professionals and engineers in these projects, would help de-risk the UK new build programme.

8. Conclusions

8.1 The nuclear engineering skill set to support the nuclear renaissance still exists in the UK, mostly preserved in the defence programme. There is a need to increase the number people to meet the requirements of the new civil nuclear build programme.

8.2 Education alone will not produce individuals of the requisite calibre, but the experience element can be achieved by placing high calibre individuals into existing nuclear projects in the UK defence industry or international civil nuclear build programmes.

8.3 The UK engineering industry has an opportunity to build an internationally competitive nuclear engineering capability on the back of the UK new build programme. But this requires a coordinated approach to investment and the development of skills.

March 2008

Memorandum 106

Submission from the Society of British Aerospace Companies (SBAC)

1. Nuclear Engineering within Aerospace—The SEEDER Project

1.1 SEEDER stands for Single Event Effects Design for Electronics Reliability. It is a programme designed to find methodologies of shielding electronics vulnerable to high levels of neutron bombardment, particularly in high altitude and fission reactor environments.

1.2 SEEDER is a part industry, part Technology Strategy Board funded programme investigating the breakdown of electronics systems as a result of interference caused by cosmic radiation. It is a three year programme, running from January 2008 to December 2010.

1.3 SEEDER is headed by MBDA and involves a number of partners from the aerospace industry, including BAE Systems, QinetiQ, AWE, Smiths and Goodrich Corporation. The programme is also boosted by the involvement of BAE Systems Barrow, as SEEDER has clear applications for the electronics systems onboard nuclear submarines.

1.4 SEEDER is funded 50% by industry, and 50% by the Technology Strategy Board (TSB).

SEEDER is the natural successor to MBDA's SPAESRANE programme.

1.5 SPAESRANE (Solution for the Preservation of Aerospace Electronics Systems Reliability in Atmospheric Neutron Environment) was a DTI-funded programme that initiated the investigation into interference with electronics caused by high levels of neutron bombardment.

1.6 The support of the TSB will ensure that the programme is driven towards generating added value through the increased competitive advantage for UK industry in the methodologies developed. These advances will be made at maximum cost effectiveness, protecting UK electronics in a highly specialised environment.

2. Single Event Effects

2.1 Single Event Effects (SEEs) are created by both natural and man-made means. In nature, cosmic rays are the source of SEEs, whilst man-made SEEs originate from the innards of nuclear reactors on land and in nuclear submarines.

2.2 Cosmic rays are essentially radioactive neutron particles which originate from deep space supernovae, and from the solar winds of our own Sun. These cosmic rays continually bombard the Earth's atmosphere, and the collisions at high heat cause the particles to become highly charged as they descend from the atmosphere.

2.3 In man-made, land-based or submarine nuclear reactors, the highly charged neutrons exist as a result of the fission reactions that occur within the reactors.

2.4 In both instances, the highly charged neutrons exist in environments where they are potentially destructive. The aerospace industry is concerned because the naturally occurring neutrons are prevalent at altitudes ordinarily occupied by civil aircraft.

2.5 While cosmic rays exist at sea level and have been known to affect electronics and living organisms at this level, they are 300 times more prevalent at aircraft altitude.

2.6 At altitude, highly charged neutrons can penetrate aircraft fuselages and collide with silicon atoms, such as those found in avionics (aircraft electronics). Memory devices, such as RAM, are particularly vulnerable to cosmic rays. The resulting impact causes a nuclear reaction, which in turn produces an electrical charge shower to spread throughout the electronic system, which can cause memory disruption, memory loss or system failure. This phenomenon is known as the Single Event Effect.

2.7 This problem is compounded by Moore's Law, which states that computational power doubles approximately every two years, as the size of transistors continually decreases, and thus the amount of transistors that can be attached to a circuit board increases proportionally. As the transistors grow ever smaller, they become more susceptible to the highly charged neutron particles. This growing problem of increasingly small transistors means that "SSEs are now recognised as the dominant reliability issue for avionics in the coming decade."[37]

2.8 Where modern aircraft use "fly-by-wire" electronic actuators the problem is exacerbated as electrical components have been known to burn out completely when impacted by.

[37] Andrew Chigg, Senior Technical Expert, MBDA, *Opening Up The Space Rain Umbrella, www.isis.rl.ac.uk*

2.9 This problem is replicated within nuclear reactors and nuclear submarines, where internal electronic devices, and in particular the memory of these devices, suffer interference as a result of these nuclear particles.

2.10 The aerospace and defence industry has been eager to assist in the development of innovative shielding techniques to increase avionics reliability in the face of naturally occurring SEEs.

3. Engineering the SEEDER Programme

3.1 SEEDER exists to develop innovative solutions to the problem of exposure of avionics technology to nuclear energy at altitude.

3.2 A successful SEEDER programme will result in increased confidence in electronic reliability, and also increased general aircraft safety for both the civil and defence sectors.

3.3 SEEDER will be conducted operationally by nuclear engineers at the ISIS neutron source in Oxfordshire. Initially SEEDER operations will consist of the testing of the quality and susceptibility of electronic components under accelerated conditions.

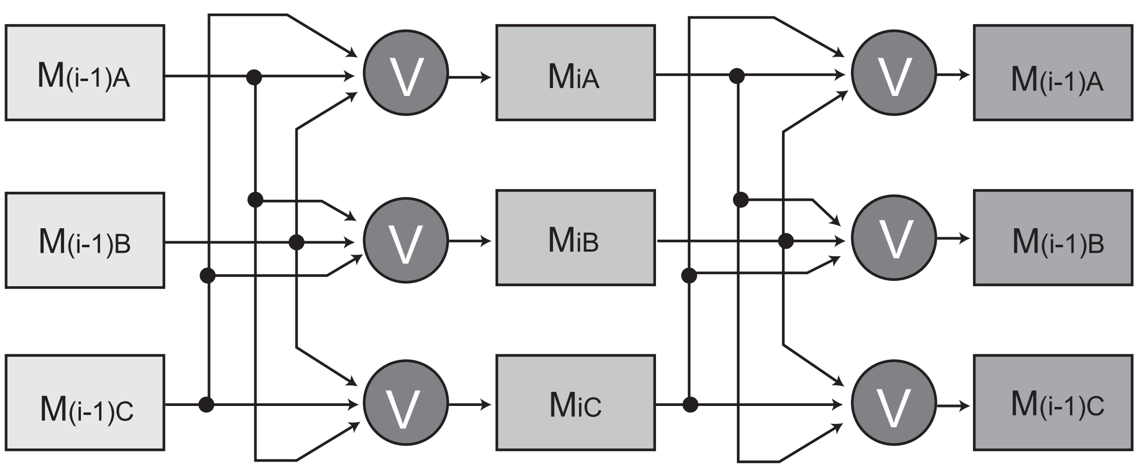
3.4 The ISIS neutron source is able to simulate many thousands of hours of particle flight time by accelerating neutrons to a highly charged state, and then colliding them with various materials to be the extent of the damage produced to the material's structure.

3.5 The nuclear research will lead to developments by electrical engineers, who would apply "triple redundancy" techniques to the relevant avionics systems to increase their reliability and place an emphasis upon certainty.

3.6 Triple redundancy prevents system failure if one component is adversely affected by an SEE by installing numerous components running in parallel, as the overall electrical signal sent by the system will be that of a "majority vote"—in other words, if three outputs read 1, 1 and 0 respectively, the chosen output will be 1.

3.7 Fig 1, below, is an example of how triple redundancy can be expanded. The diagram shows that three input signals are generated, and each signal has a "vote" which is cast—if all three signals are functional then the votes will be equal and the output signal will reflect this. If one of the input signals is malfunctioning, the "majority vote" is cast and the output signal will still be correct. A second voting system, and then a third, are added to add certainty that the original correct signal is being conveyed.

3.8 (fig 1)



3.9 The challenge for SEEDER is to incorporate triple redundancy circuitry into electronically hostile environments.

4. Added Value

4.1 The SEEDER programme will provide added value to various other aspects of technology, and will the knowledge gained will be applied in a variety of social and military environments. Whilst the primary objective is to increase electronics reliability against SEEs in a very specific environment, there are numerous other applications available, which are as follows.

4.2 Advances in knowledge gained through SEEDER will have significant applications in materials research, and practical applications in future super-fast computers, which will be operable in both civil and hostile environments.

4.3 The knowledge gained through SEEDER would also be applicable to data storage, sensors, pharmaceuticals and medical applications, especially in the fields of nuclear medicine. Biotechnology and clean energy technology would also be able to make use of this technology.

4.4 The SEEDER project will require specialist engineers, including nuclear technicians, nuclear engineers, systems engineers, electrical engineers and nuclear scientists in order for it to be a success. Short term necessity will lead to long term opportunity as the SEEDER will create technological advances that will lead to the generation and installation of technologies that will have applications in aircraft all over the world in a bid to create more efficient, safer and cleaner electronics systems. The demand for such a technology would mean that the types of engineers involved in SEEDER would be in demand for years to come.

March 2008

Memorandum 107

Submission from the Engineering Professors' Council (EPS)

1. The Engineering Professors' Council represents the interests of engineering in Higher Education. It has over 1,600 members, all of them professors or Heads of Department and virtually all the UK universities which teach engineering are represented. It has as its mission the excellence of engineering higher education, teaching and research.

2. Nuclear power provides reliable energy and does not depend on hydrocarbon fuels that may have to be obtained from unstable regimes. It is the nearest thing the UK has to a technically available, non-polluting energy source capable of delivering power on the massive scale necessary to satisfy future demand. It has an important role to play in a mixed economy of power sources including natural renewables such as wind, solar and hydroelectric power. An important factor in favour of a resurgence in nuclear power is nuclear reactors emit virtually no carbon dioxide (CO_2), the main greenhouse gas. Of course building a power station does produce significant amounts of CO_2: but the same is true of, for example, building a wind farm.

3. Nuclear power currently generates around 20% of the UK's electricity. However, all but one of the UK's nuclear power stations will close by 2023 and at present no replacements are planned. There is a growing and urgent need for nuclear power and for nuclear engineering.

4. There are of societal issues, principally concerning safety but we find that these may be over-stated. It is worth noting that the three worst nuclear accidents in the world (Windscale in 1957, Three Mile Island in 1979, and Chernobyl in 1986) have killed far fewer people and caused much less environmental damage than the oil and coal industries over a similar period of time.

5. Modern reactor designs are inherently safer than those built 20 or 30 years ago, reducing a small risk still further. For example, work underway in South Africa on the Pebble Bed Moderated Reactor (PBMR) has produced an inherently safe nuclear reactor design which is incapable of overheating or meltdown, and which has successfully addressed most of the social acceptability issues surrounding nuclear power, including proliferation and terrorism. An important point is that such a reactor has the potential to provide, for the first time, a high temperature source of process heat capable of revolutionizing the energy industry. A range of potential applications is being considered but, for the UK, the most important is likely to be the use of this process heat to generate hydrogen from water via process routes such as high temperature electrolysis and thermo-chemical cycles with low or zero carbon emissions. This technology is one of the very few on the horizon capable of operating at the scale of the oil industry. Economic generation of such large quantities of hydrogen raises the possibility of an ultra low carbon emission transport fleet in the UK. Because of this huge potential substantial government funded R & D programmes are in place in Japan, the USA, Korea, France, the RSA, and Germany. However, no such work has been funded in the UK.

6. Uranium prices have remained steady for decades, meaning that nuclear energy is far more secure than fossil fuels are likely to be. Modern nuclear power systems are likely to be more economic than the older versions, and are therefore a good investment.

7. If we do not want to become overly dependent on expertise from other countries the UK has a lot of catching up to do. The closure of for example CERL, and the demise of the UKAEA, mean that as a nation we no longer have the capacity to design our own reactors, nor even the skills to operate them.

8. A praiseworthy but limited initiative is being mounted by one of the sector skills councils, Cogent, which covers the nuclear industry. Cogent is supporting Foundation Degree programmes in Nuclear Engineering at the Universities of Portsmouth and Central Lancashire (see http://www.cogent-ssc.com/cogent_family/NSAN.php). However, questions remain as to whether providing a Foundation Degree is the most appropriate response to this important issue.

What we really need is a viable and prosperous UK nuclear industry—and to achieve that, sustained and substantial government investment will be required.

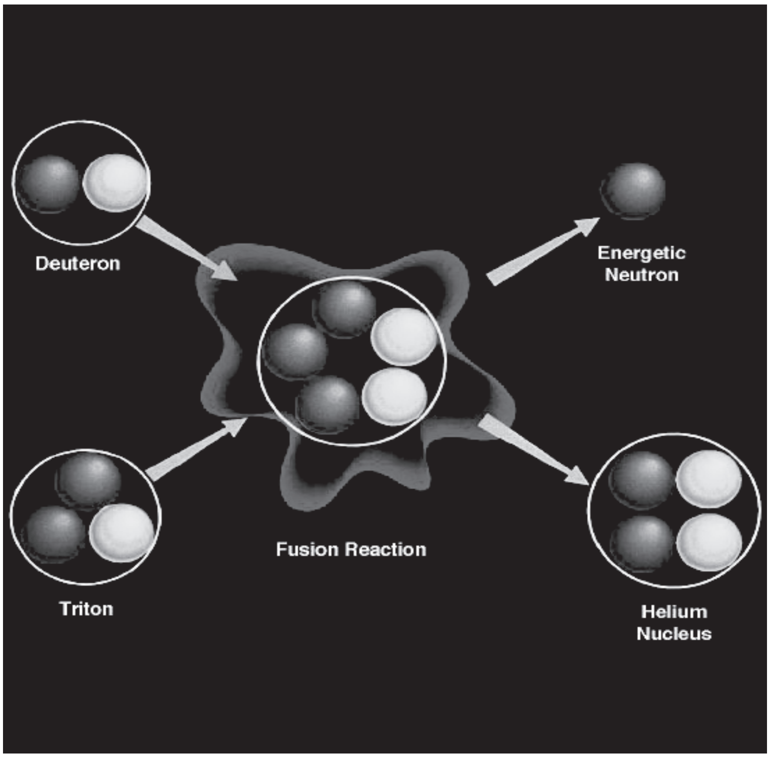
March 2008

Memorandum 108

Submission from High Power laser Energy Research project (HiPER)

OVERVIEW OF NUCLEAR FUSION ENERGY

The process of "nuclear fusion" involves the combination of two atomic nuclei to form a single, larger nucleus. If the initial atoms are small (ie near the start of the periodic table), then energy may be released during this process, because the larger atom will be more stable. That is, it has an effectively lower rest mass. As shown by Einstein (E= m c2), a change in mass will lead to the creation of a large amount of energy.



THE FUSION PROCESS

Fusion is the process which powers the Sun. It is not encountered in everyday life on Earth because extreme temperatures are required (many millions of degrees) in order for the positively charged atoms to have sufficient speed to overcome their mutual repulsion. The temperatures are so high that the matter turns into a plasma, in which the electrons are stripped from their nucleus. The fact that high temperatures are needed gives rise to the common name for this approach being *thermonuclear fusion*. The Sun delivers the initial energy to create a plasma using the power of gravity. On Earth we need to find other solutions.

The most advantageous fusion reaction for terrestrial studies is the combination of two Hydrogen isotopes (Deuterium and Tritium) to form a Helium nucleus plus a neutron. For energy production, we need to create a propagating fusion reaction—that is, one which sustains itself once we have initiated the reaction. This can be achieved by using the Helium nucleus to deposit its energy into its neighbouring atoms, thus providing sufficient heat to start the next reaction. The neutron is used to drive the power plant—it is captured in an absorbing blanket surrounding the system which heats up because of the energy deposited by the neutron. This is then simply used to heat water to power a conventional steam turbine for energy production.

Fusion is the opposite process to nuclear "fission" (the process used in nuclear power plants), where heavy elements such as Uranium are split into two daughter nuclei.

The benefits of fusion can be summarised as:

(1) Abundant fuel and energy security: the raw products can be found naturally (Deuterium comes from seawater and Tritium can be created in situ within the fusion device itself).

(2) The energy released is very high, meaning it is a naturally efficient system (multi-GW power plants are the predicted scale for fusion reactors).

(3) The process is significantly cleaner than other bulk power production techniques: There is no greenhouse gas production, and there are no long-lived radioactive products, although there is activation of the reaction chamber that can persist for ~100 years.

(4) The process is inherently safe (little or no stored energy, so no potential for runaway reactions).

Thermonuclear fusion has been studied for approximately 50 years. The proof of principle (demonstrating the validity of the underlying science) has been achieved in defence programmes (in the 1980s). What remains is to find a route to produce a stable, efficient and cost effective power plant. There are two principal routes being explored, both of which are at a high stage of maturity, albeit still requiring multi-decade investment to develop to the stage of a viable reactor. The two routes are:

(1) Magnetically confined Fusion Energy (MFE). Here, large low density plasmas made up of Deuterium and Tritium fuel are created in toroidal (doughnut-shaped) chambers called "tokamaks". The operation is essentially "steady state" rather than pulsed. The Joint European Torus (JET) based at the Culham Laboratory in Oxfordshire is the world's largest example and has demonstrated the scientific basis of magnetic confinement fusion. The international community has agreed to fund the next generation machine (ITER), to be sited in Cadarache, France towards the end of next decade. Its cost is of order $5B construction, and a similar sum for operation. See http://www.iter.org/index.htm

(2) Inertially confined Fusion Energy (IFE). Here, high power pulsed lasers are used to compress a small pellet of Deuterium and Tritium to achieve very high densities (> 30 times the density of lead) over a very short timescale (< 1 nanosecond). The National Ignition Facility in the USA is currently under construction with a mission to demonstrate the scientific basis of IFE (ie sustained, scalable thermonuclear burn). See http://www.llnl.gov/nif/project/. Costs are similar to MFE. A significant amount of IFE research is also carried out within the UK, based on experiments at the Central Laser Facility at the Rutherford Appleton Laboratory, Oxfordshire. This approach has the benefit of applicability to other scientific goals (astrophysics, material science, particle acceleration). With the advent of new laser technology leading to significantly reduced costs, an entirely civilian approach to IFE is now feasible, and forms the basis of the HiPER project (see below).

HiPER Summary

HiPER is a UK initiative for Europe to take a world leading position in the demonstration of Inertial Fusion Energy and the science of extreme conditions. This approach to energy and science is made feasible by the advent of a revolutionary approach to laser-driven fusion known as "Fast Ignition". HiPER will make use of advanced laser technology in a unique configuration, allowing fusion fuel to be compressed and then ignited to induce a propagating burn wave yielding significant energy gain (Q ~ 100).

At present, the HiPER project is a consortium of seven European countries at the national level (Czech Republic, France, Greece, Italy, Portugal, Spain, with the UK taking the coordinating role), two regional governments (Madrid and Aquitaine), industry, plus scientists from four other countries (Poland, Germany, Russia, USA) and international links to Japan, China, Republic of Korea and Canada. The project has completed a two-year conceptual design phase, and has just entered a three year "preparatory phase" in April 2008 as part of the EC's stewardship of the ESFRI roadmap facilities. This phase is co-funded by the UK. Assuming success in this phase, construction is envisaged for the latter half of next decade.

The facility will mark the culmination of a UK-led strategic alliance of laser capabilities across Europe, which includes all the major existing facilities and a significant intermediate step (PETAL), currently under construction near Bordeaux at a cost of ~€80M.

The timing of the HiPER preparatory phase has been designed to take full advantage of international work in this area. Three strands of work are being planned to converge early next decade:

— IGNITION DEMONSTRATION: It is expected that net energy production from laser fusion will be demonstrated in the USA in the early part of the next decade on the National Ignition Facility (and subsequently on Laser Megajoule in France). This will mark the culmination of over 40 years' research, and a commitment of many billion dollars.

— FUTURE PATH: Alongside this, there has been significant investment in laser facilities around the world targeted at developing an advanced route to fusion ignition. This route is designed to increase the efficiency of the fusion yield using a substantially smaller facility. If successful, this will provide the confidence to proceed with engineering analyses for commercially viable energy production and will provide the technological basis for a broadly-based science programme. These facilities (in USA, Europe and Asia) are designed to provide the scientific evidence for how this field should develop. They are too small to achieve fusion gain themselves, but should within the next five years provide sufficient information to allow the future path to be adequately defined.

— INTEGRATED PLAN: The HiPER project is designed to capitalise on this work. The design phase has established the overall strategic requirements. The preparatory phase will provide the structural and technological groundwork to allow the next big step to proceed without delay, whilst ensuring that construction decisions are only taken after validation of the proposed approach. This preparatory phase will place Europe in a clear leadership position.

The conceptual work done on HiPER has already had a significant influence on the international community. We note that the US are now actively working on fast ignition relevant modifications to NIF to follow on from the initial demonstrations of energy gain. Meanwhile, we have started discussions with the Japanese on the potential for an international approach to the next step. These changes can be capitalised upon as part of the HiPER project, and could enable HiPER to take a generational leap in capability (to high repetition rate operation) based on close coordination with our international partners.

Expected Scientific and Economic Impact

HiPER has been designed to marry together the establishment of European leadership in the science of extreme conditions with the key societal challenge facing mankind: a long-term supply of abundant clean energy.

This is a field in which the UK can honestly claim to be a true world leader. We have the world's most powerful, most intense laser (Vulcan-PetaWatt), and are set to retain this leadership for the next few years with the emergence of the high intensity Astra-Gemini (2007) and Vulcan-10PW (2010–11) facility developments. This leadership has provided us with the scientific and technological knowledge and international reputation to propose and lead the HiPER project.

The science case has been developed by over 50 senior scientists from 11 nations during the past two years. It offers a compelling argument for a step-change in laser capability for European academics. Its proposed science programme covers a broad spectrum in this rapidly developing field, with a facility capability that will offer unprecedented, internationally unique tools. The topical fields range from laboratory astrophysics, the study of extreme states of matter, planetary science, creation of relativistic particle beams, and fundamental quantum physics.

It is clear that HiPER will open up entirely new areas of research, providing access to physics regimes which cannot be explored on any other science facility. Its user base will be greatly expanded compared to existing laser laboratories, consistent with this increase in scientific breadth.

The energy mission is aimed at establishing the case for the exploitation of laser driven fusion. The project is timed so that decisions can be made following the upcoming demonstration of energy production from lasers (in ~2012 in the USA and subsequently in France). HiPER will develop the route to viable power generation by addressing the key R&D challenges—both scientifically and technologically. Its "Fast Ignition" approach promises a factor 5–10 reduction in scale (and thus cost) of the capital plant, whilst severing the principal link to classified applications. This allows academia and industry to take a lead role for the first time.

Work in the current "preparatory phase project" will concentrate on establishing the most appropriate route to moving forwards in this area. It will assess the likely technical solutions and associated risks to allow informed decisions on the required R&D and facility specification for subsequent phases.

Multiple energy solutions are demanded by a risk-balanced strategy for energy supply, with fusion able to offer the "holy grail" of energy sources—limitless fuel with no carbon or unmanageable radioactive by-products, energy security, and a scale able to meet the long term demand. Laser fusion is highly complementary to ITER, and is based on a scientifically proven approach (inertial confinement).

There are significant industrial opportunities for the UK and Europe as part of the HiPER project—in the design and build phase, the operational phase, and from the ensuing technical spin-out opportunities. With regard to the future energy applications of HiPER, the scale of the potential economic impact is clear.

HiPER would secure UK/European leadership in a field which is rapidly developing in Asia and the USA. No comparable laser system is underway anywhere in the world—HiPER will be a highly effective international attractor to the UK.

Engineering Requirements

The scale of the scientific and engineering challenge to achieve fusion energy is very significant. It covers a broad array of disciplines, each requiring a clear, long-term development plan. This demand a coherent approach linking: academic training to ensure adequate community skills; early industrial engagement to ensure opportunities for the UK are not missed; identification and funding for the required Research, Development and prototyping; and close collaboration between academia and industry to identify optimum solutions.

The technical areas requiring development include:

- Remote handling and robotics in harsh environments.
- Advanced material science for reactor vessel components.
- Microscale and nanoscale facbrication and characterisation (of the fuel pellets).
- Advanced laser technology.
- Manufacture of at high volume, low cost of large scale (metre-diameter) optics.
- Adaptive and active optics.
- Radiation hardened electronics.
- Remote injection and tracking technology (of the pellet targets).
- Cryogenic (~20K) vacuum technology.
- Thermal system management.
- Structural engineering.
- Fluid dynamics (for liquid wall chambers).
- Waste management and tritium extraction.
- Automated alignment and component replacement.

Funding

Technical work associated with the three-year preparatory phase has direct funding or in-kind commitments amounting to ~€70M from: European Commission, UK, France, Czech Republic, Greece, Spain, Italy, Poland, Portugal and the Republic of Korea, plus formal agreements with institutions in Germany, Canada, USA, Japan and China.

€13M of this is direct funding provided from the EC and the national partners (over three years) to fulfil specific project requirements of the preparatory phase.

The cost of construction and operation will be assessed during the course of the preparatory phase and depends on key technology down-selection choices in the next few years. However, it is clear that it is in the billion-Euro class of facilities.

Timeline

- Conceptual design study [UK funding, scientists from 12 nations involved] (2005–06).
- Included on ESFRI European roadmap (October 2006); UK endorsement as Coordinators (January 2007).
- Preparatory Phase Project [National and EC funding] (April 2008 to March 2011).
- Detailed Engineering Phase (estimate 2011–14).
- Construction Phase (estimate 2014–20).

June 2008

Memorandum 109

Submission from the United Kingdom Atomic Energy Authority (UKAEA), Culham

1. Executive Summary

- Fusion has enormous potential as a major, environmentally responsible, source of essentially limitless energy. The UK has a unique role and capability in fusion development, operating the world's leading facility JET ("Joint European Torus") and the innovative, compact device MAST.
- Many of the remaining scientific hurdles will be removed by the international experiment, ITER, being built in France. Due to its size and complexity, ITER will also test key technologies for power stations.
- To position the UK to be a major force in developing fusion systems once ITER is operational, Culham has begun, with EPSRC backing, a gradual transition from fusion science to technology. The nuclear components of future systems are a critical focus because they will contain the most Intellectual Property and therefore have the most commercial value.
- Recognising that engineering is key to the economic viability of fusion, Culham is developing with universities training programmes to strengthen fusion engineering.

- — The synergies between fusion and fission engineering are substantial. Therefore, fusion development would benefit from the training of a new generation of nuclear engineers. And in turn, fission could benefit from engineering expertise nurtured in the UK fusion programme.
- — Recommendation The fusion programme should play a role in revitalising UK nuclear engineering for the benefit of both fusion and fission.

Who we are

2. The mission of UKAEA Culham is "To capitalise on the major assets at Culham to (a) advance fusion science and technology to the point of commercialisation; and (b) position the UK to participate in the future fusion power economy". We are funded by EPSRC and EURATOM to undertake UK fusion research and operate JET for a collective European programme to prepare for ITER (JET is led by Dr. F Romanelli for the European Fusion Development Agreement). In the last decade, with its MAST facility, UKAEA has pioneered a promising compact approach to fusion, called the "Spherical Tokamak". JET and MAST give the UK a number of world-leading and in some cases unique capabilities.

3. Increasingly, UK universities are involved in the research. This includes joint training of students in a wide range of disciplines and at all levels. There are contributions from some twenty universities, with expanding efforts at York, Imperial College, Oxford, Cranfield, Warwick and Strathclyde.

4. At UKAEA's Culham site there are approximately 225 engineers and 135 physicists. Of the 52 PhD students in October 2007, 11 were in engineering & technology, four in materials science and 37 in plasma and related physics. For engineers, Culham has Graduate Development and Monitored Professional Development Schemes based on the UKSpec competencies giving access to chartered status. The Culham apprenticeship scheme was re-launched in 2005 and now has 14 apprentices.

Factual Information

What is fusion?

5. Fusion powers the stars. Because of the very hot temperatures required, producing and sustaining a fusion system is a major scientific and engineering challenge. Strong magnetic fields are required to hold the hot, burning gas ("fusion plasma") away from the vessel walls.

6. Fusion power would emit no greenhouse gases and so would not contribute to global warming. Its basic fuels (Lithium and deuterium—a form of hydrogen extracted from seawater) are virtually inexhaustible. Unlike fission, fusion's reaction products are not radioactive. Radioactivity is, however, produced by the neutrons hitting the materials surrounding the fusion gas. But, if these materials are chosen carefully the radioactivity is short lived and the affected materials can be recycled quickly. There are inherent safety features. Estimates of the cost of fusion electricity show that it could be competitive with clean coal and renewables. It is therefore a promising, environmentally responsible, sustainable, large-scale source of base-load electricity.

7. Reactors will fuse deuterium and tritium ("heavy" and "super-heavy" hydrogen) to make very energetic neutrons and helium. The tritium will be made by fusion neutrons striking lithium in a blanket surrounding the fusion reactor. The blanket will also absorb the neutrons' energy, and it is this heat that will be used to generate electricity. The engineering and materials science challenges for the vessel walls, the blanket and other components, have many features in common with fission systems.

The Roadmap for Fusion

8. The European plan for fusion development outlines the steps required to begin operation of a demonstration power station ("DEMO") within 30 years. The scientific basis needed to design a fusion burning plasma device has already been established on JET and other machines. The international community is building this device, ITER, in France. It will operate in around ten years and eventually achieve power output ten times the power input. Because of its size and complexity, ITER will also test key technologies for power stations. ITER operation will be accompanied by testing of the candidate materials for DEMO on the IFMIF device. Finally, a Component Test Facility (CTF) will be needed to develop blanket and other nuclear technologies for DEMO and the commercial power stations that will follow. The most promising option for a CTF is a Spherical Tokamak.

9. UKAEA Culham and its university partners aim to play a leading role in the Roadmap. Specifically we are:

- — preparing for a major role in ITER experiments;
- — building a strong technology design and prototyping programme;
- — developing the Spherical Tokamak as the outstanding candidate for a relatively compact CTF. This requires a major upgrade of MAST; and
- — taking a central role in DEMO studies.

10. Ten years from now, the UK should be participating in ITER experiments and developing the science and technology needed for the prototype stage of fusion energy (DEMO and CTF). Twenty years from now, the UK should be playing a significant role in the prototype stage of fusion development.

Nuclear Engineering in the Fusion Programme

11. The nuclear components are critical to the commercial viability of fusion power. They will also contain the most Intellectual Property and therefore have the most commercial value. If it is to play a major role in the fusion power market, it is essential that the UK develops an expertise in these critical technologies. With EPSRC's backing, we have started the transition from fusion science to engineering to position the UK to be a major force in developing fusion systems, especially the nuclear components.

12. This ambitious agenda requires trained engineers across a wide range of skills. Recently, major projects at Culham (totalling ~£100 million) have required the recruitment of many engineers. This has been achieved in many areas, often by attracting professionals from high-technology industries. However, it recruitment remains difficult in electrical and planning/project engineering. As we move more to nuclear systems engineering, we anticipate that recruitment will be at least as hard and we may have to look overseas for suitably trained staff.

13. Engineering synergies between fusion and fission include materials, structural integrity, heat transfer and the remote handling needed to maintain and refurbish reactors. To meet our needs, Culham is developing with universities training programmes to nurture fusion engineering. Fusion would also benefit greatly from the training of a new generation of nuclear engineers and fission will benefit from expertise developed by the fusion programme.

June 2008

Memorandum 110

Submission from Nexia Solutions

Nuclear Engineering Case Study

Executive Summary

The submission below outlines Nexia's key interest in the preservation of Nuclear Engineering Skills based on its commercial activities and government remit. It highlights Nexia's belief in the maintenance and growth of these skills to support National policies and suggests ways in which government could assist in this aspiration. A specific response against the case study terms of reference is also provided.

Nexia Solutions Submission of Evidence

1. Nexia Solutions is the only commercially run organisation in the UK with a specific government remit to preserve and grow nuclear engineering skills in support of national policies. Nexia is in the process of transitioning into the UK's National Nuclear Laboratory, the lab will be a government owned contractor operated organisation the competition for which is expected to commence in summer 2008.

2. Nexia Solutions will be an applied laboratory which delivers engineered and implementable solutions not just theoretical concepts. To achieve this the lab will have a strong, professional engineering capability.

3. Nexia is accredited for concept, detailed design and manufacture supporting its customer projects, facilities and internal investment in innovation.

4. Nexia seeks to provide challenging, varied and stimulating experience, particularly at the start of a career resulting in an emphasis on graduate recruitment. This approach is reinforced by Nexia's remit as a "skills pipeline". Nexia is also accredited to provide monitored professional development (MPDS) for the major disciplines.

5. Nexia believes that training and development of a new generation of nuclear engineers in the UK is a vital necessity for the successful prosecution of the UK government initiatives of clean up and new build.

6. Complete reliance on foreign expertise to build, operate and decommission new UK nuclear stations runs counter to the principal of improving the UKs energy security as control over supply continuity will remain vested abroad.

7. The NDA oversees a huge annual clean up budget and will continue to need the current, (and in future, expanded) UK nuclear engineering skillbase to support this procurement for many years to come. This support may come in the guise of an "expert buyer" or "practitioner" but in either event a new generation of UK based engineers will be required to protect the national interest.

8. Nexia's contribution to the growth of the UK skills base is governed by its ability to recruit and retain high quality engineers in its own organisation alongside its efforts in training coaching and mentoring engineering talent in academia and across the industry.

9. Recruitment into Nexia is influenced by:

— the quality and quantity of supply;

— the confidence of Nexia to commit to recruitment plans based on long term growth; and

— Nexia's ability to **offer** a challenging and rewarding career.

10. Retention within Nexia is influenced by:

— the quality and quantity of alternatives open to the recruit in competing industries;

— the confidence of Nexia to invest in the employees development; and

— Nexia's ability to **deliver** a challenging and rewarding career.

11. Nexia believes government can have a key influence on successful skill base growth through improving *confidence* of employees and employers in the future of the industry **and** through incentivising accelerated delivery of tangible progress in clean up and new build. For Nexia this means specifically:

— Commitment to the National Laboratory concept as an institution to which young engineers can aspire.

— Long term national programmes with a focus on real progress which the laboratory is entrusted to establish and deliver. This will allow Nexia to provide the type of career paths and opportunities which will encourage talented engineers to build a long term future within the industry.

Annex

Some specific Observations against the terms of reference are included in this annex.

The terms of reference for the nuclear engineering case study are as follows:

— The UK's engineering capacity to build a new generation of nuclear power stations and carry out planned decommissioning of existing nuclear power stations.

New Build

— Planning and licensing process complete by 2011, would require input from experienced engineers and scientists, limited skills are available now within organisations such as The National Nuclear Lab and Sellafield Ltd. (The Nuclear Industries Inspectorate, which regulates safety at UK plants, has admitted that it is already finding it difficult to recruit and believes this is a common problem across this energy sector).

— The designs should be reviewed to make sure they accommodate provision for remote inspection, visual and NDE, and also remote repair. For example the AP 1000 is reported to have a design life of 60 years and routine inspection and unforeseen repairs may be required during that time to maintain the safety case and possible extend the life of the reactor beyond its design life.

— The use of standardised designs such as the AP 1,000 or EPR means that there will be minimal input required from designers and scientists during the design phase.

— Current investment in nuclear related education and training needs to be maintained to ensure current highly experienced but aging working force is replenished in a timely manner. NTEC, NNL, NSAN are already gearing up to maintain skill levels and funding must continue in this area. (Fewer than 6% of the estimated 100,000 people who work in the industry—including 23,500 at degree level—are under 24, while 31% are aged 45 and over).

— To support decommissioning investment in remote handling, dismantling, size reduction and robotics needs to continue to be able to accelerate these timescales and costs and minimise dose to operators and the general public.

Decommissioning

Current Reactor Stations

— Within the next 15 years with the exception of Sizewell A, all currently operable power stations will have been taken off line, and all will be in their care and maintenance phases by the time Sizewell A closes in 2035.

— There is world wide expertise in the decommissioning of reactors however there is also world wide demand for these skills so a "grow your own" policy would ensure the required control over the supply and demand curve.

— There will be a big demand for reactor decommissioning skill through out the UK for the next 20 years or so.

- Care and maintenance phase will make demands on materials scientists, remote engineering surveillance systems as well as conventional civil asset care and maintenance skills on all reactor sites for around 80 years.
- Final dismantling will be primarily a conventional civil demolition and waste management activity, but this activity is two or three generations away.

Legacy R&D facilities, production and Reprocessing Plants, Ponds and Silos

- Decommissioning activities associated with these types of facility will be more challenging than reactor decommissioning due to their one of a kind status. Each facility will present its own challenges and will require a higher degree of design, development and R&D. The challenges are primarily those of characterisation, segregation, remote handling and size reduction. Sites such as Capenhurst (closure date) 2120, Culham 2020, Dounreay 2036, Harwell 2025, Springfields 2031, Sellafield 2120, Windscale 2065, Winfrith 2020, will continue to place demands on specialist nuclear R&D, engineering design and civils capabilities for the next 120 years.
- the value in training a new generation of nuclear engineers versus bringing expertise in from elsewhere;

The UK's nuclear skills shortage is being compounded by the fact that already around 30 new atomic plants are under construction in 11 other countries, with dozens more planned around the world, from China to Russia and the US.

- the role that engineers will play in shaping the UK's nuclear future and whether nuclear power proves to be economically viable; and

  Science and Engineering skills will be required for the following areas:

  - next generation reactor technology/design;
  - development of Fusion technology;
  - dose reduction/containment and shielding;
  - advanced materials/nano tube/self cleaning;
  - decommissioning, decontamination, size reduction, robots and remote handling;
  - remote intervention and repair, remote surveillance, inspection and examination;
  - waste management/deep disposal/dry store;
  - fuel technology/MOX II;
  - reprocessing/Thorp II;
  - recovery of heat from nuclear waste;
  - development of nuclear by products Hydrogen fuel cell; and
  - military/nuclear subs.
- the overlap between nuclear engineers in the power sector and the military.

Significant particularly in the areas of:

  - next generation of nuclear subs (Astute II);
  - reactor safety;
  - reactor opertion and maintenance;
  - remote intervention, inspection, NDE and repair;
  - decommissioning/dismantling; and
  - waste management and disposal.

July 2008

Memorandum 111

Submission from Sellafield Limited

Summary

This submission, in support of the Innovation, Universities and Skills Select Committee case study into nuclear engineering, is provided by Sellafield Limited and is consistent with their 2008 Skills Strategy.

Sellafield Limited directly employees approximately 11,000 full time equivalent staff based primarily at three locations: West Cumbria, Risley (near Warrington), and Capenhurst (near Chester). It works closely with the Sector Skills Council (SSC) covering Nuclear technologies (Cogent), and the National Skills Academy Nuclear (NSAN) in their aim to support a sustainable future for the UK Nuclear industry. Sellafield Limited has also been consulted as part of the Sector Skills Council submission to this committee.

The key Sellafield Limited findings are:

- Sellafield Ltd has a relatively stable workforce for the majority of its skill sets; the Lifetime plan shows a continuing requirement for engineers and scientists at levels similar to the present to support existing Operations. Significant retraining of the workforce to support decommissioning is expected in approximately eight to 10 years.
- The next five years present a specific resource challenge with increased demand for engineering design, project and commissioning resources to deliver the projects to remediate the site and meet the Regulatory Specifications. This is in the context of an increasingly competitive market place for resources with these skills and is impacting on market rates which are rising at approximately 10% per annum.
- Sellafield Limited is currently experiencing shortages for Safety Case specialists and market rates are leading to higher than acceptable levels of attrition.
- Government support is required to sustain the development of the skills base through the provision of additional funding. Specifically, the number of scheduled retirements for the Sellafield Limited workforce over the next 20 years is rising and investment is needed to develop new staff across all skill sets and in particular to meet the demand for engineers and scientists. This is likely to coincide with potential new nuclear build requirements.
- Skills planning is a strategic imperative for Sellafield Limited; who are working closely with the Sector Skills Council to ensure the right framework is in place for training and development of its workforce.

Challenges facing Sellafield Limited

1. Sellafield have not been able to recruit the number of engineering design resources required and the supply chain has also had issues. The number and quality of engineering design resources has been a factor in extending project schedules. A stronger technical community is also required to deal with the technical risks posed by the projects. Sellafield has not been able to ramp up in terms of the commissioning resources needed to meet demand. This is of particular concern because the organisation has a small current population of this skill set.

2. In addition to the Remediation work which creates a need for new assets, Sellafield has many unique bespoke plants and requires a stable and experienced professional workforce to operate, maintain and improve these assets. The main plants are no longer new, and many of the staff who developed the processes, and designed and built the plants have retired. As the plants are currently forecast to be in operation for many years, stability and the ability to maintain succession is at least as important as was historically the case.

3. At post-graduate level, there is a focus on courses specifically targeted at the nuclear industry. However there is some merit in attracting graduates with a sound basis in engineering principles. Many of Sellafield Limited facilities are bespoke and the organisation needs to develop those nuclear skills with support from education providers. The requirement is often the ability to engineer from first principles.

4. The nuclear technology supply chain is more fragmented than was historically the case, and there are fewer scientists and engineers employed in nuclear related R&D. The in depth knowledge base of the Sellafield plants and processes therefore tends to reside with less people that in previous decades, and Sellafield is reliant on this smaller group of experts. Some disciplines are receiving attention to reduce vulnerabilities. Formal establishment of the National Nuclear Laboratory with a partnering approach to maintain capability is an important contributor to ensuring the required future support capability.

5. There is very little fundamental research and the number of people involved in Research and Development across the industry is much lower than 20 years ago. It is unclear as to whether this level of resource affects our ability to be innovative now and support future developments.

6. Specifically, active facility availability is reduced relative to historic, with no current decision to make the British Technology Centre (BTC) phases 2 and 3 active. Facility availability is an important factor in the development and retention of the future experts.

7. Regarding new reactor build, fuel development activities, should they be required, could be carried out for uranium fuels at Springfields, and mixed plutonium/uranium fuel at Sellafield. The BTC phase 2 facilities have the capability to conduct plutonium/uranium fuel research should a decision be made to make them active.

8. In recognition of the above challenges, Sellafield Limited has conducted and will continue to conduct detailed reviews of the gaps in nuclear skills. As a result, Sellafield has developed bespoke academic and non-academic training programmes. Examples include a foundation degree in Nuclear De-commissioning and a Team Leader Development Programme.

SKILLS AND RESOURCE REQUIREMENTS IN RELATION TO THE SELLAFIELD LIMITED LIFETIME PLAN

Immediate and Short Term

Sellafield Limited is experiencing difficulty in attracting and retaining specific skills due to market pressures and a shortfall in the availability of those skills. The skills affected are in engineering design (all disciplines), commissioning, project management and programme control.

There is an immediate shortage of safety case specialists, in particular, and, given the length of time to train and develop these skills, this may impact the programme of work.

The requirement for these skills continues throughout the Lifetime Plan.

Medium Term (five to 10 years)

The extension of the operational lives of THORP and Magnox Reprocessing, entails that it will be necessary to maintain the workforce at the current levels, with the necessary plant and nuclear safety knowledge for longer than originally expected.

Sellafield Limited is expected to experience demographic issues and there will be a need to replenish staff. There is a need to retain sufficient plant and nuclear knowledge beyond operations into Post Operations Clean Out (POCO) and the Initial Decommissioning phases.

Long Term (over 10 years)

The extension of THORP and Magnox Reprocessing operating lives and the consequential delays to decommissioning programmes means that the major transition of the workforce into a predominantly decommissioning phase is delayed. The workforce will need to be retrained in decommissioning skills. If there is limited investment in UK Nuclear Skills, then by 2020, Sellafield Limited is expected to experience significant resource shortfalls.

July 2003

Annex

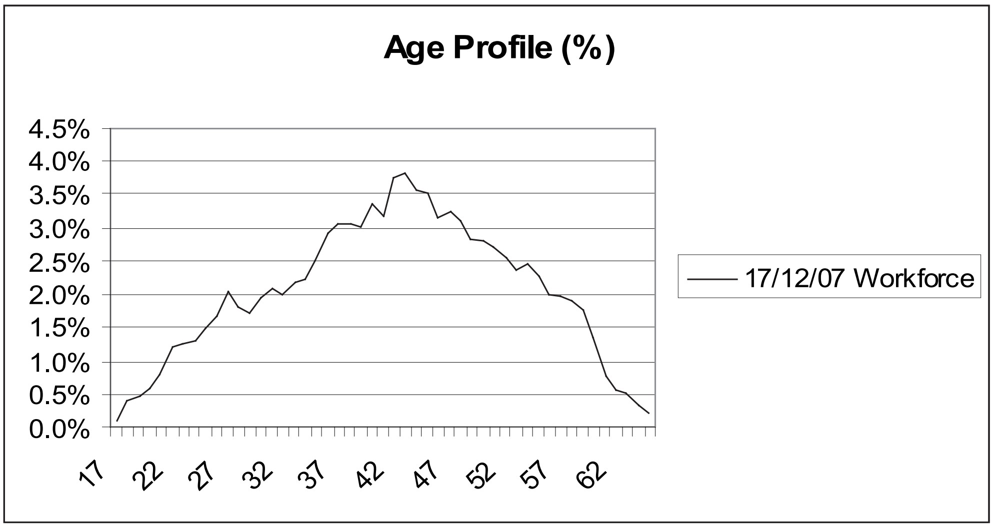
DEMOGRAPHIC DATA

Sellafield Limited has detailed data covering the existing workforce. The current mean average age is 42.5 years with a mean average length of service of 12.6 years.

The age profile of the workforce is as shown in Figure 1. Sellafield Limited will experience an increase in the number of retirements per annum over the next 20 years although this is not currently presenting widespread issues.

Figure 1

AGE PROFILE (DATA EXTRACT 17 DECEMBER 2007)



Memorandum 112

Supplementary evidence from the HM Nuclear Installations Inspectorate following the oral evidence session on 16 July 2008

On 16 July 2008 Dr Mike Weightman, HM Chief Inspector of Nuclear Installations and Director of HSE's Nuclear Directorate, gave evidence to the Committee in connection with its inquiry into Nuclear Engineering. During the course of that evidence Dr Weightman offered to provide the Committee with supplementary information on two items. This memorandum provides that supplementary information.

(i) The Generic Design Assessment Process

In responding to a question from the Committee about the Generic Design Assessment (GDA) process for new nuclear reactors, Dr Weightman informed the Committee that this had been put forward as a proposal in HSE's submission to the Government's Energy Review in June 2006[38]. An extract from this submission is attached to this note—see Annex A. The Energy Minister subsequently wrote to HSE requesting that it worked with the other nuclear regulators to develop the proposals for Generic Design Assessment ready for implementation in early 2007. Regulatory guidance on GDA was published in January 2007.

In developing the proposed GDA process HSE had a number of objectives:

— build upon the proven UK nuclear regulatory process, to protect people and society, ensuring risks are adequately managed;

— ensure a rigorous, robust and transparent examination of new build proposals;

— provide more opportunities for the public and other stakeholders to comment on safety issues on an informed basis than has been the case in the past;

— ensure the process is clear and transparent to the public and to industry;

— Minimise uncertainties and allow a step-wise reduction in "regulatory risk";

— allow for advice from overseas regulators to be taken into account to the extent that is appropriate; and

— give an estimated timescale for GDA that supports these objectives, given appropriate resourcing, adequate submissions and necessary responsiveness from those putting forward designs for assessment.

GDA would be part of a two phase process leading to a nuclear site licence (which is required before construction can begin). GDA would entail an assessment of the safety features and ultimate acceptability of a nuclear reactor design as the basis for granting a nuclear site licence. If successful, this would lead to the issuing of a statement of "Design Acceptance" by HSE, which would remain valid for a number of years. The second phase would involve an applicant seeking a nuclear site licence to construct such a reactor at a specific site.

HSE divides GDA (Phase1) into 4 steps, which were anticipated to take up to 3 ½ years (see the table below):

Phase One: Design Acceptance

Step	*Process*	*Approx Timescale*
1	Design and safety case preparation based on generic site envelope	Requesting party is responsible
2	Fundamental safety overview	6–8 months
3	Overall design safety review	6–12 months
4	Design Acceptance Assessment	Up to 2 years

Phase Two: Nuclear Site Licensing

Site licence assessment, with subsequent issue of site licence if application is judged to be acceptable. In addition to the design, and site related matters, the capability of the licence applicant is also assessed.	6–12 months

Starting in August 2007, four different designs were taken through Steps 1 and 2, by both HSE and the Environment Agency, culminating in the publication of the regulators' findings in March 2008[39].

38 http://www.hse.gov.uk/consult/condocs/energyreview.htm
39 HSE published almost 50 assessment reports on 18 March 2008: www.hse.gov.uk/newreactors/reports.htm

The Canadian designer subsequently withdrew from GDA to focus on its home market leaving three designs which are now being taken through Step 3. These designs are:

— AREVA/EdF EPR (France).

— GE/Hitachi—ESBWR (US/Japan).

— Westinghouse AP1000 (US).

The target GDA completion dates for all three designs remains 2011, although this is crucially dependent on NII[40] being able to achieve its necessary staffing levels, and on the quality, completeness and timeliness of the vendors' safety submissions.

(ii) The Costs of GDA to the Industry

As with virtually all of its other activities in relation to the regulation of the UK's nuclear industry, HSE recovers its costs for GDA from those companies submitting designs for assessment. The original GDA target completion timescales (around 3 ½ years) were predicated on being able to draw on a certain level of external support through contracts with Technical Support Organisations (TSOs). On that basis, we originally estimated that our recoverable costs would be a minimum of around £6 million per design.

The completeness of the designs and the associated safety cases for the three designs is less than anticipated; and, the work of nuclear regulatory colleagues in the USA and France is commensurately less well advanced. Hence, it is now anticipated that more use will have to made of external technical support than originally planned. We have informed the GDA applicants that our best estimate costs are now around £13 million per design. The final costs will of course depend on the amount of effort that is eventually entailed. This will be dependent on a number of factors including the level of advancement of the companies' safety submissions and the amount of TSO effort we may need to call upon. Expressions of interest from a large number of TSOs have been received and these are currently being considered. We are also actively exploring the opportunities for information sharing and staff secondments with regulators from France, the US and Finland who are also engaged in regulatory assessments of each of the three remaining designs.

July 2008

Annex A

EXTRACT FROM HSE'S SUBMISSION TO THE GOVERNMENT'S ENERGY REVIEW—"THE HEALTH AND SAFETY RISKS AND REGULATORY STRATEGY RELATED TO ENERGY DEVELOPMENT, 28 JUNE 2006"

Extract From Executive Summary

The generation of electricity by nuclear power stations

The design of nuclear power stations continues to evolve. For the purposes of this report, we assume that proposals for new construction of new nuclear power stations in the UK would utilise what are described as Generation III (or III+) designs. These power stations will generally have some or all of the following characteristics:

— a standardised design for each type to expedite licensing, reduce capital cost and reduce construction time;

— a simpler and more rugged design, making them easier to operate and less vulnerable to internal (fire, flood) and external (earthquake, aircraft impact) hazards;

— higher availability and longer operating life—typically 60 years;

— greater use of passive safety systems, inherently safe design features, or more diverse, segregated and redundant plant;

— reduced risk of core melt accidents;

— minimal effect on the environment; and

— higher fuel burn-up to reduce amount of fuel used and the amount of waste.

From the safety viewpoint, therefore, vendors claim a reduction in risk compared with the older designs. While HSE cannot agree with these claims in advance of our safety assessments, our expectation is that third generation reactor systems will demonstrate appropriate levels of safety with risks no greater than those of existing reactors, and there are therefore no reasons in principle why such reactors cannot be safely operated within the current UK regulatory framework.

40 NII (HM Nuclear Installations Inspectorate) is part of HSE's Nuclear Directorate that covers nuclear safety regulation under the Nuclear Installations Act 1965 (as amended).

The health and safety risks that principally concern the public are those relating to the release of radioactivity. There are specific measures taken to restrict the exposure of workers and the public to ionising radiation during normal operation. It appears likely that the average radiation doses to workers and the public to ionising radiation from Generation III reactors during normal operation will be no higher than the best standards currently achieved, and thus acceptably low. This assumption would be rigorously checked during the assessment process. Any new reactor design would also be rigorously checked to ensure an acceptably low level of risk of releases of radioactivity due to accidents. The history of nuclear accidents has led to safety improvements and before licensing any new nuclear power stations, the Nuclear Installations Inspectorate (NII) (part of HSE's Nuclear Safety Directorate) would require a demonstration that the potential for accidents was robustly protected against.

Regulatory control is achieved by a comprehensive and well-tested framework of legislation governing the health and safety of the nuclear industry. The system of regulation is based on requirements for nuclear site licences and conditions associated with the granting of these licences, backed up by exacting assessment, inspection and enforcement arrangements. The Nuclear Installations Act 1965, as amended, allows HSE at any time to attach such conditions as appear to it to be necessary or desirable in the interests of safety, and in respect of the handling, treatment and disposal of nuclear matter. These conditions cover safety-related functions including:

- marking the site boundary;
- the appointment of "suitably qualified and experienced persons" to perform any duties which may affect the safety of operations on the site;
- the production of adequate safety cases for all operations affecting the site and the preservation of records;
- the handling and storage of nuclear material;
- incident reporting and emergency arrangements;
- design, modifications, operation and maintenance;
- control, supervision and training of staff;
- decommissioning arrangements and programmes; and
- control of organisational change.

Licensees are required to make a written submission concerning safety arrangements, referred to as the safety case. The licence conditions and the safety management system described in the safety case are monitored by NII through a robust system of inspection and enforcement.

It is the responsibility of the licensee (or licence applicant) to provide a comprehensive demonstration (a safety case) that safety will be properly controlled through all stages of the plant's life. NII takes a holistic "whole life" approach. It therefore expects the safety submission to cover not only the design, but also aspects such as construction, maintenance, operation, radioactive waste and decommissioning. Although the format for safety cases is not prescribed, HSE has published Safety Assessment Principles (SAPs) against which it assesses the adequacy of licensees' safety cases.

NII's methodologies have been subject to searching independent scrutiny. The SAPs were the subject of consultation within the industry and, for the development of the HSE's *Tolerability of risk* document, a formal public consultation was carried out. The Nuclear Safety Advisory Committee (NuSAC) advises the Health and Safety Commission (HSC) independently on nuclear safety issues, including for example on the nuclear safety issues arising from this energy review, and the committee often seeks evidence from NII.

Construction of a new nuclear power station would not be allowed to commence until a Nuclear Site Licence has been granted. NII will not grant a Licence unless it is content with the proposed reactor design, the site location, and the licensee's organisation. To be satisfied with the design, NII would require an acceptable safety submission.

While there are no significant changes required in the legal provisions relating to the development of a further generation nuclear power stations, there will continue to be evolution in administrative processes. HSE is considering further developing the arrangements for pre-licensing assessment of candidate designs, as set out in Annex 2.

A multi-stage assessment and licensing process is under consideration. Phase One would be a design acceptance process with four components:

- Step 1: design and safety case submission based on generic principles;
- Step 2: a fundamental safety overview;
- Step 3: an overall design safety review; and
- Step 4: detailed design authorisation assessment.

Phase Two is site and operator specific and is HSE's assessment on which to base the granting of a nuclear site licence. This involves assessment of the plant, the site and the operating organisation. While Phase One may have a duration in the order of three years if various conditions are satisfactorily addressed, Phase Two may take approximately six to twelve months if the applicant provides a detailed and adequate submission and other permissions (for example planning, Electricity Act) are forthcoming. This process is intended to provide a transparent, rigorous and robust regulatory approach to the safety of any new nuclear reactor build, reflecting the various views of our stakeholders and our commitment to being an open and accountable regulator.

Our overall conclusion is that there is a well-established regulatory framework for the UK nuclear power industry and, since this has been in place, there has been a good safety record. This framework has been vindicated in public inquiries and has been subject to peer review by international experts.

NII has satisfactorily regulated nuclear reactors of "first" and "second" generation designs. Generation III reactors will be an evolutionary design making use of proven technology and operating experience, benefiting from modern safety analysis techniques and philosophies. It is therefore expected that licence applicants could demonstrate appropriate levels of safety with risks no greater than those of existing reactors, and there are no reasons in principle why such reactors cannot be safely operated within the current regulatory framework. However, for NII to play fully its part in future regulatory arrangements it will need to be appropriately resourced.

Memorandum 113

Submission from Professor J Billowes, Head, Nuclear Physics Group, University of Manchester

Funding of Nuclear MSc Programmes

The Engineering and Physical Sciences Research Council (EPSRC) has funded collaborative (ie in partnership with public and private sector organisations) postgraduate training in higher education institutes through Collaborative Training Accounts (CTAs). Currently there are over 90 accounts running activities such as engineering doctorates, knowledge transfer partnerships, industrial CASE and masters training.

Most CTAs were funded through calls in 2004 and 2005. The scheme is now closed to new applicants and current CTAs will run until the end of September 2009.

A new scheme will start from September 2009 called Knowledge Transfer Accounts (KTAs). These have a different focus to the CTAs: their purpose is to fully exploit EPSRC-funded research and encourage a culture of academic research transfer to industry rather than to fund postgraduate training as an end in itself.

The "nuclear engineering" Masters programmes affected by this change are the MSc in Physics & Technology of Nuclear Reactors (University of Birmingham) and the MSc in Nuclear Science & Technology (offered by the UK's Nuclear Technology Education Consortium, NTEC). The Birmingham course director has commented on the ending of the CTA scheme: "The potential impact would be to reduce the number of students by a factor of 4, which could have significant implications for the viability of the course."

A number of nuclear-related MSc programmes are also offered by other universities such as Liverpool (Radiometrics) and Surrey (Radiation & Environmental Protection, Radiation Detection & Instrumentation) which will be similarly affected by the ending of the CTA scheme. All these long-standing programmes are financially fragile and reply on the joint relationship between industrial support and Research Council underpinning. If these programmes disappear, the UK would lose about 350 postgraduate-trained professionals entering the nuclear industry over a five year period. The programmes would perhaps be sustainable through recruitment of non-EU students—but this would be of little long-term benefit to the UK.

January 2009

Memorandum 114

Submission from the National Nuclear Laboratory

EXECUTIVE SUMMARY

The submission below outlines the National Nuclear Laboratory's (NNL) key interest in the preservation of Nuclear Engineering Skills based on its commercial activities and government remit. It highlights NNL's belief in the maintenance and growth of these skills to support National policies and suggests ways in which government could assist in this aspiration. A specific response against the case study terms of reference is also provided.

NNL SUBMISSION OF EVIDENCE

1. The NNL is the only commercially run organisation in the UK with a specific government remit to preserve and grow nuclear engineering skills in support of national policies. The lab will be a government owned contractor operated organisation the competition for which commenced in summer 08.

2. The NNL will be an applied laboratory which delivers engineered and implementable solutions not just theoretical concepts. To achieve this the lab will have a strong, professional engineering capability.

3. The NNL is accredited for concept, detailed design and manufacture supporting its customer projects, facilities and internal investment in innovation.

4. The NNL seeks to provide challenging, varied and stimulating experience, particularly at the start of a career resulting in an emphasis on graduate recruitment. This approach is reinforced by the NNL's remit as a "skills pipeline". The NNL is also accredited to provide a Monitored Professional Development Scheme (MPDS) for the major disciplines.

5. The NNL believes that training and development of a new generation of nuclear engineers in the UK is a vital necessity for the successful delivery of the UK government initiatives of clean up and new build.

6. Reliance on foreign expertise to build, operate and decommission new UK nuclear stations runs counter to the principal of improving the UKs energy security as control over supply continuity will remain vested abroad.

7. The NDA oversees a huge annual clean up budget and will continue to need the current, (and in future, expanded) UK nuclear engineering skillbase to support this procurement for many years to come. This support may come in the guise of an "expert buyer" or "practitioner" but in either event a new generation of UK based engineers will be required to protect the national interest.

8. The NNL's contribution to the growth of the UK skills base is governed by its ability to recruit and retain high quality engineers in its own organisation alongside its efforts in training, coaching and mentoring engineering talent in academia and across the industry.

9. Recruitment into the NNL is influenced by:

- The quality and quantity of supply.
- The confidence of the NNL to commit to recruitment plans based on long term growth.
- The NNL's ability to offer a challenging and rewarding career.

10. Retention within the NNL is influenced by:

- The quality and quantity of alternatives open to the recruit in competing industries.
- The confidence of the NNL to invest in employee development.
- The NNL's ability to deliver a challenging and rewarding career.

11. The NNL is already tangibly progressing and fitting into wider strategic picture ie. work already underway with the US, Japan and S Africa for Hot Cells services, the breakthroughs in the research and development of a number of key products and services and its work with universities.

12. The NNL believes government can have a key influence on successful skill base growth through improving confidence of employees and employers in the future of the industry and through incentivising accelerated delivery of tangible progress in clean up and new build. For the NNL this means specifically:

- Commitment to the National Laboratory concept as an institution to which young engineers can aspire.
- Long term national programmes with a focus on real progress which the laboratory is entrusted to establish and deliver. This will allow the NNL to provide the type of career paths and opportunities which will encourage talented engineers to build a long term future within the industry.

September 2008

Annex A

Some specific observations against the terms of reference are included in this appendix.

The terms of reference for the nuclear engineering case study are as follows:

The UK's engineering capacity to build a new generation of nuclear power stations and carry out planned decommissioning of existing nuclear power stations

New Build

- Planning and licensing process complete by 2011, would require input from experienced engineers and scientists, limited skills are available now within organisations such as The National Nuclear Lab and Sellafield Ltd. (the Nuclear Industries Inspectorate, which regulates safety at UK plants, has admitted that it is already finding it difficult to recruit and believes this is a common problem across this energy sector.)
- The designs should be reviewed to make sure they accommodate provision for remote inspection, visual and NDE, and also remote repair. For example the AP 1000 is reported to have a design life of 60 years and routine inspection and unforeseen repairs may be required during that time to maintain the safety case and possibly extend the life of the reactor beyond its design life.
- The use of standardised designs such as the AP 1000 or EPR means that there will be minimal input required from designers and scientists during the design phase.
- Current investment in nuclear related education and training needs to be maintained to ensure the current highly experienced but ageing workforce is replenished in a timely manner. NTEC, NNL, NSAN are already gearing up to maintain skill levels and funding must continue in this area. Fewer than 6% of the estimated 100,000 people who work in the industry—including 23,500 at degree level—are under 24, while 31% are aged 45 and over.
- To support decommissioning investment in remote handling, dismantling, size reduction and robotics, we need to be able to accelerate these timescales and costs and minimise dose to operators and the general public.

Decommissioning

Current Reactor Stations

- Within the next 15 years with the exception of Sizewell A, all currently operable power stations will have been taken off line, and all will be in their care and maintenance phases by the time Sizewell A closes in 2035.
- There is worldwide expertise in the decommissioning of reactors however there is also world wide demand for these skills. A "grow your own" policy would ensure the required control over the supply and demand curve.
- There will be a big demand for reactor decommissioning skill throughout the UK for the next 20 years or so.
- Care and maintenance phase will make demands on materials scientists, remote engineering surveillance systems as well as conventional civil asset care and maintenance skills on all reactor sites for around 80 years.
- Final dismantling will be primarily a conventional civil demolition and waste management activity, but this activity is two or three generations away.

Legacy R&D Facilities, Production and Reprocessing Plants, Ponds and Silos

- Decommissioning activities associated with these types of facility will be more challenging than reactor decommissioning due to their one of a kind status. Each facility will present its own challenges and will require a higher degree of design, development and R&D. The challenges are primarily those of characterisation, segregation, remote handling and size reduction. Sites such as Capenhurst (closure 2120), Culham 2020, Dounreay 2036, Harwell 2025, Springfields 2031, Sellafield 2120, Windscale 2065, and Winfrith 2020, will continue to place demands on specialist nuclear R&D, engineering design and civils capabilities for the next 120 years.

The value in training a new generation of nuclear engineers versus bringing expertise in from elsewhere

The UK's nuclear skills shortage is being compounded by the fact that already around 30 new atomic plants are under construction in 11 other countries, with dozens more planned around the world, from China to Russia and the US.

The role that engineers will play in shaping the UK's nuclear future and whether nuclear power proves to be economically viable

Science and Engineering skills will be required for the following areas:

- Next generation reactor technology / design.
- Development of Fusion technology.
- Dose reduction / containment and shielding.
- Advanced Materials / nano tube / self cleaning.
- Decommissioning, decontamination, size reduction, robots and remote handling.
- Remote intervention and repair, remote surveillance, inspection and examination.
- Waste management / deep disposal / dry store.
- Fuel technology / MOX II.
- Reprocessing / Thorp II.
- Recovery of heat from nuclear waste.
- Development of nuclear by products Hydrogen fuel cell.
- Military / nuclear subs.

The overlap between nuclear engineers in the power sector and the military

Significant particularly in the areas of:

- Next generation of nuclear subs (Astute II).
- Reactor safety.
- Reactor opertion and maintenance.
- Remote Intervention, inspection, NDE and repair.
- Decommissioning / dismantling.
- Waste management and disposal.

Annex B

TYPICAL CAREER PATHS

The following outline is provided to illustrate typical career paths in "Nuclear Engineering" within the NNL.

The NNL strives to offer as broad a grounding as possible in all facets of the industry for recent graduates and professional recruits. Once chartered, engineers may choose to specialise in a particular role or discipline.

Early Career

Engineers will typically be employed as professional recruits and immediately registered on the NNL's Monitored Professional Development Scheme (MPDS). Engineers will undergo training and gain experience with a view to achieving chartership in, or around four years. As professional recruits they will also benefit from a comprehensive behavioural competance training programme. All staff will have a mentor who will assist them in gaining accreditation from the relevent institution. A young engineer might expect to have been exposed to all the major engineering related career routes on offer such as project management, commercial, team management and technical specialisation as well as the traditional lead and principal engineer option.

Young Professional Engineers

Once chartered, engineers will typically select a career path to pursue in the early phases of their professional life. These might be:

- Technical specialism in a particular discipline such as modelling or control systems leading to a potential "Technical Lead" appointment.
- Appointment as a "Lead Engineer" to oversee projects from an assurance perspective.

— Technical specialism in a business area such as waste management or disposal leading to a potential "Technical Authority" appointment.

— Appointment as a "Project Engineer" with a view to persuing a career in Project Management.

Many engineers will embark on a career path at this stage and continue to build a succesful career in one discipline, others will aspire to become proficient in a variety of roles and this is actively encouraged within the NNL.

Senior Professional Staff

The NNL recognises that individual engineers will achieve long term career satisfaction in a variety of ways. Some NNL engineers have developed to become nationally or even internationally renowned technical specialists whilst others are providing technical leadership over broad programmes of strategic importance to the UK. A proportion of engineers have also developed into senior positions within associated areas such as commercial or projects or chosen to leave the NNL and pursue a career elsewhere in the industry.

In summary the "Nuclear Engineer" within the NNL will posess a grounding in the industry unrivalled by any other organisation. This is due to the sheer breadth of activities with which the NNL is associated. NNL engineers are routinely called upon by government and its agencies to lead and shape National Policy. The NNL will be well placed to continue to provide this assistance provided it is entrusted to establish and deliver long term programmes in the National interest.

Annex C

NEW BUILD SKILLS PROFILE

The specific skill requirements and skill mix during the evolution of new build in the UK will change according to the particular stage in project development. The typical major phases for a nuclear project can be described as:

1. Pre-investment development work to establish cost, timescales, regulatory issues, research and Development needs and an overall business case for the investment.
2. Design, construction and commissioning including obtaining all necessary regulatory approvals and permits.
3. Operation including asset maintenance, performance upgrades and periodic safety case reviews.
4. Decommissioning.

Looking at each of these phases in turn and specifically at the nuclear engineering skills in the context of UK new build approach of buying proven designs in the International market shows how skill requirements change.

1. New build is currently in the pre investment phase. Activities which are underway include Generic Design assessment by regulators, site assessment by Utilities supported by reactor Vendors. The nuclear skills needed here are relatively small numbers of experts to support Regulatory assessments in areas such as Reactor core analysis and fuel management, nuclear safety expertise to review safety cases information provided by Vendors and waste management expertise to assess proposed waste arisings and management routes.

   The next stage in this phase will be site specific proposals made by Utilities this will require considerably greater effort than currently needed however much of the nuclear engineering will be carried out by the vendors primarily using their own resources. Nuclear engineering expertise will again be needed to support Regulatory assessments of proposals using similar skills as described above but likely to need more detailed consideration of site specific issues (eg seismic conditions, environmental discharges). This phase is likely to last ~3 to 5 years.

2. Following approval to proceed with the investment major detailed design, equipment procurement, civil construction, equipment installation and commissioning work occurs. Regulatory oversight continues and will need nuclear engineering skills to accomplish this. In addition substantial nuclear design work and specialist nuclear equipment procurement will be carried out by Vendors however most of this work will be done in the Vendors design offices. The extent of local design and procurement work is not clear at this stage and this could be an opportunity for UK nuclear engineering skills to play a significant role in enabling UK suppliers to work on new build. The skills needed here are understanding Nuclear design and fabrication standards and Nuclear safety engineering. This phase last for ~5 years.

3. The operation of Nuclear plant requires a continuous level of engagement by Nuclear engineering skills to ensure the plant remains within its safety envelope and to support troubleshooting and plant performance enhancements. This phase lasts for ~60 years.

4. Once operations have ceased the decommissioning of the reactor can be started. The early phases of work such as removal of fuel and wastes does require Nuclear engineering skills however the skill mix changes once the key nuclear hazards are removed and skills such as environmental and conventional safety skills.

Memorandum 115

Submission from Professor Steven Cowley, Director UKAEA Culham

ENGINEERING AND FUSION—BUILDING AND SUSTAINING EXPERTISE

— Fusion has enormous potential as a major, environmentally responsible, source of essentially limitless energy. The UK has a unique role and capability in fusion development, operating the world's leading facility JET ("Joint European Torus") and the innovative, compact device MAST.

— Many of the remaining scientific hurdles will be removed by the international experiment, ITER, being built in France. Due to its size and complexity, ITER will also test key technologies for power stations.

— The early success of ITER, and therefore the rapid development of fusion power, is highly dependent on the expertise built up by UKAEA Culham for JET. Indeed, JET must continue until ITER begins operation to maintain these skills and to prepare operational scenarios for ITER. If the UK's JET expertise is sustained and nurtured, it will ensure a central role for the UK in ITER's success.

— To position the UK to be a major force in developing fusion systems beyond ITER and to the point of commercialization, Culham has begun, with EPSRC backing, a gradual transition from fusion science to technology. The nuclear and heat exchange components of future systems are a critical focus because they will contain the most Intellectual Property and therefore have the most commercial value. Twenty years from now, the UK should be playing a significant role in the prototype stage of commercial fusion development.

— The key to achieving this ambitious agenda for UK fusion is the retention of highly skilled scientists and engineers and the recruitment and training of a new generation. At UKAEA's Culham site there are approximately 225 engineers and 135 physicists.

— Recruitment remains difficult in electrical and planning/project engineering. As we move more to nuclear systems engineering, we anticipate that recruitment will be at least as hard and we may have to look overseas for suitable staff.

— Training is essential since many of the necessary skills cannot be "bought off-the-shelf." Culham has several vigorous training programmes. Of the 52 PhD students at Culham in October 2007, 11 were in engineering & technology, four in materials science and 37 in plasma and related physics. For engineers, Culham has Graduate Development and Monitored Professional Development Schemes based on the UKSpec competencies giving access to chartered status. The Culham apprenticeship scheme was re-launched in 2005 and now has 14 apprentices.

— The synergies between fusion and fission engineering are substantial. Therefore, fusion development would benefit from the training of a new generation of nuclear engineers. And in turn, fission could benefit from engineering expertise nurtured in the UK fusion programme.

September 2008

Memorandum 116

Supplementary evidence from Adrian Bull, UK Stakeholder Relations Manager, Westinghouse Electric Company, following the oral evidence session on 16 July 2009

AGE PROFILES AT SPRINGFIELDS AND OTHER INFORMATION

When I gave evidence to the Committee on 16 July 2008, I undertook to provide some supplementary information, which I did not have to hand at the time. The specific exchange which led to this was as follows:

> Q213 Mr Marsden: You are talking about young people. I am being ageist on this occasion. I want to hear about older people. What are you doing for older women, for example?
>
> Mr Bull: I am not aware that we have any specifics —
>
> Q214 Mr Marsden: What about adult apprenticeships generally?
>
> Mr Bull: I would have to write to you with the figures on that. I do not have the break down by age profile of our apprentices. I know we have about 70 in the system at the moment.

Adult Apprenticeships

In terms of adult apprentices, we have only had one apprentice in this category—a male, who was a transfer from being a process worker to the "craft" side. Part of the reason for this is that the funding arrangements for apprenticeships are dictated, to a large extent, by the age of the learner, and this acts as a disincentive for the employer to promote adult apprentices. We would be happy to provide more details on this issue if it would be helpful.

Gender Balance

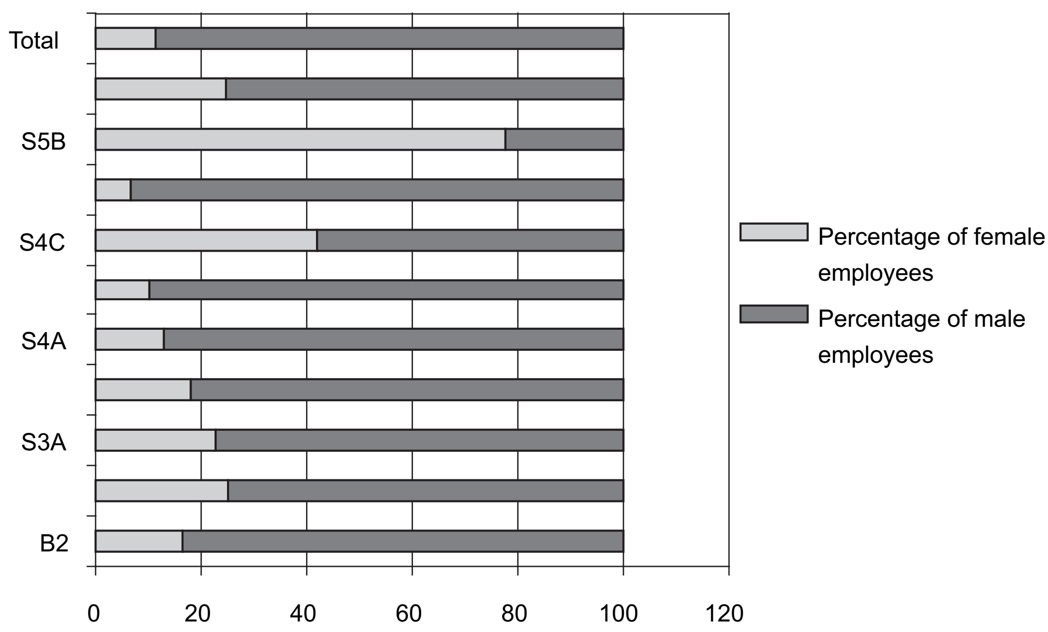
We find that external recruits into the apprenticeship programme tend to be school/college leavers. In that regard, we find that we have fewer applications from females. This is aligned to the overall gender split of the industry which, as the Committee are aware, tends to be male dominated.

To counter this, we have been active in trying to attract young females into the industry. For instance, we actively encourage our female apprentices to promote the scheme through school visits, or by attending open evenings at schools.

In terms of our graduate applications, we find these tend to come more evenly from both genders. However, the females still tend to be in the business areas and engineering is more male dominated. Again our graduates attend Young Generation Network activities, host YGN events, and promote the industry through supporting Young Enterprise activities out in the schools to promote the industry to both genders.

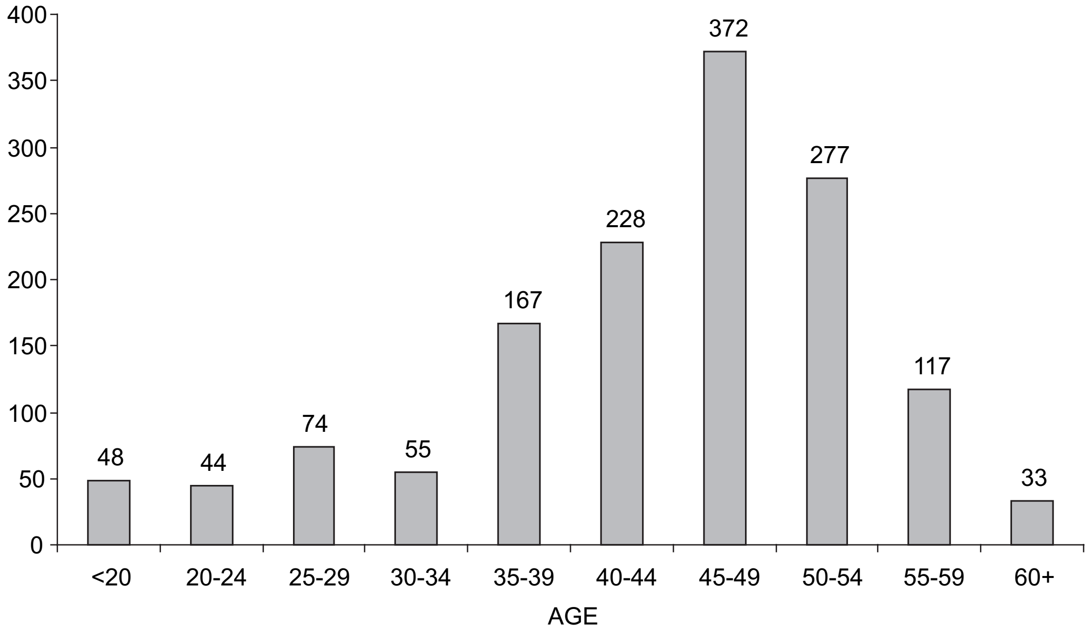
The gender split of our workforce is shown below. Overall 12% of our employees are female, but this proportion varies significantly in some grades. The chart below shows the split according to grade—with the overall figure shown in the top bar, and then grade-by-grade, with the most senior (B2) being shown in the bottom bar.

The S5B grade, where there is a very high proportion of females, comprises only nine individuals—seven of whom are female. The S4C level which is around 40% female, has around 60 people, and covers a number of secretarial and administrative posts, among other roles. It is pleasing to note that in the senior grades the proportion of females is averaging out at around 20%.



AGE BALANCE

Overall, the age profile of our workforce at Springfields is as shown below:



This profile is—to a large extent—a consequence of the boom period of the nuclear industry in the late 1960s and 1970s, when we, along with most nuclear companies, took on a substantial number of new young recruits. The subsequent fallow period during the 1980s and 1990s was a period during which our level of business tailed off along with natural wastage from the workforce, so there was relatively little new recruitment over that period.

This same issue exacerbates the gender split—we have a much more balanced intake nowadays then was historically the case, but our overall workforce demographics mean that the gender balance is dominated by the characteristics of our recruits from 20–30 years ago.

TRAINING

On the training side, the Committee will wish to know that we carry out a lot of internal training for all employees—not just for new entrants. Training in safety is a key priority for us, and such training is applicable to all ages. Close to 1000 employees on site have undertaken some form of IOSH safety training during the past three years.

We are also currently planning the roll-out of training in the "Westinghouse Fuel Manufacturing System", which will be applicable to all employees at all ages.

TRANSFERABILITY OF SKILLS

On this topic, it is worth mentioning that some of the work of the National Skills Academy for Nuclear (NSAN), such as the Skills Passport, will be making it easier for staff to work in different areas across a site, or indeed to carry out assignments in different companies.

Springfields has completed a pilot for NSAN on the introduction of the Nuclear Skills Passport and is a member of the steering group for the development of phase 2 of the passport project. The passport will enable the transfer of workers around the sites with much more ease than currently happens. The training provided will be accredited to a common standard and this will result in a reduced requirement for training each time a person moves to a new site, as an individual will have recorded on their passport the training that they have already completed.

SUPPLY CHAIN CONSIDERATIONS

I would like to add one piece of additional information to support a point I made under Q188. I was asked about the UK's ability to be sure it could count on resources, and I made the point that as the talk starts to get closer to being real orders, so the resources will be ring-fenced to meet those orders. The relevant quote from my evidence is:

> "…We as Westinghouse are not going to make contracts with anybody that we cannot honour. Once we sign up and get customers lined up we will start to focus on ring-fencing our resources, both in terms of human resource and in terms of our ability to source the heavy components and so on to make sure that we deliver."

I have checked up, and I am able to advise the Committee that there has been more than one occasion when Westinghouse has turned down proposals from potential customers (or decided not to bid on a tender when invited) because we could not deliver to the timeframe requested without going back on commitments already made. In addition we have turned down several discussions with countries that we did not feel were yet ready to take forward their first nuclear power plant.

At the time I was not sure how much of this information might be commercially sensitive, so I was unable to offer this at the time, but I hope that by adding it now it reinforces the point I made. I am afraid I am not able to name the companies or countries involved, for commercial reasons.

Finally—there is one error on the draft transcript, which I have only just spotted on re-reading it, as I prepared this response. Question 186 was directed to me and I responded in some detail. Yet the follow up question reads:

> Q187 Chairman: So you are confident you can deliver?
>
> Mr Davies: Yes.

I am pretty sure that the question was asked of me, and therefore that it was me who responded "Yes". Any other turn of events would have been surprising. If it is not too late to correct this, I think it would be helpful to do so.

If any of the above information is unclear, or if the Committee would like any more detail, I will be happy to clarify further.

October 2008

Memorandum 117

Supplementary evidence from Ms Fiona Ware, Vice President Operational Excellence, AMEC's Nuclear Business, following the oral evidence session on 16 July 2009

You requested that I respond in writing to comment on the long-term skills that are of national importance but which are not funded by industry (Q163).

For future success, UK companies will require a strong capability and position in the provision of front-end, high added value skills to build a competitive advantage over other organisations in a rapidly growing international nuclear marketplace. To ensure future UK plc commercial competitiveness, these skills need to ultimately reside in the private sector, unless there is a change in Government policy to create a nationalised nuclear industry.

Because of the long term nature of Nuclear Technology development programmes, there is a reluctance for private sector organisations to invest because of the long return periods. These technologies are increasingly the subject of joint international development programmes generally supported by national government programmes. Under these circumstances, the private sector will not hold any IPR associated with these developments and hence it is even more difficult to make a business case to invest. However, the skills developed during these programmes will be required in order to allow us to bid for work in an international market place. We therefore need a programme to foster and develop the critical skills areas for the future otherwise, as a nation, we will be wholly dependant on overseas technology providers and therefore vulnerable in terms of security of supply and future competitive positioning in the industry.

This leads to a skills and technology development model with the level of investment by the private sector increasing as the skills and technology move towards commercial deployment. It must ensure that the future long-term skill requirements are identified, nurtured and progressively deployed into the UK supply chain. Long-term initial technology exploration (such as fusion science) or UK specific technology developments (such as radioactive graphite disposal techniques) will be best handled through the proposed National Nuclear Labs. The latter technology once proven can then be made available equally to UK companies via the NDA for competitive bidding for implementation, thereby ensuring best value for the taxpayer in pursuing the UK decommissioning programme.

Critical areas for investment to give UK plc commercial competitive advantage for the future in a global market place and associated supporting programmes are:

Reactor Physics GEN IV;

Advanced Materials—EU Framework programmes;

Waste Management techniques—NDA;

Actinide transmutation;

Fuel Strategy—links GNEP;

Reprocessing technologies, eg Molten Salts;

Waste Characterisation; and

Waste form stability /degradation (Repositories).

It is in these areas that skills must be built in UK private sector companies to establish a competitive position for the future. This can be done competitively through a bidding and award programme for research and development grant funding. This will then drive competition in the marketplace to maximise the level of funding from private sector companies, reflecting the transition to maturity of the technology in a commercial environment.

September 2009

Oral evidence

Taken before the Innovation, Universities, Science and Skills Committee

on Wednesday 18 June 2008

Members present

Mr Phil Willis, in the Chair

Dr Roberta Blackman-Woods	Dr Ian Gibson
Mr Tim Boswell	Dr Brian Iddon
Mr Ian Cawsey	Dr Desmond Turner

Witnesses: **Professor Sir Richard Friend**, Cavendish Professor of Physics, University of Cambridge, appearing on behalf of the Institute of Physics, **Dr Ian French**, Philips Research Laboratories and **Dr Sue Ion**, Vice President, The Royal Academy of Engineering, gave evidence.

Q1 Chairman: Welcome to our first panel of witnesses to the first evidence session on a case study of plastic electronics engineering, which is part of an overall inquiry into engineering which the Innovation, Universities, Science and Skills Committee is undertaking. I welcome in particular Professor Sir Richard Friend who is here on behalf of the Institute of Physics. Welcome to Professor Sue Ion, Vice President of the Royal Academy of Engineering, and an old friend of the Committee—sorry, a friend of the Committee, who is here quite often! Welcome to you, Sue. Last but by no means least, welcome to Ian French of Philips Research Laboratories, who is here representing himself today and certainly is not here in an official capacity on behalf of Philips Research Laboratories.
Dr French: That is correct.

Q2 Chairman: I confess that when plastic electronics was mentioned as an interesting area by Sir David King, at his valedictory session with the Committee, before he stood down as the Government Chief Scientific Adviser, it was he who said that this could be the most exciting development for UK plc. Logystx UK said in evidence to us: "Plastic electronics will disruptively impact every aspect of conventional living across the globe over the next decade." What did they mean, do you think, Dr French?
Dr French: I think they have taken some basic developments and extrapolated far, far too far. I think that plastic electronics has potential in relatively small areas short-term; and these areas would have to be very successful before it could be extended to much larger areas. For instance, David King said that it could replace silicon chip technology. If that happens, it is beyond 25 years from now and the plastic electronics then will be unrecognisable to the plastic electronics we have today. I think that the case has been very overstated.

Q3 Chairman: Professor Friend, do you share that pessimism of this new exciting technology?
Professor Sir Richard Friend: No, I do not. I think one has to look back to see how radical technologies innovation has been and understand that what we take as technology here for ever is not a wise course of thinking. You can look at almost any aspect of current electronics and reckon that it is a pretty crazy way of making things, and a lot of it is very susceptible to revolution. I do agree with the statement that it would not be wise to try and replace silicon in areas where silicon works very well; but the opportunity is to take electronics into areas where it currently does not play.

Q4 Chairman: Like where?
Professor Sir Richard Friend: At the moment, in order to make a circuit with electronic devices in it, you really have to make it on a very stable, expensive substrate—a slice of a silicon crystal, or a sheet of very expensive glass—and that means that these are prized items that have to be placed carefully and used carefully. If, on the other hand, we can have functionality painted or printed everywhere, then there are huge ranges of applications for semiconductors that are currently not served.

Q5 Chairman: Dr Ion, does it have remarkable potential to be disruptive technology; in which case, what do you consider is the real potential from your own point of view and from the Academy's point of view?
Dr Ion: From the Academy's point of view, and indeed from the view of the Council for Science and Technology, which undertook a report on the plastic electronics area as part of a wider study for strategic decision-making for technology policy last year, we have seen plastic electronics as a disruptive technology, one that would have application in many areas from medical devices right through to retail and fashion, through to potentially new forms of photovoltaic cells—so a very broad spectrum of products and processes together, and therefore worthy of strategic investment by the UK because of the academic lead in many of the essential elements to get towards these products. We thought it had a very large potential. The timescale though, because of the variety of products and processes, is less predictable. Some will come earlier to market and some will come out in 15 or 20 years or maybe

beyond a 20-year time frame. That is why we classified it as high potential, high risk in the report that we wrote.

Q6 Chairman: What do you think are the limitations and bottlenecks? We were excited by David King's vision—and I take the point you are making, Dr French—but let us just get excited for a little while: what are going to be the bottlenecks; what will stop us really making the sort of progress, even over the next 25 years, that these disruptive technologies can bring? I know that Professor Friend may have different views. I am coming to him in a moment.
Dr Ion: Access to capital is a key issue to get you from good laboratory scale work through to a prototype that you can then industrialise. That is true of many areas in the UK where there has been high potential and where traditionally big, vertically integrated companies would have been able to make those kinds of investments. They would swallow the hits as part of their long-term R&D investment and they would get you from lab to prototype, where the design may change significantly in order to industrialise it to enable mass manufacture. That is a bottleneck for this sector. The ability to bring together key players in electronics, electronic design, chemical engineering and material science, in order to deliver you the sort of products that you might envisage is absolutely essential; and it is not clear that the UK has the wherewithal to do that effectively. Initiatives like PETeC up in the north-east have that sort of aim in mind; but whether or not that investment is sufficient or geographically correct or whatever may not be enough.

Q7 Chairman: Dr French—come on now, be more positive here! I am pretty sure that you do see huge disruptive potential for these technologies, but what is holding this back?
Dr French: The main problem for disruptive technologies is always existing technologies. If you want to try and replace the functionality, it is very, very difficult for a disruptive technology to enter. If you want price reduction, you have to think of price reduction of a greater that an order of magnitude to justify disruptive technology, because existing technologies always improve and always get better and cheaper; so anything you are aiming at now will have moved on. The real opportunity for plastic electronics is in areas where you create new devices that currently do not exist. The first real application for plastic electronics will probably be in flexible displays. There are a lot of technologies being developed to make them in different companies, and there are lots of permutations, but you need a new application area for disruptive technologies to really take hold. Once it is established, and once there is the infrastructure and the knowledge base, then it can probably be spread out sideward. A lot of proposals for what plastic electronics will do, apart from the plastic displays, will be largely for replacement technologies. LCD is getting better and cheaper all the time. Electronics and functionality are getting faster. More and more TFTs, transistors, crowd into smaller areas. It is very difficult for new technologies to compete in an existing area.

Q8 Chairman: Obviously, Professor Friend, displays is an area where this technology is currently envisaged; and yet when we received evidence from the TSB, they did not believe that it would play at the high end of this market; that it would not fit into that high-end space. Do you agree with that?
Professor Sir Richard Friend: If you are looking at where a relatively radical technology is going to get into the market place, it is not going to be, as Ian French has said, as a replacement of something existing; you have to go in with new functionality. The e-books space looks very attractive, where the chance of having something flexible and not breakable and easy to read is very appealing. Once it is established, that will then reduce the cost base or improve the quality of manufacturing. Off that, doubtless other applications will flourish. That has been the pattern all the way through. If one looks at what was done with thin-film silicon that is currently used to make transistors for liquid crystal displays, that was originally produced as a kind of curiosity, as little solar cells in Japan; but it turned out that that gave them the competence to be able to translate it into making large areas of transistors. Along came liquid crystals in need of an active matrix backplane technology, and off it went. No-one looking at the state of that early application for amorphous silicon would have foreseen what it turned out to be very important for. We have to recognise that we are at an early stage of this technology. We can identify that there are all those indicators to say that it can be disruptive; that it has reached a level of manufacturing competence that it ought to be able to find its way into some useful products. Beyond that, everything is possible.

Q9 Mr Boswell: Following on from that, I think that the Members of this Committee with a humanities background will be rather tickled to know that e-books are a likely runner, as you have identified. I just wonder if the other two wanted to give their own thoughts about areas that they see as being relevant to this. Could it be, for example, that plastic provides the option for overcoming some of the constraints in relation to medical devices, for example, that might have to use silicon?
Dr Ion: The area of medical devices in its widest sense was an area that was discussed with us when we looked at it—for example, smart bandages, where you are able to put an electronic carrier on that would send signals that are very cheap—and so in health service space, throw-away. That is only one area. There is potential yet to be realised, but medical devices certainly, and wider than I have just described.
Dr French: My main activity is in plastic displays that we are trying to industrialise through a Taiwanese company. I spend a lot of time looking for applications. There is a range of smaller specialist applications like intelligent bandages, maybe implantable drug delivery—where having flexible

electronics compared to silicon is advantageous in a large area—and plastic imaging. I see potentially lots of small specialist areas that may be more suited for the UK, with high added value. Personally, I do not see any large break-through areas.

Q10 Mr Boswell: I wanted to ask a question about the people end of this in areas of operation, as to whether or not this is research or whether it is realistic to look at long-term manufacturing in the UK because of levels of expertise that are difficult to reproduce elsewhere—but also, given that we are looking at engineering generically, researchers in this field—do they think they are engineers? Do they call themselves engineers and what is their typical profile? Are these materials scientists who have got some electronics or are they electronics specialists who are looking now at materials or something else? What is the pattern of this?
Professor Sir Richard Friend: At the moment this is not a well-recognised mainstream occupation, and the strength is that it has been hiring into it people from many different backgrounds, from chemistry, from materials science and a significant amount of physics, and increasingly from engineering of all sorts. That is one of the areas where the UK does very well; that we do seem to be quick to be able to pull together these different skills.

Q11 Mr Boswell: You can make a team with the various areas of expertise!
Professor Sir Richard Friend: The evidence seems to be that in the larger early-stage industrialisation activities in the UK we have been very successful in hiring really excellent teams that do have this breadth.
Dr Ion: I would agree with what Richard has said there. Traditionally, in the United States you would probably find this sort of activity in a materials-science and engineering department where the breadth of coverage would encompass that which you would expect to see in the plastic electronics arena. In the UK, as Richard said, many of the current experts have their origins in physics departments or in electronics departments, where people with an interest in nano electronics have decided that this is a rich field of research for them. EPSRC's initiative to bring together multi-disciplinary work under this sort of banner is also quite helpful in bringing together materials scientists, physicists, chemists, chemical engineers and electronics experts to move towards challenge-based initiatives rather than particular narrow areas of research.
Dr French: I think you need a whole range of experts from very narrow specialists that typically work on materials, to generalists, to systems people and a whole range. They can be pulled together if there is an interesting proposal for them. Plastic Logic has shown that very admirably.

Q12 Mr Boswell: Is it an area where it is too early to organise representation in terms of either authenticating professional expertise or, dare I say, lobbying government or research councils?
Dr Ion: Lobbying for its own sake it is difficult to justify; but initiatives that would move the platform along, and not consider it as a narrow area but consider it as it is, which is a very broad spectrum of technologies with potential uses and different process routes to market and different products to market—because you do not know which one is going to win out. Richard gave an earlier example in the silicon-based area—it is important to treat it as a platform and not something that is narrow.

Q13 Dr Turner: Can I go back to a very basic question? Can you define for us in terms that an intelligent layman might understand, just exactly what plastic electronics is?
Professor Sir Richard Friend: Everyone will give a different definition. To go back to what I said earlier, traditional electronics requires that you manufacture—usually at high temperatures on to an extremely rigid substrate. That limits the materials set you use, and it particularly limits the substrates you could use. We would like to deposit or print a wider range of materials on to a wider range of substrates, and a way of doing that is to use materials that one would call "plastics", that is more correctly polymers, that would provide the semi-conducting behaviour. They are not unique. There are interesting developments with nano crystalline inorganics, which can be processed in the same sorts of ways. I would describe plastic electronics as the move away from the traditional semi-conducting manufacturing environment towards a large-area, low-temperature process, which enables flexible displays or, for example, low-cost solar cells, which I believe will be a very important area in the future. It is fair to say that the difference in principle is not one of electronic principles but of materials and fabrication methods.

Q14 Dr Turner: Can you envisage any situations where you might want to produce a hybrid product, which embodied both traditional solid-state electronics and plastic technology?
Professor Sir Richard Friend: If you were to look inside the prototypes around at the moment, they embody both technologies; but there are the bits that you want to have plastic and flexible, and of course there is considerable need for innovation of the conventional bits of silicon that might provide some of the drive support for the device.

Q15 Dr Turner: Are there applications where the organic semi-conductor can have such advantages over silicon-based or inorganic that they will essentially out-perform not necessarily in physical performance but commercial performance? One obvious example is photovoltaics, which are extremely expensive to manufacture using traditional technology; but is there potential for making an order-of-magnitude reduction in the manufacturing cost of photovoltaics?
Professor Sir Richard Friend: There is. There is an interesting figure of merit which is the right one to use for solar cells, and that is: if you buy a solar cell and put it on your roof and leave it switched on all

the time so that all the electrons are used to displace carbon-generated electricity, how long should you have to have it on your roof in this part of the world before it has repaid the carbon debt involved in making it and putting it there? The figure I hear for silicon is five years, which means that most silicon solar cells do harm to the environment and not good, if they are not switched on all the time. We have to reduce that period of time by an order of magnitude, and I think that will be very hard to do with silicon; I think that it will need a radical technology, and plastic electronics in its broad sense is probably the way that is going to happen.

Q16 Dr Turner: What about medical applications? Would it be possible, using plastic technologies, to produce, say, an automatic pancreas that you could implant in a diabetic—that sort of application?
Professor Sir Richard Friend: I am not particularly expert in that area. I think one has to be very careful to understand what the advantage is. It may be an issue of bio-compatibility, and there are certainly some organic conductors that appear to show good properties in that respect; or it may be about flexibility of the final structure. The thought of being able to make something as complex, where there are all the physiological operations as well, is certainly challenging. It may happen!
Dr Ion: When you are looking at plastic electronics it is important not to look at it as a competitor to silicon but something that is different. The silicon-based industry has moved for many years now to higher and higher device performance, and smaller and smaller means to achieve that. At the moment the response in the plastic electronics arena is nothing like as good as that, but it will improve over time. That is where the innovation in the electronics side, coupled with things like printing technology and mass manufacture of much larger devices, will come into its own. Very simplistically, you could envisage a plastic sheeting that is rolled out across rooms, which is able to be deployed as photovoltaic delivery of electricity. It may be quite some time off, but it is that kind of challenge that will bring together the electronics experts, the chemical engineering experts and the materials experts to hit a challenge of that type.

Q17 Dr Turner: We have discussed two obvious areas of application. Dr French, can you tell us something—
Dr French: Can I make a comment on plastic electronics? To me, plastic electronics is really thin flexible devices, and they can be made by a whole range of different techniques, including organic and inorganic semi-conductors. I do not think that polymer TFTs will be the successful technology in the long run; and that will be decided by the market and the industry over the next few years.

Q18 Dr Turner: We talked about two examples of possible areas of application, which essentially use functionalities or desired functionalities we are already familiar with. You rightly suggested that to get real disruption you have to introduce new functionalities that at the moment we have not even dreamt of. Can you give us some examples?
Professor Sir Richard Friend: It may not meet your criterion, but lighting is a very important area where there is obviously a huge premium now on energy efficiency. Semi-conductor, light-emitting structures, both inorganic and organic, appear to be able to offer more efficient ways of converting electricity into light and are vastly more efficient than current technologies.

Q19 Dr Iddon: Plastics become brittle over time, as the plasticisers in them leach out. Is there any evidence so far about the stability and durability of plastic electronics devices, or is it too early days?
Professor Sir Richard Friend: There is no single statement about how stable a plastic is or is not. The evidence to date is that you can take a technology that emerges out of a university environment, where it lives for a day, good enough to get a letter published in *Nature* but not enough to make a technology; but you can spend some tens of millions doing some proper engineering and then the transformation of performance is absolutely spectacular. The original light-emitting diodes that were made in Cambridge in the early 1990s would last for long enough to get our letters published in *Nature*. They now last for in excess of 100,000 hours, which is a very long time. The message that I picked up when starting my life as a physicist is that one should never under-estimate the power of engineering to convert something that appears not necessarily to be promising into something that is spectacularly good.
Dr French: I think all the indications are that the plastic electronics being developed will be good for lifetimes of five to 10 years and probably beyond.

Q20 Dr Iddon: Which is probably as long as the device is needed!
Dr French: Yes, I think so.

Q21 Dr Iddon: Another concern, particularly of younger people, is the environmental friendliness of new devices. Can you compare the environmental friendliness of existing silicon devices with future plastic electronics devices? Are there any advantages to be gained on disposing of the devices, for example?
Professor Sir Richard Friend: There are two aspects. The first is the environmental unfriendliness of making it in the first place; and that is both the energy used and the chemicals used in making it. The silicon industry is notoriously bad in that respect because it uses some very toxic chemicals and huge amounts of energy, but what we are calling plastic electronics should be an order of magnitude better. The devices themselves contain less material, and most of it is carbon based and essentially it is non-toxic, so disposal should be relatively trivial.
Dr Ion: I would not disagree with what Professor Friend has said there.

Dr French: I think most devices you make will only be hybrids anyway for the next 15 or 20 years, with very, very small areas of silicon giving very fine functionality and computing, and a larger functionality at lower levels being given by plastic electronics. If you take the total hybrid on its own, then I think having an book keyboard compared to paper-making, shipping books around the world, printing and disposal, will give us significant environmental benefits.

Dr Ion: The plastic electronics component of new devices and new products will probably be small in the overall scheme of things, so the overall environmental impact of the total product is likely to be greater than that of the plastic electronics component of it.

Q22 Dr Blackman-Woods: I have seen some of this research in Durham on lights and materials, and it looked pretty exciting to me, I have to say! Some of the academics at Durham expressed to me that it is quite difficult moving from the laboratory into manufacturing. Do you think that is true? What is the biggest challenge in doing that?

Professor Sir Richard Friend: I think that question has in part been answered earlier in respect of the need for capital to be able pay for what can happen in the early stages of a recession environment. The current challenge we have is that across the West we have lost the large corporate R&D labs. Bell Labs has gone. We never quite had Bell Labs! We do have a much better R&D base in the universities than we used to. The UK is rather good at the moment. The challenge is in understanding the instruments that are needed, and it is not just government money in various forms but it also needs to come from the markets to be able to those next stages. I do not believe it is a skill shortage that is critical; it is more capital and management commitment.

Dr Ion: It is not just the financial aspects; it is bringing the right players together at that point in time. Whilst the initial breakthrough might have been in the physics or the materials science or whatever the proposition is, the delivery of it to the marketplace will involve manufacturing of some sort; so the addition of relevant mechanical engineers and electronic engineers at that point to industrialise the process is absolutely essential. That is an area where we have not been as good as we could have been at bringing the right people together and financing their activities.

Q23 Dr Turner: You have outlined what is essentially a generic problem in the UK with, for want of a better word, the innovation process and its capital input. It does not function, and so we have lost out in many areas, and other countries then reap the commercial benefit. Can we make a case to institutions that if UK plc is to benefit from plastic electronics, then it has to do something about its capital provision processes? Do you think that the new engineering technology—is it board or institute—I can never remember because we create institutions with such rapidity—

Dr Ion: The ETI.

Q24 Dr Turner: The ETI—has the potential to fulfil the function you have identified; and have you made that case to it?

Professor Sir Richard Friend: I have to say that I do not know in great detail what the ETI is going to do, but my understanding is that it is likely to put support into existing industries because a pre-requisite is that there be a large company that puts its support in. I am not convinced that it is an instrument that is likely to nurture new technology across into the manufacturing environment. I believe it has been created for a different purpose.

Dr Ion: I think the jury is out on that one. Richard is right that the combination of private sector and public sector monies into it—given the way it has been set up you would think it ought to yield some demonstrated benefits. However, because of the influence of the private sector and its wish to have certain technologies pushed forward as part of their right of passage, then it may well still not do what you want it to do, which is to allow interesting and innovative energy technologies to get beyond that research and early development stage, out to a point where they can be successfully deployed. It is the energy sector—and the plastic electronics arena covers a much wider sector than just energy. It is clear that something has to move. We just do not seem able to get beyond the valley of death in the UK, where universities get to a certain point and then cannot get any further.

Professor Sir Richard Friend: If I am allowed to make a parochial plug for Cambridge, the capital markets in Cambridge have been relatively successful, not just in the plastic electronics sector; but there does seem to be some ability to raise money to have got a number of technologies to a relatively large scale.

Dr French: I think Dr Blackman-Woods's comment was very interesting because one thing that is capital, but also manufacture is getting harder as we have less manufacturing in the UK. NESTA talks about hidden innovation: there is a lot of knowledge in making things that is not captured in research labs, and it is getting harder to transfer things into manufacturing.

Q25 Dr Blackman-Woods: Can I go back to the point you made, Sue, about bringing engineers into that process. Why is that not happening? Is it because of the organisation of universities, or because they are not available, or does this only happen when the technology goes out to be commercialised? I would like you to say something more about that?

Dr Ion: I guess it is at the point where you decide you are going to make the investment in the prototype and beyond stage, which, if the finance were there, would automatically bring those sorts of people into play. It is not just the availability of the money; it is the timescale to get it. If you look at the initiatives that we already had in place in the UK, it has taken a long time to get them to realisation. Even with PETeC in Sedgefield, it has taken a long time to get it to where it is even beginning to have a point to make. We are behind the pace in other areas. Plastic Logic, and its investment in Dresden took 15 months from nothing to a working factory! We just do not appear to be able to do that in the UK.

Q26 Dr Blackman-Woods: One of the points that UK Displays and Lighting make is that academics here do not have access to research facilities and materials in the UK. Is that the case, do you think?
Professor Sir Richard Friend: I do not believe we are disadvantaged. I think the UK academic sector is relatively well placed.
Dr French: I have visited lots of research institutes in Japan, Korea and Taiwan; they are different, but I do not believe the UK is that disadvantaged, personally.

Q27 Dr Blackman-Woods: We have mentioned the plastic electronics technology centre at Sedgefield. I was very interested in your comment as to why geographically that could be a problem. It is just outside my constituency, but I am very glad it is there, I have to say! We are expecting great things of it. Will that help improve access to research facilities, do you think? Will it help commercialise some of this research—and what is wrong with where it is?
Dr Ion: I am not saying that where it is is wrong *per se* in terms of regionally, but when you look at where you would choose to site things, in terms of where there is an existing lead, then the Cambridge endeavour and what has been done there is a very big success story, with not a lot of public money in taking it forward. The north-east initiative is potentially a good one. You are effectively asking everybody who was a player in it to move to the location that is identified. There is expertise in Newcastle; there is expertise at Durham and there is expertise in Teijin and the other big chemical industries that are around the Teeside area—so everybody has to move to take part in the Sedgefield initiative.

Q28 Chairman: They would have to move to Cambridge—
Dr Ion: That was not the point I was making, Chairman! It was just that—why would you not choose to site it more closely to one of the players in the region that was an existing player and make local transport easier not national transport necessarily?
Chairman: I am rebuked!

Q29 Dr Blackman-Woods: I just thought I would sidestep that and say why it should be absolutely where it is, but I am not going to do that. However, the question is still: will it help?
Dr Ion: It should because one of the areas of weakness is the area that PETeC has been set to address, which is basically a small prototype factory where you can plug and play, where you can have your ideas for commercialisation, for industrialisation, in what has hitherto been in one of the universities or even the industrial sector located close by, and actually try it out. The scope is there for there to be a number of different prototype units at any point in time; so the benefit it ought to bring will be technicians, who are multi-skilled and able to switch from one area to another; and a general scientific knowledge base that is able to help those who are seeking to commercialise get there faster, so it ought to work.
Dr French: I think there is a more fundamental problem—not where it is but whether it is doing the right thing. In the area of plastic electronics there are several different permutations of materials and manufacturing techniques that have been tried by different establishments and companies around the world. PETeC has chosen a very specific one, which is roll-to-roll manufacturing of organic semi-conductors. If in five years' time that is proven to be the wrong technology to back, then it would not matter where PETeC would be; it would be a failure.

Q30 Dr Blackman-Woods: So it needs diversification.
Dr French: I think it is wrong to try to second-guess the industry at the moment as to which will be the dominant technology in 10 years' time.

Q31 Dr Blackman-Woods: That is interesting! We are picking up that this area of research is being hampered by the fact that it is not really recognised by the RAE in the research on materials and process.
Dr French: I think the UK is doing rather well so far.
Dr Ion: The recent RAE exercise took into account the ability to do inter-disciplinary research as well as to do the normal mainstream single discipline research. If the panels have done their job properly, then they will have taken it into account and the industrial interest into account and the inter-disciplines into account. The jury is out because we do not know what the outcome is but they ought to have taken that sort of initiative into account.
Professor Sir Richard Friend: I am not aware that the RAE has influenced this positively or negatively.

Q32 Dr Blackman-Woods: Where should we say the key institutions leading research are—or can you suggest three that we should go and look at?
Professor Sir Richard Friend: There is a useful list of active institutions in the assembled evidence that you have, simply in terms of people on the ground doing research. The two largest are Cambridge and Imperial College, but there is very distinguished work distributed around the country, and Durham is certainly one of these.

Q33 Mr Cawsey: I want to go back to manufacturing. We know about Plastic Logic going to Dresden because of the 15 months and, as you said, we do not seem to be able to do that in the UK. Is that a God-given decree so there is nothing we can do about it? Do you envisage that we will end up with mass manufacture of plastic electronics in the UK; and, if we are going to, what steps do we need to take to ensure we can do what other countries already are?
Dr Ion: In general terms there is no reason why manufacturing could not take place here in the UK. It is not an established industry world-wide. It has potential for modularity and a number of modules—

small manufacturing pieces of a value chain—before a product is brought to market—not necessarily the mass investment that is required for a silicon fab, say—so you are talking of tens or hundreds of millions of investment as opposed to billions of investment to take it forward. Capital investment is high, but the differentiator between the Western world and Asia is getting less as expenses rise in the Asian market place. There is no reason why the UK could not play a role in manufacturing in a yet-to-emerge market. We need a faster way to get integrated, joined-up decision-making. At the moment people have to go to many different places to get the money together—a mixture of central government, RDA and private sector. I do not have any magic answers here, but it just seems there ought to be some merit in looking at how moneys are released, tax benefits given, *et cetera*, to make the decision chain an easier one—a one-stop shop instead of a many-stop shop—for an emerging SME that might become a larger company.
Professor Sir Richard Friend: It is dangerous to argue from the particular, which was the decision of Plastic Logic to go to Dresden, to the general. There are examples of manufacturing going on in the UK, and there is some mention in the submissions of G24i, the company in Wales attempting to produce novel solar cells in a large area of technology—not exactly plastic electronics but nearby. I do not know why that came to be in Wales, but presumably the capital and manpower was found to be attractive. On the whole, I would take comfort from the fact that Plastic Logic went to Dresden and not to Asia. I do not believe that the fundamentals in Germany are very different from those in the UK. We should perhaps learn from the Dresden experience and take that as something we ought to be able to replicate here.
Dr French: I do not see manufacturing of plastic electronics as being significantly different from other forms of manufacturing, so I imagine that high-volume manufacturing will tend to be done more towards Asia, and there will be significant small specialist manufacturing in the UK. I am not an expert, but I think small manufacturers need a whole raft of help from the Government still, in changes.

Q34 Mr Cawsey: Can plastic electronics be considered purely a printing process? Is that a desirable way to describe it?
Dr French: No. The technology I have invented that is being commercialised in Taiwan at the moment uses traditional TFT LCD factories to make plastic displays. The displays are made on a glass substrate and then released by a data process, but the end result—the product that would be delivered to a customer would look identical to the Plastic Logic TFT devices that are made by printing.

Q35 Mr Cawsey: I understand that plastic electronics devices can be printed at room temperature as opposed to silicon being in fabrication plants. Is there going to be a long-term requirement for fabrication plants and do we utilise the ones we have in the UK to the full extent?
Professor Sir Richard Friend: This is existing silicon plants?

Q36 Mr Cawsey: Yes.
Professor Sir Richard Friend: There has been some recycling of these in the Polymer Vision activity—a former Philips plant.
Dr French: I think that this plant has become redundant and it will either be discontinued, or hopefully we will find new uses.

Q37 Mr Cawsey: It strikes me—and this is particularly true of this sector—that one of the things we do well in the UK is R&D and coming up with ideas, but then the manufacturing of them in the end is done elsewhere, for all kinds of reasons. We saw the silicon semi-conductor industry establish some fabless companies. Do you think in plastics that will be the same in the UK?
Professor Sir Richard Friend: I enjoyed reading the submission from Teijin Films, which pointed out that in the LCD industry the two most profitable companies are not Asian. One of them is Merck, that is principally in Germany but also in the UK, that sells liquid crystals into that industry; and the other is Corning Glass which has a unique technology for making the glass back panes and is extremely profitable. Those are materials technologies. There is no reason why the UK should not be an extremely successful model in the plastic electronics world.
Dr Ion: I agree with that. Going back to your point about re-use of existing silicon fab organisations, Innos, in their polymer division at Southampton, made very good use of an existing silicon fab factory down in the Southampton area, and that was part of the reason that they have been as successful as they have been and as speedy as they have been.
Dr French: I agree with what Richard says about materials. Materials can be provided to the display industry, but the question of design, the model for fabrics design—the amount of design content and IP content in the design of a display is a small fraction of that for an IC. At the moment, all the design for TFT LCDs is done on site by small design teams.
Chairman: Thank you very much indeed. I do not know whether to be excited or depressed at this moment in time, but we thank you very, very much indeed for your contributions this morning.

Witnesses: **Mr Mike Biddle**, Technology Strategy Board, **Mr Vince Osgood**, Engineering and Physical Sciences Research Council, **Dr Hermann Hauser**, Amadeus Capital Partners Ltd., and **Mr Fergus Harradence**, Deputy Director of Innovation Policy, Department for Innovation, Universities and Skills, gave evidence.

Q38 Chairman: Welcome to our inquiry on plastic electronics. We welcome in particular Vince Osgood of the EPSRC, Mike Biddle of the Technology Strategy Board, Hermann Hauser of Amadeus Capital Partners Ltd., and Fergus Harradence from the Department of Innovation, Universities and Skills. Welcome to you all, gentlemen. Can I start with you, Fergus? Funders such as EPSRC and TSB support plastic electronics research and development. To what extent do the funding arrangements of the EPSRC and TSB overlap so that therefore we are not getting perhaps the best bangs for our bucks—or do you feel there is not a problem?
Mr Harradence: I do not think that they overlap. The TSB and the EPSRC work together as closely as possible as part of a wider arrangement between the Technology Strategy Board and the research councils, whereby the research councils will align £120 million of funding with TSB activities over the three financial years of the current Comprehensive Spending Review period, starting from 1 April 2008 and running to 31 March 2011. The TSB and the Research Councils are both co-located in Swindon, and working relationships between the organisations are very strong. That is certainly the perception of the Department, and we seek to encourage that.

Q39 Chairman: Mike, in terms of funding, just to give the Committee a clear idea, are we talking about co-funding, or replacement funding, or overlapping funding? What is the mechanism for sorting that out?
Mr Biddle: The competition process itself is very collaborative. We have the proposals in; everything is marked on its merits by the independent assessment panel. We end up with a ranked list and then we go through that with the research councils to look at what they might fund and what we would then invest in separate to that. A recent example—the Advanced Lighting and Laser Displays Competition that we have just held was over-subscribed. Some of the money that came in from EPSRC helped us to put some more projects through, so that was a good example of where we do work together.

Q40 Chairman: Vince, the EPSRC report on investment stated you had £68.2 million in projects "of direct relevance to plastic electronics". What does "direct relevance" mean?
Mr Osgood: It means we support long-term basic strategic and applied research. We can identify within that £68 million of research, training and Knowledge transfer activities that feed in directly to the plastic electronics chain. Some of the things that Richard Friend mentioned this morning—the chemistry, physics, engineering and materials science that underpin plastic electronics, we can identify specifically. There are broader areas of chemistry, and other areas, even mathematics, that may in time relate to it, but do not have that direct link at the moment. It is things[1] that we can identify that are playing within the plastic electronics space that is the 68 million.

Q41 Chairman: We will come on to the funding of developments later with Hermann, but sticking with research at the moment, is there a tendency to be—if not quite picking winners in terms of research, actually moving in the direction of saying, "We are only going to fund this research council in those areas which we can actually see having some tangible benefit"? Does that not militate against your core mission?
Mr Osgood: Our prime criterion is to fund high-quality research. Unless it is high-quality research in whatever area, we will not fund it. You are right to say that there has been an increased emphasis in recent years on demonstrating that the research that we fund has an impact. That requirement has been there on the research councils since the original research councils of 1965. Certainly building on the White Paper of 1993, *Realising our Potential,* we said that the research that we should do should contribute in some shape or form to both the economic competitiveness of the UK and its quality of life. It has to be high-quality research first.

Q42 Chairman: You do not believe that has been compromised!
Mr Osgood: I do not believe it has been compromised. We have certainly given increased emphasis in our delivery plan over the next three years to a number of mission-focused programmes and cross-Council programmes in areas of national priority, energy being one, healthcare another, and security. All of those require high-quality research and training, and that is where the research councils come in.

Q43 Chairman: Fergus, talking about specific missions, were you with the old DTI?
Mr Harradence: Yes. Technically, I am on loan from the Department for Business, Enterprise and Regulatory Reform.

Q44 Chairman: You have just been loaned! Right—so long as you are not loaned to the Scottish Office we are all right! The DTI developed a proposal together with UK Displays and Lighting, for a managed funding programme for a very exciting programme for plastic electronics; and yet the proposal was never funded. Can you tell us what the stumbling block was there and the lessons to be learned; and is this something that could be funded in the future with perhaps TSB filling the void?
Mr Biddle: The programme that was discussed was prior to myself joining the Technology Strategy Board, which became an executive non-departmental public body in July of last year. What

[1] *Note from the witness*: "research, training and Knowledge Training activities"

I can say is that in regard to current investment of Technology Strategy Board money, some of it, in conjunction with Research Councils, amounts to £38 million to date, which is not a million miles away from that £50 million that was discussed as part of that investment programme. We look at things on a case-by-case basis. We always justify any investment we make against four criteria: can the UK do it; is now the time to act; can we add value; and is there a global market? You mentioned earlier about picking winners; I would not say we are doing that, but we are trying to pick people who make sure they can exploit the science and technology within it. It is all very well to do good science for science's sake, but at the end of the day we are trying to help UK businesses to make money. That is where we are trying to put our investment, and that is the amount of investment we have made.

Q45 Chairman: You listened to my earlier comment that part of the motivation for this particular case study was the comments of Sir David King. He spoke so passionately about this area, but there was a hidden criticism that I picked up in his comments to the Committee: that we do need to start picking winners, and that plastic electronics is a potential winner; and that unless we start to back it we will not move anywhere. Yet this project with UK Displays and Lighting, which seemed to be an incredibly exciting project, has just died a death.
Mr Biddle: The important part there, though, is that it is not just a case of throwing money at the problem—if you will excuse the phrase. That always helps, but, let us be honest; there is also a recognition in businesses themselves. I was at meetings with UK Displays and Lighting when they were discussing what they should be doing for the future, and some of those people have submitted evidence to this session. They recognise that part of the value-added is to try and attract new thinking into the area through entrepreneurship, business leaders and creative designers. There is an element where you can help by investing in the centre and there is an element—we talk about innovation climate in the Technology Strategy Board and part of that is making sure we bring people together. Our recent strategy was entitled *Connect and Catalyse* for that very reason: we recognise that although we have £1 billion to spend over the next three years in conjunction with the regional development agencies and the research councils, that that is just a pot of money; it is what you do with that and how you can leverage that investment for the benefit of the UK.

Q46 Chairman: The TSB has identified, quite rightly in my view—I do not speak for the rest of the Committee—a role for it in bringing things together and acting as this very, very strong broker, particularly in the plastic electronics industry, which is an emerging technology with significant potential, as we have seen. Clearly, you have identified that there is a lack of joining-up, but what is it that is not joined up?
Mr Biddle: One of the examples I can give is not in the plastic electronics arena but it is something we are doing through our innovation platforms, and that is to do with low-carbon vehicles. We are working on an integrated delivery programme that tries to do exactly that; recognising that there is a lot of good research going on in the science base; recognising that there is a lot of business-applied research going on; and also looking for businesses and venture capitalists to pull that through. Sometimes, seeing the pathway through that can be difficult for people trying to interact with organisations like ours. We are trying to show that there is a path there, so through that integrated delivery programme, which admittedly is in the low-carbon vehicle space, we are trying to achieve that joined-up approach which you mentioned.

Q47 Chairman: But you see that there is a need for that within plastic electronics?
Mr Biddle: I think the need there is for us to connect and catalyse. I know it is the tag line for our strategy, but we will look at investment decisions on a case-by-case basis with regard to whether we may have competitions *et cetera*; but there are things we are already doing. We need to be looking at what we are already doing and how we can leverage that. Part of that £38 million I mentioned was approved just last week, which is a large project totalling £12 million, and it is an investment of over £6 million by ourselves, which is not something that is currently public so I cannot announce it here, but the new investment now is in something that is very, very exciting for this technology area. That is something that we will continue to be interested in in the future.

Q48 Chairman: So you are excited by this!
Mr Biddle: I did pick up on that, whether we should be excited! I do think it is exciting. I think the UK has an opportunity within this. One point I would like to make, if possible, is that everyone always looks and says that we can do R&D in this country, but we cannot do manufacturing, but I am all for "bigging up" the UK and I think we should sing about ourselves a bit more. For example, in our high volume manufacturing strategy that we published recently we pointed out that by GVA[2] the UK was the sixth largest manufacturer in the world last year. People forget that and say it has all gone, but if you accept that fact and you do not fight for it then it is going to happen; and it is important that we try and champion it and make sure that things can happen.
Chairman: Hallelujah!

Q49 Dr Iddon: Mr Hauser, how important has venture capital been in starting up the UK's plastic electronics industry?

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[2] *Note from the witness*: "Gross Value Added, or the difference between the value of a company's sales and the cost of brought in materials and services, which is used as a measure of the economic contribution of businesses. DIUS produces annual Value Added Scoreboard comparing the top 800 UK and 750 European Companies by Value Added."

Mr Hauser: I am only familiar with two companies that are Cambridge-based: Cambridge Display Technology and Plastics Logic. In terms of the amount of capital we have raised in the CDT, I think it was in the order of £50 million—although this is a dollar-denominated industry so if I make a mistake in dollars, please forgive me. We have raised about £100 million, $200 million for Plastic Logic.

Q50 Dr Iddon: What made Plastic Logic, in your estimation, such a good investment? Was it people, invention or what?
Mr Hauser: Well, I am excited about this. In fact, I am very excited!

Q51 Chairman: This is the theme now!
Mr Hauser: You have to be a believer and put your money where your mouth is in this industry of venture capital. What I see is that although it might not blow the silicon industry out of the water tomorrow, the potential of plastic electronics is at least equal to the potential of silicon technology, which has been around since the 1950s and so has had sixty years to mature. We are just at the very beginning of plastic electronics, but it is such a historic and unusual event that practically 100% of our electronics is made out of a material called silicon and here we are at the threshold of a new material that the world accepts is a very interesting new way of doing it, which is a lot cheaper to produce and a lot more environmentally friendly, and addresses new products. It reaches the parts that silicon cannot reach and so you can make light, flexible e-readers out of it; and silicon systems cannot do it because you need a glass substrate, which makes the e-book brittle and too heavy. If you want a reading experience that is akin to paper, where you hold it in one hand and lean back and change hands and read it with the other, as we do with paper, then at the moment this is not possible with the silicon-based industry. I have a prototype in my briefcase—but this is a public meeting and we are only launching the product now so I cannot show it to you. I am happy to show it to you afterwards, and I hope that you will be very excited when you see it! It is the best quality I have seen to finally replace paper.

Q52 Dr Iddon: In your estimation, why could we not keep Plastic Logic in this country and why did we lose them? The point has been made earlier that it was better to lose them to Germany than to Asia, but why did we not spin them out as a manufacturing company in Britain?
Mr Hauser: This is a very good point, and I have been asked this question many times. The answer is that we did not lose it to Dresden. The best way of thinking about it is in a number of dimensions. First, where did the £100 million end up that we spent on this? The first £30 million or so was directly spent in Cambridge on doing the R&D and employing the people—and there are about 100 PhD level people employed in Cambridge. That is where a third of the money went. Two-thirds of the money is going to be spent in the factory in Dresden—but look at where that money went! That money did not go to Germany; that money went to the equipment that comes from Asia. As you rightly said, we have got to be very grateful that we managed to get this into Europe at all. When we looked for a site to put our plastic electronics factory, we worked together with KPMG on 290 different sites all over the world because, clearly, it is our fiduciary duty, as investors, to find the best possible production site for this. Wales was the closest in the UK, and it made it up into the top six out of the 207, so that was not bad—but it was a sad experience. The three final sites were New York, where we got the best subsidy and a free part of the East Fishkill, which was the big IBM research laboratory for silicon. We could have had that one for free, and the politicians said we could have fantastic subsidies, but we had to meet the Governor. I said: “I do not want to meet the Governor. Tell me the formula you use.” That left Singapore, where there was a clear formula: “You invest that much, employ that many people; this is the subsidy you get.” It was the same as Dresden: it was formulaic, so we could make a business plan out of that rather than having to go and sidle up to politicians. The final decision for Dresden was based on the following criteria—and then I will tell you how we almost came a cropper. The first criterion was the availability of highly qualified staff. Dresden was Silicon Saxony and that has 10,000 people employed in large-scale manufacture for AMD—the number two microprocessor in the world—100% of AMD’s microprocessors come from Dresden. They had shut down their Austin facility because Dresden was so much better. There is a large Siemens factory that employs over 5,000 people. So we had access to the right people who knew about high-quality, high-yield manufacturing, which is a skill honed over many years. The biggest surprise to me—because if you had asked me whether we were going to put this factory in Europe I would have said “absolutely no chance” when we started this—but when we arrived in Dresden we were met by the Burgermeister, the Mayor, and all his team. He said: “We really want you here. We want plastic electronics. It is a key strategic imperative for us to have this here—what do you want?” I said: “Well, in Singapore they are going to build us a factory in six months; can you build us a factory in six months?” He said: “Yes, sir. What else do you want?” This is Germany; this is Europe. I said to him? “Show me the last factory that you built in six months.” He pointed out the window and said: “See that building over there?” I said “yes”—it was a huge thing. He said: “This is the central distribution hub for FedEx for the Eastern Bloc—we built that in four months.” I said: “Okay, how do you get planning permission? If we try to build anything in the UK it takes a year before I get planning permission.” He said: “It is very simple, sir. We will give you planning permission to dig a hole. By the time you have dug the hole we will have all the other planning permission.”

Q53 Chairman: It is not like Harrogate—I will tell you that!

Mr Hauser: We signed this deal in May last year. They said: "We will have the building built in six months. They had it built in six months. We have put all the equipment in and we are switching on the factory in September. At the moment we are a week ahead of schedule. This is unheard of in Europe. The last reason, it must be said, of course, is that at that time it was the last year that they were a category 4 area in Europe, so they could give us more subsidies than anywhere else in Europe.

Q54 Dr Iddon: That is an interesting story, and I am sure there are some lessons to be learned there. It is a "can do" attitude, obviously, and I appreciate that. Are venture capital companies falling over themselves now to invest in this area of manufacture?
Mr Hauser: No, it is still a big risk. We have just managed to raise another $50 million, but it is still tough because you have to be a believer in this new category of e-readers and e-books. We believe that it is going to be the I-pod of text, but other people think that it might still take a few years yet.

Q55 Dr Iddon: You are interested in manufacturing devices. Would the venture capital industry invest in fabless production at the other end of the chain?
Mr Hauser: This is extremely rare; venture capital does not normally invest in manufacturing; this is the one exception we have made because it is so state-of-the-art. We normally only invest in very knowledge-intensive businesses, but here the factory is the first such factory in the world, so in that sense it is very knowledge-intensive. There was no factory that we could go to. As you rightly pointed out, what we would really like to do is to have a fabless model where we just go to somebody else to have it manufactured, but that was not possible here. I should just add that we were lucky that we finally ended up in Europe, because when we bought this equipment—and, as I said, most of the capital went to Japanese tool manufacturers—we asked them to deliver the tool to Dresden in Europe, and they said: "Sorry, we do not do Europe. We do not have factories in Europe and we do not have the CE mark." We actually had to pay for the CE mark so that they would deliver it into Europe.

Q56 Dr Iddon: Your three sites were Singapore, Dresden and Wales. It seemed that one of the important reasons you went to Dresden was the subsidy. Was that also available on the Welsh side?
Mr Hauser: It was, but not to the same extent.

Q57 Dr Iddon: How big a role does subsidy play in your decision-making?
Mr Hauser: In order of priority it was the availability of trained personnel, and that was in place in Dresden. The speed of response and willingness to work with us on a very, very tight timescale—again, Dresden won—and again the subsidy.

Q58 Mr Cawsey: Fergus, this is mainly for you. I want to talk a little bit about the small business research initiative. We talked to Lord Sainsbury some time ago now, and this was part of his review. There was some concern that this initiative is not as successful as its US counterpart, and his recommendation was that we should make it more so. Why has it been less successful in stimulating R&D than the American system?
Mr Harradence: I think that when Lord Sainsbury looked at this and wrote his report maybe identified three reasons. First, in the UK the initiative is seen as a stand-alone initiative for commissioning research across a whole range of areas—a lot of it policy-relevant. It is not seen, as it is in the US, as a process to facilitate and encourage technology development. That is the way that it is managed in the US, and it is managed in a fairly rigid way in order to achieve that objective. Second, the problem in the UK is that there is no link between SBRI and other support mechanisms and other programmes, and in particular no link at the end of the SBRI process to standard government procurement procedures, which again is one of the big strengths of the US system and one of the reasons that it is so successful in that it helps companies develop, grow and attract investors, because there is the prospect that if you develop the technology successfully a government body in the US in a very large procurement project will purchase that technology, and you effectively have first right on that. Third, there is a lack of a quality control and auditing mechanism, which meant that a lot of the projects that were tendered under SBRI notionally, as part of the Departmental research budgets, were not technology-relevant, unfocused; and there was no-one coral-ing these and auditing them and saying, "Is this the right project; is this consistent with the overall objective of the scheme?"—and, if not, refusing to advertise the product and make the departments go away and do some more work on it.

Q59 Mr Cawsey: If that is a good analysis of all the reasons why, what are you doing now to make sure it is more like that?
Mr Harradence: We are essentially taking forward the implementation of the recommendations that Lord Sainsbury made in his report. We have spent the last six months developing a model for a reformed small business research initiative that we are intending to pilot with the Ministry of Defence and Department of Health this year, and hopefully the Department for Transport as well. To give you an idea of what the reformed SBRI will look like, we are trying to define a minimum SBRI budget of about £100 million per annum that will be a formal budget, not simply a percentage of departmental external research and development budgets that fluctuate, and are parcelled out into different bits of the organisation. Again, there is no central management and no consistency. We would like to see each department have an individual budget with which it funds SBRI projects. Second, we want a more consistent structure for the contracts, again modelled on the American SBRI approach where

you have phase 1 projects worth £50–100,000, which essentially support the feasibility and proposals you receive from companies; and a second phase value of between £250,000 to about £1 million, which enables you to take the development of the technology forward if the results of the first stage are sufficiently promising. Also, more transparent, open, systematic process for tendering SBRI contracts through the Technology Strategy Board and also through individual departmental websites with more regular procedures, more consistent templates for advertising, better information and consultative mechanisms with potential stakeholders or companies or academics who can bring forward ideas under the programme and put in place an auditing function which the TSB would manage, which will oversee the scheme and ensure the departments are meeting their commitments.

Q60 Mr Cawsey: Do we have any UK plastic electronics companies that have benefited from the programme at the moment?
Mr Harradence: Not that I am aware of, and I would say it is unlikely because there would be a lot of areas at the stage of development of plastic electronics that are too early for SBRI. SBRI is not intended and is not used in the US as a means of developing the platform technology or doing some of the early stage research into potential applications. Where it would add value for plastic electronics and other technologies is the point at which someone has an idea for how to use the technology in a particular way that would lead to a specific application; and the aim of SBRI would be to fund development of that with a view that at the end of that process they had achieved or were close to achieving a commercial product.

Q61 Mr Cawsey: To take the Chairman's theme, we have all got to be excited about this today. You presumably would say that the old scheme was not applicable yet but the new one might be.
Mr Harradence: The old scheme could have been, but I think it unlikely it would have been used in that way. I would hope that the new scheme that we are developing, which will be more tightly focused on R&D and technology development with a much tighter definition of R&D for a start—we are not going to move to the—we are fairly used to the Treasury definition they used in relation to the tax credit—

Q62 Chairman: I find it quite strange that you have Amadeus Venture Capital prepared to raise $200 million to invest in a technology, and yet a Government scheme does not consider it worthwhile even looking at! I find that incredibly strange, in terms of Plastic Logic.
Mr Harradence: I have not said that we would not consider it.

Q63 Chairman: You said you had not considered it. Does that mean that Plastic Logic never came to you for support, because this seems to be a classic case to fit into the UK SBRI programme, existing or otherwise!
Mr Harradence: They may well have come for some form of support. I think it is unlikely they would have sought support under the SBRI initiative.
Mr Hauser: Plastic Logic had government support from a number of government schemes.

Q64 Chairman: Not SBRI?
Mr Hauser: Not SBRI.

Q65 Mr Cawsey: The American programme provides 100% funding to small businesses engaged in research that has the potential for commercialisation. Would this be what you could do in the UK, given the current state aid rules?
Mr Hauser: Yes.
Mr Harradence: The most fundamentally important point is that SBRI projects are awarded as contracts not as grants, which means state rules are less applicable in this area. Provided the contracts are tendered on the basis of an open, competitive process that is consistent with EU rules, and a market rate is being paid for the work done, the state aid rules do not apply.

Q66 Mr Cawsey: So you would consider 100%!
Mr Harradence: That is the intention, yes.

Q67 Dr Turner: Does it have implications for IP ownership?
Mr Harradence: The intention is—this happens in the majority of cases at the moment, but the intention of the reform scheme is that ownership of the IP will be vested in the company that does the work. There might be exceptional cases where a Government department chooses to retain the IP, for example the defence sector or health technologies, but we would envisage that in the vast majority of cases the IP will remain in the companies that have the potential to exploit it.

Q68 Chairman: We understand that Cambridge Display Technologies received support under the SBRI scheme. Can you confirm that?
Mr Harradence: I cannot, but I can look into it.
Chairman: Thank you very much indeed.

Q69 Dr Turner: I would specifically like to ask Mike, whose board has made a significant investment in the plastic electronics technology centre: does it worry you that Plastic Logic only estimate a 50% chance of success for the venture?
Mr Biddle: I think the important part of the PETeC initiative is it that it is the whole of the UK, so obviously Plastic Logic were involved with it in the early stages. The important thing is that we work with the industry to make sure that they can make it work for them. In fact, I have been part of some very robust discussions in the technology industry advisory group to make sure that industry gets what

it needs out of that centre. What is very good is that the people running PETeC are listening to that and building on the input they are getting.

Q70 Dr Turner: Why do you think they were so concerned?
Mr Biddle: I do not think that is for me to comment really; Hermann may have some background on that. It is an important intervention for the UK, and it provides an open access facility. There was mention earlier by Ian French that it was not going to do what it needed to do, and it was going to be roll-to-roll. Roll-to-roll is one of the things that is on the evolution map, but it is not where they are starting off; they are starting on a sheet basis. Roll-to-roll is like a traditional printing house, so if you want newspapers you use the big machines and it flies through. It is almost like the vision for plastic electronics where you can add—where it can be most disruptive, but obviously there is an evolution path to that; you cannot just turn that roll-to-roll machine on; there is a lot of engineering and a lot of science that needs to happen first. This is some of the stuff that the PETeC will be doing. They are getting in some of the equipment and they are going to be honing some of the processes. This will then be something that different companies can play into. I am aware of a project that came in through our recent competition, and they are going to be using that centre to make sure they do iron out some of these pre-production issues because it is only when you turn the handle—and Richard made the point, never underestimate the value of engineering and I absolutely agree with that. It is when you turn the handle on these things that you start to see where the genuine issues are, and then you can address them.

Q71 Dr Turner: Hermann, perhaps you could throw some light on your concerns. There is almost a suggestion that it is perhaps not quite the right model.
Mr Hauser: Stuart Evans produced the paper, and he has a more detailed knowledge of this than I have. The point about roll-to-roll is very different from the Plastic Logic approach, which his much closer to a traditional LCD fab, albeit not on glass but on plastic. There is no doubt that the final vision is roll-to-roll, and this would be the cheapest and highest-volume way of producing plastic electronics. In that sense, it is even one step further than Plastic Logic.

Q72 Dr Turner: Do you think they would take too big a risk, trying to run before they can walk?
Mr Hauser: Roll-to-roll is being pursued in a number of places all round the world. It is not an exotic technology. It is longer term. There is a big debate on whether or not this is going to be the winning technology or not. It might well be.
Mr Biddle: They are actually trying to walk first in that roll-to-roll is something they are looking at, but it is not where they are starting from. They have a planned, phased programme. That is what they are looking to implement, and it is sheet processing along the lines Hermann described.

Q73 Dr Turner: Does the TSB have a role in development PETeC's business strategy?
Mr Biddle: We do not define their business strategy; they create a business plan and we look at that against the criteria I mentioned earlier, to see whether it warrants investment. We thought that by investing in the equipment—and the investment we have made is specifically in capital equipment—it would provide the open access facility the UK needs. There was talk earlier about whether it was in the right area; but there are important links between both PETeC and the CIKC in Cambridge, which is an EPSRC initiative. There are also links through that technology industry advisory group and through the knowledge-transfer network and UK Display and Lighting also into the Welsh centre for printing and coating. We are trying to make sure that we are investing in the right opportunities to make things open for the entire UK and try and join that up and make it clear where people can access it.

Q74 Dr Turner: Logystx UK have told us that the requirement for centres such as the PETeC and OMIC to become financially self-sustainable over a five-year period is perhaps going to distract them from carrying out their role of encouraging entrepreneurial activity in the rest of the UK because they are going to be so concerned about their own survival. Do you see this as a problem?
Mr Biddle: It creates dynamic tension, if you will excuse the phrase, in that obviously there is what they need to do for the entire UK and what they also need to do to make sure they are available for the UK; but they also point out that interacting with some of these companies across the world—because, at the end of the day I am for the UK, and hopefully that came across earlier but we are operating in a global supply chain. Part of the interaction with the people, possibly in the Far East, is almost a badge of honour; if you cannot interact with some of those people then maybe you have not got the right technology! It is fine line for them to walk, and they have addressed that in the business plan and are trying to walk that line. I will just point to the fact that through their advisory group, that is a sounding board for them to make sure they walk that line correctly.
Mr Osgood: EPSRC is not directly involved in the funding for PETeC, but the same issues of our funding apply for example in relation to Innovative Knowledge centres, which are for five years of funding initially; and there has to be the right tension between opening up an opportunity and a large amount of funding, but actually ensuring that things are delivered through that process. Many of our funding activities have—and we are moving more towards that—longer/larger[3]—those sorts of tensions, in giving people freedom to operate but actually having a requirement that they are producing useful activities is one that is relevant in the science base as well.

[3] *Note from the witness*: "funded awards"

18 June 2008 Mr Mike Biddle, Mr Vince Osgood, Dr Hermann Hauser and Mr Fergus Harradence

Q75 Dr Turner: You do see the need to move to longer-term funding in appropriate circumstances?
Mr Osgood: As a research council, we are encouraging our research community to think beyond what is typically project-based funding, which is an RA—three years' worth of project funding into something more ambitious, which may be typically 2 million or so over a longer period. We have seen a growth in those programmes over the last few years and now we have something like 120 programmes of value more than £2 million—

Q76 Dr Turner:— registered for much longer than three years!
Mr Osgood: Yes, and they would be typically five to six years. We would see over time about a third of our funding going into more of those longer-term ambitious projects.

Q77 Dr Turner: Can you see a role for rolling funding programmes when they could have a longer duration than that?
Mr Osgood: I could certainly see that we would have longer-term funding for particular areas—not necessarily the same programme, because the configuration may change over time. In this area of plastic electronics and its forebears, we have probably been providing university funding for at least 20 years. In the area of opto-electronics at Southampton, we have been funding that group almost continuously for 35 years—different projects, different emphases, different adjustments. Long-term funding is always available, but we tend to put it into somewhat shorter but now slightly longer packets.

Q78 Dr Gibson: I do not know whether you would agree with me, but the success of most enterprises in this country and across the world depends on bringing through young people not just to carry out the ambitious, exciting programmes that you guys are talking to us about; but they get involved and come up with the smart, crazy ideas that do make a difference. Vince, what are you doing to excite young people to come in and do PhDs and research fellowships? I know you have had partial success in the sense that people from Cambridge have gone on into big companies and run them. Are we doing much to get young people coming in to this field, and how?
Mr Osgood: In general, I think the nature of the research itself brings people in, and the fact that we have world-leading research groups in this country draws people in, not just home-grown but people from around the world who want to work with those research leaders that have been developed in the UK. We are certainly expanding our early-stage career fellowships to enable younger people to take more control of their research—

Q79 Dr Gibson: How many have you got—tens or thousands?
Mr Osgood: Hundreds—not thousands but certainly hundreds. In this area of plastic electronics we have something like 80 PhD students both on research projects and through doctoral training grants at universities, using our money. There are a further 140 post-doctoral researchers on the research grants[4].
Dr Gibson: Can you give us a figure from the Council over the last five years for how that has increased or decreased or whatever, and roughly what is it worth in terms of research council investment?

Q80 Chairman: Can I ask a rider to that, Ian, in terms of information? Can you also let us know how many of these are working in university labs or out in industry labs?
Mr Osgood: We have a number of schemes where we give the case awards to the industrial—

Q81 Dr Gibson: Case awards, yes.
Mr Osgood: There are industrial case awards, where the student spends a proportion of their time—30% typically, within the industrial collaborator. We also have Engineering doctorate programmes where the Research Engineer will spend 70% of their time working on an industrial project in an industrial environment.

Q82 Dr Gibson: Is that increasing too? I remember when case awards came in it was quite an exciting idea. Are you decreasing it or increasing it?
Mr Osgood: We are increasing both the level of Industrial Case and we are also increasing the proportion of user-led research.

Q83 Dr Gibson: Can you give us some figures on that?
Mr Osgood: I can provide you with them.

Q84 Dr Gibson: Are there any success stories to say that because you had this programme a company of the stature of Amadeus arose in the middle of Cambridge Research Park—
Mr Osgood: Yes.

Q85 Dr Gibson: You have one or two super heroes!
Mr Osgood: I have one or two examples. We took part in an RCUK-led study by external consultants on the economic impact of research council investments, and there was one particular research engineer[5] that they identified. The capitalisation of his research work was to the value of £100 million.

Q86 Dr Gibson: But I am looking at how many you found and how many come through it and where they go on to. When you talk about funding these case fellowships[6], what about the reports I have in front of me here of one company that was refused a case fellowship, called UK Display and Lightings application: on what basis was that turned down? How do you make a decision whether one company is going to make it or not?

[4] *Note from the witness*: "currently funded by EPSRC"
[5] *Note from the witness*: "Studying for an engineering doctorate"
[6] *Note from the witness*: "These are CASE studentships, not fellowships"

18 June 2008 Mr Mike Biddle, Mr Vince Osgood, Dr Hermann Hauser and Mr Fergus Harradence

Mr Osgood: That was a highly competitive process this year. I do have the case in front of me. We had something like 80 Industrial Case awards each year which we reserved for working with agents—that is both the KTNs and RDAs. All the KTNs, of which UK Display and Lighting were one, made a bid for proposals. They were looked at competitively. Some of the comments led to them not getting them.

Q87 Dr Gibson: Read them out. These are the referees' reports. Go on, tell the world.
Mr Osgood: They did not demonstrate any added value to—

Q88 Chairman: They did not get money from the DTI either, so—
Mr Osgood: Yes. They did not demonstrate any added value to the student as a result of that award being awarded through the KTN; so some of the other KTNs, for example, had proposed to put in place mentoring schemes for the individual students and gave them showcase opportunities for working with members[7], so it was comparing one with the other. In the electronics space the Electronics KTN received three, Photonics KTN one, and Integrated Electronics and Products KTN two, all for three years. So there are six per year in the electronics space awarded through the KTNs, although none to UK Display and Lighting; but we do have a pool of 30 awards and we are encouraging the KTNs, particularly their innovative SMEs, to apply to the pool; so although the KTN may not have received any indirectly, its member companies can be bidding against the pool. Those decisions will be known next week.

Q89 Dr Gibson: Since you are so excited and passionate about this area, how far short do we fall in terms of the studentships that you acknowledge are important for now and the next few years and the future? How far short are we in numbers? You are talking for the Department, I guess as well. Are we three thousand short or four thousand, because it often depends on numbers? I do not know if it does entirely, but are we short, and do you ever get angry about it, that will curtail your success?
Mr Osgood: I do not get the feeling that we are short at the levels of PhD students and RAs. I do not think we have any evidence that we are short in this area.

Q90 Dr Gibson: How do you make that judgment then—one PhD student and—
Mr Osgood: Total numbers come in through a variety of avenues, not all supported directly by EPSRC. There may be a shortage of domestically produced PhDs in this area. We do enable universities to apply for project students on the research projects.

Q91 Dr Gibson: Only universities?
Mr Osgood: Largely universities we fund, yes. Any students that we fund directly like CASE[8] have to be UK nationals.

Q92 Dr Gibson: Why is that then?
Mr Osgood: It is part of the general Government policy of—

Q93 Dr Gibson: I thought they liked foreign students; they pay astronomical fees.
Mr Osgood: The universities certainly like foreign students, both at the undergraduate level and the postgraduate level, but our studentship funding is for UK nationals.

Q94 Dr Gibson: How many universities have we that are engaged in these studentships, roughly? I do not know how many universities there are now—they grow by the day.
Mr Osgood: I was going to say that we support up to about a hundred. The vast majority of our funding, something like 75%—and this would relate to studentships and grants—go to the top 20, so it is concentrated in 20, but the remainder has spread more thinly; there are some which have a small number of students.

Q95 Dr Gibson: What other sources of money could there be to help studentships in this area? Would regional development agencies put money in?
Mr Osgood: And we can encourage them. Our arrangements for our own studentships are such that if somebody else is prepared to pay up to 50%, effectively you can double the number of studentships. If we awarded a KTN three students a year and they drew in other funding, they could double that and have six.

Q96 Dr Gibson: How many are involved in that kind of transaction, roughly? Is it on one hand?
Mr Osgood: It is probably not more than two hands.

Q97 Dr Gibson: It is not that many, so there is a great opportunity to increase the numbers.
Mr Osgood: There is certainly an opportunity, and that applies equally to the universities across the whole of their doctoral training accounts. It is something like 2,000 studentships, new PhDs, per year that we will support. Equally, the universities can attract additional funding to make use of those and potentially double them.

Q98 Dr Gibson: As a research council man, then, do you think universities have got the message about the importance of this field, to the level you feel it is important for the nation?
Mr Osgood: It is certainly growing in importance and excitement. We have just had a call for doctoral training centres, where we put more of our students into cohorts—so 10 per year per centre for up to five years—a totality of 50 PhD students. We had 280 outline bids last week. We have short-listed 90, with

[7] *Note from the witness:* "Member companies of the KTN"

[8] *Note from the witness:* "Studentships awarded through funding to research projects are open to non-UK students"

the intention of funding 45, and a number of those are in this space. So, yes, I think universities are getting excited and—

Q99 Dr Gibson: Is there any grade 5 assessment in research in your programmes attached to any of this kind of work, do you think? Can you point out any to me? You can point to Imperial for engineering areas and so on. Can you do that anywhere else, in terms of grade 5 plus?
Mr Osgood: Yes, Durham, Cambridge, Manchester.

Q100 Dr Gibson: So there are star outlets!
Mr Osgood: Yes. The 10 most concentrated universities that we fund in this particular space will be 5 and 5-star.

Q101 Dr Gibson: Does the Government know this?
Mr Osgood: It is in our case—whether that has penetrated through or not—
Dr Gibson: Whether they read it or not! Thank you very much.

Q102 Dr Iddon: Mr Hauser, one of the attractions of Dresden, going back to that lovely city, was the availability of skills. What is it about the availability of skills in Dresden; is it the fact that on reunification so many of the old industries were destroyed and therefore there was huge unemployment at reunification, or is the federal government of Saxony making a special effort to train skills for the electronics industry that is clustering in Dresden? These will be different lower skills from postgraduate skills that Dr Gibson has just been talking about?
Mr Hauser: The two main reasons were—one that I did not know was that Dresden was the micro-electronic centre of the Eastern Bloc before the Iron Curtain came down, so all the D-rams, the microprocessors that they were not able to import from the West because of the export restrictions that we had came out of Dresden. They had tremendous expertise. They have a university that is the best university in the Eastern Bloc on that, and arguably one of the best universities in electronics in the world. The Frauenhofer Institute is associated with it, again producing very high-quality people. In the end, our main criterion was the availability of highly qualified operators of the factory. My last comment on that really is that once the factory is fully staffed and up and running, we will be employing 140 highly skilled but comparatively lowly paid operators in Dresden, whereas we will continue to employ a hundred PhD level people in Cambridge; so our payroll in Cambridge is considerably higher than in Dresden.
Chairman: On that note, could I thank you very much indeed for being splendid and very enthusiastic witnesses this morning.

Wednesday 2 July 2008

Members present

Mr Phil Willis, in the Chair

Mr Tim Boswell	Dr Brian Iddon
Dr Roberta Blackman-Woods	Ian Stewart
Dr Ian Gibson	Dr Desmond Turner
Dr Evan Harris	

Witnesses: **Professor Sir David King**, former Government Chief Scientific Adviser, **Mr Chris Williams**, UK Displays and Lighting Knowledge Transfer Network, **Dr Tom Taylor**, Plastic Electronics Technology Centre, and **Mr Nigel Perry**, Centre for Process Innovation Ltd, gave evidence.

Chairman: Could I welcome our first panel of witnesses this morning to the Innovation, Universities, Science and Skills Committee's plastic electronic engineering inquiry and welcome Chris Williams from UK Displays and Lighting Knowledge Transfer Networks (what a mouthful, Chris), Dr Tom Taylor from Plastic Electronics Technology Centre, welcome to you Tom, and Sir Nigel Perry, from the Centre for Process Innovation Ltd, welcome to you. I wonder if I could ask my colleague, Dr Turner, to begin this morning.

Q103 Dr Turner: Chris, your organisation, with the name that does not trip off the tongue very easily—we will call it UKDL for the time being—how do you measure its success as a knowledge transfer network? Can you give us any examples of the success stories to date?
Mr Williams: We have a very large number of examples of success. We are officially measured by the Technology Strategy Board on four metrics. The first metric is how many active members do we have who come and participate in our events and training sessions and what percentage of the total market does that represent? How many events do we hold and how many projects are we able to create between our members that are then subsequently submitted for funding under collaborative research, either under the Technology Strategy Board programme or into Framework Seven, and, finally, how much commercial money have we helped our members raise? Since companies like Plastic Logic and Dupont Teijin are founding members of my network, of course I am going to claim sole responsibility for the success of Plastic Logic raising $140 million in its recent funding round. That is probably a slight overstatement, but we certainly have been instrumental in creating consortia of companies to bid into the technology programme in the UK.

Q104 Dr Turner: You can truthfully say then that the landscape in plastic electronics in the UK would not be where it is now without your organisation?
Mr Williams: I believe that is an accurate statement.

Q105 Dr Turner: What do you find the big challenge in commercialising technology in this particular field, or is it the same story as innovation across the whole field?
Mr Williams: The biggest challenge I see is overcoming prejudice in the UK. Plastic electronics is not conventional electronics, so our conventional electronics industry has mostly disappeared with the end of the Cold War, and, with the move of whole consumer electronics to the cheaper labour countries, it is assumed that anything with electronics will be done in the Far East, and that is simply not the case. There are so many examples already of companies that are integrating simple elements of plastic electronics into their existing product portfolios to add value to what they already do, and of course the very highly sophisticated developments of the likes of Plastic Logic, who you heard at the previous session, Polymer Vision, who are producing part of their assembly in Southampton. They are coming to the market later this year, and with the colleagues that I have here at the table, with the PETeC Centre and their supplementary colleagues around the UK, with CIKC, with the Welsh Centre for Printing and Coating, with OMIC in Manchester and with the activities of Imperial in London, there is a solid base of research support for bringing this technology to the market place.

Q106 Dr Turner: You collaborated with what was then called the DTI (we now know that as something that sounds like a character from Jane Austen, and behaves like one as well) on a proposal for a managed funding programme for plastic electronics. This never actually came to pass. Is the Technology Strategy Board taking up this line of approach and, if not, do you think it worth trying to revive the principle of the managed programme?
Mr Williams: I think the concept of a managed programme is essential for this nascent industry, and part of the problem that we have is that we are creating new solutions, we are adding value into other product areas. I am able to point out that plastic electronics will be used in life sciences, it will be used within the food packaging industry and it will be used within the pharmaceutical industry. All of those areas need help to understand what it can do for them and what it can bring to them, and the

idea of a managed programme, the basic concept, was that the community of plastic electronic interested companies in the UK would determine what it needed to move to mass exploitation but it would not be a dictat down from DTI, "We think this is a good idea. Let us do that, chaps." It would be the community saying, "These are the problems that we have got. Let us address those", and then the community as a whole will benefit and will drive the technology into commercial exploitation.

Q107 Dr Turner: Why did it not happen and what are the chances of making it happen in the future?
Mr Williams: It did not happen because the proposal run by DTI and the report that was created, which was very well received inside DTI, came just at the time that DTI was going to then split itself into two and the responsibilities travelled down to TSB. TSB have their own interpretation of innovation: they have their innovation platforms, they have the collaborative research programme, they have the knowledge transfer networks, and we are very supportive of those activities, obviously, they pay us, but at the same time they have no vehicle in position today to run a managed programme in the way that DTI used to do—they have no facility at all—and it would be very valuable for our sector, and I am quite sure it would be the same for other sectors, if that were added to their armoury of tools.

Q108 Dr Turner: But at the moment you cannot see any receptiveness to that in BERR?
Mr Williams: Not at the present time, no.

Q109 Dr Iddon: Could you tell us how valuable the support EPSRC gives to plastic electronics is and whether you feel they can do more in this field?
Mr Williams: The support that the sector is getting from EPSRC is a curate eggs: some very good bits and some bad bits. The good bits are the programmes that they are running on responsive mode research and the investment that they have made into some universities round the UK. If you were to go to some of the lesser universities—Nottingham, Trent, Strathclyde, Hull, Bangor, Aberystwyth—you would find that the equipment centre they are working on is not up to the quality level of those in Cambridge, for example, or in Manchester, but there is a big problem in that the whole ethos of EPSRC is set up to support excellence in science, and in taking the technology forward there are bits of work that have to be done that are, frankly, boring and that will not contribute in any way to a universal RAE rating, and we at UKDL, on behalf of the PE community, have been told, quite bluntly, by our university members they are not interested to do the boring bits because it will not help them in the RAE, and that is where I think EPSRC do need to make some form of contribution in helping the boring bits of science be done because they are essential to complete the whole package.

Q110 Chairman: Can we ask Nigel and Tom if they could comment on that, in terms of EPSRC?
Dr Taylor: We see a continuum here. EPSRC is funding fundamental research, but the challenge for this industry, the challenge for the innovation, is to make those connections that Chris was making to the market place, to applications. The sheer scale of this industry requires private sector investment on a large-scale. So what we have to do is to take the innovations that have come in the UK and get them to a point where they are attractive, to attract investment, and this is something the UK has struggled with. I am not going to suggest any one particular solution, but all the players have a role to play here, including EPSRC. I do not think it is our place to say that they should change their model, but they need to be cognisant of the fact that some of these research areas, particularly plastic electronics, will have commercial application, and it is possible to align the work that is coming out of universities to make that attractive to the private sector.
Mr Perry: I think I would agree with Tom's point. It is a supply chain, if you will, that reaches from the basic research in universities right the way through to the market, and it is important that that supply chain is connected. An understanding of where plastic electronics and printable electronics will be used in the market place is still only emerging. There are lots of applications, there are lots of potential opportunities ranging from smart bandages, through wallpaper, through displays, through to lighting, et cetera, and being able to make the connection so that messages pass up and down that supply chain is critical. I think what EPSRC is doing in pursuing excellence is to be very celebrated. It is the connection then into the support that TSB gives and then the TSB gives on, through devices like CPI and others, and then into industry that is crucial.

Q111 Dr Iddon: I thought we had convinced those who judge universities formally by the RAE that they had to take applied research into account. What you are telling us is that you do not think they are taking applied research into account.
Mr Williams: They are still looking at the excellence of applied research, and in taking little elements of superb science and integrating them together, there are some very boring little bits of work that need to be done, and the universities, generally, are finding it very difficult to be motivated to address those areas.

Q112 Dr Gibson: Can I follow that up? Fundamental Blue Sky assessments can be pretty boring too, as the speaker who has just come in will vouch for, I am sure. You have to repeat things, for example, to establish it. When you say that the RAE is pressurising these people to do things, is that because it is only to get publications? Is that what it is all about? Is that what they mean by boring, that there is no publication and so they will not do it? All research can be boring in a sense?
Mr Williams: It is not so much that the performance of the work itself is boring, it is the review of the proposed activities by the panels within the EPSRC college. When they are looking at the scientific content of a proposal they will grade a project proposal and deem it suitable for funding, or not,

above the line or below the line, as to the quality and the excellence of the science or the engineering within that project proposal, and if bits of the work are simply, you do not have to be a super scientist to achieve that, it is just tedious work, that project will not get rated as strongly as a project that does contain excellent science.

Q113 Dr Gibson: It is their individual judgment, is it?
Mr Williams: Yes.

Q114 Dr Iddon: Can I pursue this argument a little. You tried to engage the EPSRC to sponsor case studentships in this area and that did not come off. Why do you think you failed to get that engagement going and what do you have to do to reverse the position?
Mr Williams: As the KTM we were new boys on the block, and we have not had involvement with the case studentships before; so I can understand the historic arrangements that existed for the award of case studentships going against us in that instance. We are working very closely with the EPSRC in different ways. We are working closely with Imperial to help them create their case for the DSC proposal that they are submitting through to EPSRC, and that has a very heavy focus on industrial content and industrial training of graduates and postgraduates with plastic electronics, and we are also learning more from liaison closely within EPSRC how can we create a better case for a proposal for securing case studentships next time round.

Q115 Dr Iddon: I guess this question is to all three of you. Countries like Taiwan and Japan seem to have an ability to drive early stage technologies like this one forward much quicker than we can in Great Britain. There seem to be barriers in our country, and so we lose out to the Far East. What do we have to do to emulate the Far East in getting these early stage technologies to the market?
Mr Perry: It is something we looked at very closely when we set up CPI, which is to understand how this innovation supply chain worked, and what we discovered by looking at the American system, where the numbers are quite clear and easy to get hold of, is that for every dollar, pound, euro or yen, or whatever, is spent on the basic research, it can take up to three-times that amount of money to actually commercialise and turn the research into a useful product or service. The interesting question is where does that 63-times extra money come from? The answer, we believe, in CPI, is that it comes from the private sector. So the innovation pace is really set by the ability to engage the private sector in actually translating that research into useful goods and services. The CPI model is based on bringing industry, together with academia, together with the rest of the necessary know-how and, very importantly, the necessary assets to actually allow industry to de-risk innovation. Innovation is a risk-management process. Reducing that risk and getting the investors in to support it is what it is all about. I would suggest, though I have never studied the Japanese system, that there may be a greater industrial involvement and there may be a greater risk-management consciousness in that process. Certainly in those systems that we have looked at, like the American system and potentially like the Dutch system and the German system, we see more industrial involvement, more de-risking processes and more use of devices like the Centre for Process Innovation earlier on in the process.

Q116 Dr Iddon: But Tom, we are risk averse in this country, are we not?
Dr Taylor: I think I go back to the comment that Nigel put. We tend to be risk ignorant; in other words, not understanding all the factors in order to manage the risks. We can create a culture similar to the Dutch models by working in a connected way across the institutions you have got arrayed before you at the committee this morning, across the EPSRC, the TSB, intermediate organisations like CPI, to tackle the risks. The risks in innovation are most manifest early on when the technology uncertainty is highest, and that is something that is done often very well in other countries. So when ideas are thrown out of universities, at that point you need to create a climate in the UK where private sector finance, private companies, find it acceptable to invest, where we are a competitive place to do that work, and that is the challenge. The city institutions understand financial risk. They need to engage with bodies which can help them appreciate the technology risk, and that is that, and that is something where there has historically been a gap. CPI, as Nigel has said, was set up to address that very point, but we are almost unique as an organisation in the UK doing that.

Q117 Dr Iddon: Can you help in this context, Chris, your organisation, UKDL?
Mr Williams: Yes, we are totally committed. We are spreading the word so that we can encourage the pharmaceutical companies to bring the plastic electronics into their area by the implementation of anti-counterfeiting circuitry on the packaging. Looking at food packaging that can detect if the food has gone off is very attractive to major stores in the UK. A project in both of those areas submitted into the technology programme did not receive funding because the risks were high and they fell below the point at which the funding had to be cut off in recent calls of the programme. So the interest is there in large industries in the UK to adopt this technology, and it will happen, but it is the function of funding being available.

Q118 Chairman: Can we welcome Professor Sir David King to our panel? It is very nice to see you again, David. This particular inquiry, looking at engineering in the broad sense but plastic electronics as a specific case study, one of the motivations for it was as a result of your valedictory appearance before the old Science and Technology Committee where you said this, "In Britain we have a world leading position in a technology that could wipe out silicon chip technology and convert photovoltaics into easily accessible materials at a much cheaper price,

and I am talking about plastic electronics." It was a very bold statement that you made at that time before the committee. Are you still as excited? Do you still feel that you under-egged rather than over-egged the possibilities of this technology?
Professor Sir David King: I am probably not guilty of underrating the possibilities, but I do not draw back from those comments at all. What I, of course, was emphasising is the need in Britain to get away from the idea of: let us not back winners. I think, fine, let us not back losers, let us not back companies that are no longer fit for purpose, but when we see something on the horizon that has a real potential for our economy, and I am looking particularly at the high added value end of the manufacturing economy. Then I think we should back it and back it to the hilt, and so I was just using plastic electronics as an example of that. If we look across to South Korea, when Broadband was developed in South Korea it had no foothold anywhere, I would suggest, just as plastic electronics had no foothold anywhere a few years ago. The South Korean Government stepped in with massive funding and, within a relatively short space of time, Broadband had taken off in South Korea before the rest of the world even knew about it; and that was the Government backing a winner, and that winner has massively turned their economy around. So I am simply saying sometimes we have to have the courage of our conviction and back something where we appear to be in the lead. We have this massive strength in the science base, we all believe in science, innovation and wealth creation, so we see it as an investment into our future. How do we make sure that that develops? I think we have become good at first stage development, at VC development, so the number of small high-tech companies we have in the UK is now actually exemplary; we lead the way in Europe. All I am looking for is the next stage of development where we take these small companies that are showing promise into the plus 50 million valuation level, where they become real players in our economy, and what are the blocking points there.

Q119 Dr Iddon: In the previous set of questions, the one thing that was not mentioned is that Taiwan and Japan have a partnership approach between industry and government. Do you think that that partnership approach exists in the UK? If it does not, should it be developed in line with what you have just said?
Professor Sir David King: Yes, and you could use other examples as well. If we look at the Fraunhofer Institutes in Germany, they are directed at particular sectors of their manufacturing industry as a back up, and it is very real government money that goes into those Fraunhofer Institutes. We have the knowledge transfer networks, I think we are toying with getting into that position, but we are not big players in the way these counties are in backing nascent industries.

Q120 Chairman: In terms of the UK Government, do you feel that they are making sufficient efforts to support this emerging technology? I take your point that the Government has been averse, and the old DTI was averse to picking winners.
Professor Sir David King: Yes, and the Treasury.

Q121 Chairman: The Treasury, then, all right. They rule everything, but do you feel that there is a sense of change as a result of the changes to the machinery of government, the way in which we are now looking at innovation, innovation is at the heart? Do you feel the Government is backing plastic electronics?
Professor Sir David King: I do not think I see sufficient signs of progressive change in this area, but it is not just government action. We have the one of the leading financial centres in the world in the City of London, and my question really was why in the City of London the big financial players had not developed an expertise to examine what is happening in our science parks to invest into these promising high-tech companies. So it is not just government funding that I am looking for, it is stimulating that wonderful city and its financial sector to understand the opportunity on its front door step. I think we need to look at that as an infrastructure issue and see what needs to be done to help.

Q122 Dr Gibson: Do you think sometimes, David, that in this country they say, "Other countries are good. We will let them get on with it and then we will buy it in", and so on? We are always saying that America does everything, but then the Japanese, Indians, and so on. The second question, where does this sit with some of the other industries that have been overlooked in the last few years where we also missed a trick or two? Is this one of many or half a dozen in your opinion?
Professor Sir David King: I am sure it is one of many. To take that point, I see plastic electronics as a very obvious exemplar, but I am sure there are many other examples. Around Cambridge alone there are 1,600 small companies. Within that you will find a whole range of interesting activities, and many of them world leading; so this is really just an example. If we look at what Britain does, I think we play cricket. This is all about fair play.

Q123 Chairman: We try!
Professor Sir David King: Winning is not the point, and that is what I am trying to drive at here. Somehow we feel that we should not be backing companies because this gives an unfair advantage. I know that within the rules of the game that is correct, you are not supposed to give unfair advantage, but at the same time are not the Fraunhofer Institutes giving German industry precisely that? It happens in the United States as well, of course. I do not believe Silicon Valley would have taken off if it had not been for the Department of Defence spending masses of money in the nascent industries in that area. So we just need to look how

other countries have nurtured the development of new industries from the science base, and I think you will find that we have got very little in that space.

Q124 Chairman: Can I take one area where the Government does have some control, and that is over the whole procurement issue. The Government talks a very strong tale about using this procurement muscle, 150 billion or whatever it is, in terms of fostering and supporting British industry and its development. Do you feel that there is an avenue there, Sir David, to use that procurement to actually support these emerging technologies?
Professor Sir David King: Chairman, this is a drum I have been banging on for quite some time. My example here was the development of the electronic breathalyser. Some years ago the Home Office put out an advertisement for an electronic breathalyser. There was nothing on the market at that point, you had coloured crystals that you blew through, and a Welshman developed an electronic breathalyser in his garage at home. His name is Tom Jones, but it was not that other Tom Jones. He formed a company round the development and wrote to the Home Office. The Home Office announced that they could not procure his gadget without having competition from at least two other manufacturers. At this point he had patented the device. His company was then bought out by an American group, prompted by DARPA, and DARPA then procured the device and then the Home Office bought it from the American company. I just give that as an example of how we have lost out in the past, and it just seems to me that procurement, wisely used, could really transform this whole picture. The Americans understand that: they have been playing this game through DARPA for a long time. As I said, Silicon Valley would not have come into being without this process. If you take the 150 billion procurement, the problem (and I was always up against it) is that if you have a voluntary scheme where you simply encourage each permanent secretary to use a proportion of their budget for procurement, which I believe is still the Government's position, those permanent secretaries will be pulled hard in the other direction to demonstrate value for money on their purchases, and we are talking about risk procurement here. You are buying an object which is as yet unproven and you are asking for the product to be delivered in five years' time. That in itself means, in my view, you have to ringfence a proportion of the procurement budget and take it from each department, and then that money must be spent in the interests of that department, but it must be seen to be risk procurement.

Q125 Ian Stewart: Does that not also indicate that in this country our government is good in terms of funding research and development but not so good in implementation funding?
Professor Sir David King: That is right, but, Ian, what is interesting here is, we have already now got past first base, to use an American term, and to second base. In other words, we have got all these small high-tech companies, I believe the highest density of small high-tech companies possibly in the world down here in the south of England. It is the next stage that we have lost track of. How do you pull these companies through when they have become very promising?

Q126 Chairman: Can I broaden this out? Chris, you were nodding. The record will show that Chris Williams was nodding as Sir David King was speaking there. I suspect the whole panel agree—is that a fair comment—with Sir David's assessment in terms of the use of government procurement? Do you have a quick comment, any of you, to make on that?
Mr Williams: I have 430 member companies that would ask me to say, "Hear, hear", to everything that Sir David was just saying.

Q127 Chairman: Can I broaden this, Chris, to the issue of what else is happening around the world. Sir David has mentioned the United States, but if you take liquid crystal display and the amorphous silicon industry, both started here and yet the huge commercial exploitation occurred elsewhere. What are other countries doing, taking aside the United States? What else is happening in Europe, for instance, which is allowing these technologies to be fully developed?
Mr Williams: Europe is working probably in parallel with the general thrust of activities that we have in the UK, but Europe and the UK are certainly ahead of most of the rest of the Far East. The Far East has invested so heavily into conventional semi-conductor manufacturing, conventional display manufacturing on glass, that most of those companies are loath to simply say, "Right, here is a new cheap way. Throw away all of that kit; we will go and make it on plastic instead." They have to make very good use of those facilities. Certain European companies who have developed processes compatible with the older technologies of making on glass are, of course, trying to promote that technology on glass, and you heard from Ian French that is such a process, so their end users will be in the Far East.

Q128 Chairman: But in terms of plastic electronics, which countries are actually taking this seriously in terms of doing the very things which Sir David is saying that we ought to be doing in the UK?
Mr Williams: Germany, very strongly, a little bit in Korea, a little bit in Japan. The little bit in Korea happens to be with Samsung and LG, so it is likely that it will potentially explode forwards, but the range of activities that we are doing in the UK and that we see taking place in Germany are much wider than they are looking to do in the Far East at the present time.

Q129 Chairman: Nigel, huge opportunities?
Mr Perry: I think so, but I think if you concentrate on the end device, then we may be missing the story in its totality. The reality is that the UK contributes to those industries in Korea and in Germany very

significantly with materials and very significantly with knowledge. So if we just say, “Here is a television screen”, or, “Here is a light”, or something, the country in which that is made is one part of the story, but the materials that have been procured and actually assembled in that country and where those materials have come from is very significant. Tom will perhaps comment on some of the experiences that we have, but we believe the UK has a very strong materials position, irrespective where the devices actually end up being constructed.

Q130 Chairman: Tom, very briefly please; I am running out of time.
Dr Taylor: A couple of issues that were raised just then. In the submission from Dupont Teijin, they highlight a couple of good examples of where value is extracted throughout the supply chain. The UK is very strong in certain areas in the existing industry, so it is a misnomer that, because those liquid crystal screens are made in Korea, all the value ends up with the OEM. In fact, 70% of the value is in the constituent parts that go into the whole, some of which is supplied from overseas. Hitachi make more money now supplying materials and chemicals into the flat panel industry than making flat panels themselves. Merck Chemical make a return on sales of 55%—that is a billion euros a year—supplying the liquid crystals. They have research and development here in the UK that is an extension of a UK invention. We sometimes focus on the negatives here, but the positives are that the UK is contributing widely to this.

Q131 Chairman: Tom, can I stop you there, because one of the things that I want to challenge you on is this notion that somehow large-scale manufacturing has to be outside of the UK. Surely one of the challenges to us, if we have emerging technologies, is not to accept that automatic premise that the large-scale manufacture must automatically occur somewhere else. Why can it not occur in Britain?
Dr Taylor: I would agree with you. I support what Chris said earlier; that we must overcome the perception (and I have picked that up sometimes within the Civil Service system within the UK) that the UK is no longer a manufacturing country. We are the sixth largest manufacturing country in the world to date, and the point we have been making about the supply chain is that we think the iPod is made by a US company, but the circuit design is made by a UK company; so we are extracting value. What we have to do here is understand that in a supply chain there are value points (so there are points where you can get competitive advantage and extract large amounts of a value), there are commoditised points, there are very competitive points where the UK does not compete, and it would be dangerous for us, or you would need a very long pocket, to change that. If we play our hand right, we can leverage what we have already got to get a big position in this industry. That, I believe, is already emerging, I think, in the UKDL, and I think we play a part in that. Coming back to your question, the UK has a large materials industry. Dupont Teijin Films is a leading player across the globe with research headquarters in the UK, driving innovation from the UK. There are many other examples, particularly in the supply chains, and we must not get fixated always with the end product. Having said that, there are certain end products where the UK, potentially, has a competitive position to win in. So there are some very complicated products. I think supplying a video colour display is a particularly difficult challenge to do the whole chain. The point we have just made is that it is better that we have a small piece of a very big pie than to try and go and for the whole pie, but there are other technologies, particularly emerging plastic electronics lighting, printable lighting solutions, printable photovoltaic solutions, printable sensors, where the manufacturing chain could well be in the UK. So I think the two points are firstly, do not give up on this because the UK is competitive in a number of spaces; secondly, the picture is not purely the OEM bit at the end, but getting UK technology (and our whole centre is set up to do that) into that supply chain so that the products of tomorrow contain a lot of value created in the market.
Chairman: You have made that point. Tim.

Q132 Mr Boswell: I would like to go a little bit further back into looking at the array of research we have already got in place, because we have now gone well down stream but interestingly so, and really pick up a point that Sir David has already made implicitly when he talked about the south of England. We are not here wanting to start a hare in full about regional policy, but I am interested, in a way, as to the relationships between the centres of expertise we have got—the PETeC, Welsh Centre for Printing, and so forth—how they have come into being, where they are, whether there is, as sit were, an overall strategy for establishing a network of centres and what is the value-added in having centres like that rather than injecting them one way or another into the existing university provision? Is there somebody controlling this? Has somebody planned it? Have you sorted it out for yourselves or how have we got what we have got?
Mr Williams: It is the desire of the TSB (Technology Strategy Board) that there should be a unified programme.

Q133 Mr Boswell: So some of this would have come into inception at least before TSB got going?
Mr Williams: Yes. It certainly was the desire of the DTI that there should be a co-ordinated national activity. One of the risks that plastic electronics has is that it is very easy to become totally regionalised, because one of the roles that the KTM has, the UKDL, is to work with each of these centres of excellence and bang heads to bring them together in a national strategy—so we now have PETeC represented on the board of CIKC, CIKC represented on the Board of PETeC, likewise with WCPC—so the regional centres are actually fully aware what each of them are doing and how they can work together. I think we have actually created a multi-legged support platform, and each of them

have a specialty focus. To pick up the point that Mr Iddon has raised: high volume manufacturing. The programmes are funded to implement high volume manufacturing on reel-to-reel plastic, or paper, or card in the UK based on programmes run through the Welsh Centre for Printing and Coating.

Q134 Mr Boswell: And because they are regionally based they can plug into the local SMEs very readily.
Mr Williams: Yes.

Q135 Mr Boswell: So, realistically, you do all talk to one another, if I might suggest modestly, under your remit, Chris?
Mr Perry: Absolutely. We talk each other, and it is willingly, it is not with our heads banged together, with due respect to Chris.

Q136 Mr Boswell: In terms of plugging gaps or wanting to steer particular institutions in particular directions where they may already be inclined, who is running that? Is that you, Chris, in conjunction with the players?
Mr Williams: In identifying the skills of a particular centre or particular university, we have a responsibility as part of our mandate to introduce to them industrial companies who have an interest in those skills and resources wherever they are around the UK. So we are acting as a national sign-posting mechanism to bring people in.

Q137 Mr Boswell: You are the clearing house?
Mr Williams: Exactly. We are the technology marriage bureau.

Q138 Mr Boswell: That is helpful. Can you bring into this bit of the equation (and all of you can, please, contribute) to the UK universities? A lot of them have got big research groups in these areas?
Mr Williams: Yes.

Q139 Mr Boswell: We have now created separate centres. How is the band being orchestrated altogether and to some extent is there a conflict between commercial considerations, including the potential of their own spin-off companies, for example, as against the overall benefit for the UK or the gap-filling that you are, presumably, anxious to achieve?
Mr Williams: There is a tension inevitably, a mild commercial tension, but we are simply driving forward a programme of interest for UK PLC. So we try and overcome that by pointing out the benefits of companies working with universities, universities working together and looking then at the best way to exploit that in every possible way.

Q140 Mr Boswell: If I were, hypothetically, in the position of having a good idea and maybe some pre-developed technology, you would be able to fit me up with the people I needed to get hold of?
Mr Williams: Yes.

Q141 Mr Boswell: There is a specific point to you Chris, and others may want to contribute. I think in your evidence you suggest that academics are often unable to access state of the art facilities. Richard Friend rather said the contrary. Maybe he can, but why is there this difference of view? I have set it up for you by saying, if I have got a good idea it is going to be all right, somebody will get hold of it and eventually, if Sir David works his miracle, we will have finance as well, but are there gaps here and how can we address them most effectively? How can we expose them and how can we then address them?
Mr Williams: There are severe gaps in the quality of resource available to universities around the UK that are interested in engaging in plastic electronics.

Q142 Mr Boswell: I think you did mention that earlier, did you not?
Mr Williams: Yes. It is really when they are looking to bid in for project work and to create the industrial consortia to work with them. They can be extremely limited in terms of the resources available to them, so it can very often be a self-fulfilling prophecy that companies will prefer to deal with a Cambridge or a Manchester, simply because the resources are better, rather than with a Brunner, or with a Hull, or with a Bangor.

Q143 Mr Boswell: Nigel, you wanted to come in.
Mr Perry: I was going to make a point in the CPI context. What we discovered again when we looked at starting it up is that the skill-set that is required to actually do some of these things is different but complementary to the skill-set you find in universities? If you talk to industry, if you actually examine the market place, you will find this integrating role is needed, which is people pulling everything together. That is exactly what CPI is there to do. So the industry will talk to CBI; we will then talk to and engage with the academics; we then provide the assets, and so it is actually recognising where the skills are that are needed, what part of the chain you are in, what part of the process you are in. Putting large assets of the sort that we have going into PETeC into a university may not yield the results you want because you would then have to complement it with the skill-set that you would need to commercialise and drive the—

Q144 Mr Boswell: Specifically, if you need access to a higher grade facility, be it Cambridge or Manchester or wherever, in order to support a particular piece of development on behalf of one of the members or otherwise, are there levers that you can use, as it were, to bang heads together and say, "Do not sit on this kit. Make sure that it is available to somebody so they can then develop it"? Have you got some, if not sanctions, at least some fairly strong moral persuasion if necessary?
Dr Taylor: There are always moral arguments present and available, but there are two challenges for us. The first one is CPI is not an academic institution, so we cannot be funded by Research

UK, we can only be funded by the TSB and by the RDAs, et cetera. Where a university has a particular piece of kit, we do provide very strong encouragement that that piece of kit is made available, but we have noticed that there are differing policies across the UK universities as to how to access that kit depending on IP policy, depending on full economic costing, et cetera. It is for that basis that we would strongly argue that the kit is located at CPI, because we are about as independent as you get. We are not privately owned; we are in the centre space.

Q145 Dr Blackman-Woods: I think these are questions probably for Tom and Nigel. PETeC is going to open later this year. What is it going to do? What facilities is it going to have and why will it benefit the plastics electronic community?
Dr Taylor: We have been involved in this endeavour now for four years. It started in flexible electronics with a joint venture with Dupont Teijin Films, creating what has been termed an open access facility. That is a facility that is shared with Dupont Teijin Films and then shared with the rest of the population, and the PETeC Centre has grown into an extension of that model. We received keys to the building last week and it is currently being kitted out to open in September. It has been set up to provide as broad a range of high technology, leading-edge capability as is possible given our existing resources. We have been very careful not to pick any one technology winner and not be too narrow, but to have as broad a range of technology as we can afford, while at the same time starting off with a focus. We have had to do that, otherwise we would be diluted. Our initial focus was on the display area, and that was informed by the market. It was also informed by the particular skill base in the north of England, the material strengths and the capability that was arranged to us. The capability in that area is broader than some of the evidence that I heard or saw at the last session. The underlying technology starts roll-to-roll. The film that is made is manufactured in a roll process. Some of the technologies that add value to that are done on a roll process and roll technology is being looked at to add further value. Currently there is no technology developed to have complete roll-to-roll manufacturing throughout the whole chain, so at a point down the chain you get more diverse technologies, and we have been able to secure a sufficient private sector and public sector backing to get a range of technology solutions, so companies in the UK will have access to high technology capital equipment. The open access model allows for public funding to establish such a facility and then a trading vehicle to give people access to that, and that includes advanced printing technologies, a review of flexigraphic printing, advance patterning technologies, a novel UK technology that is being pioneered, inkjet printing, and some of these other technologies, will all be present within PETeC. So there is a diversity of technologies. This was initially focused in the display area, but, as it has evolved and we have achieved a critical mass in that area, we have been able to enter the lighting and one or two other sectors, particularly where the UK has strengths, and we have been able to get consortia together to do that. Recently a large TSB sponsored project is allowing the acceleration of a UK LED lighting solution.
Chairman: Okay, I think we have got a good flavour.

Q146 Dr Blackman-Woods: What would you say to your critics who say you are putting all your energies into one production process: if that fails the PETeC is going to fail, that this is a dangerous route to go down?
Dr Taylor: I would say that that is misunderstanding the complexity of the situation. People see the very impressive roll technology that we have assembled at Wilton in combination with Dupont Teijin. We have not been able to show people all the new technology that is emerging in PETeC, I think it is probably fair to say, but it is diverse. It has to be. It cannot be everything to all people. One of the things we have to do is to focus and to make choices, and in doing that we will not satisfy all quarters.

Q147 Dr Blackman-Woods: What about Plastic Logic's assertion that PETeC has only a 50% chance of success?
Dr Taylor: Given the chances of success in a high-tech industry are often put at one in 10, I would take that as a compliment. A 50:50 chance, I think, says we are above the curve, and I believe we are above the curve. Our order book, our business development, is well ahead of the business plan that we assembled 18 months ago. We have seen more interest, we have been able to diversify our operation faster than we thought, we were able to achieve critical mass much sooner than we first thought. On the metrics that were set with the fund providers, with the bids that we won, we are ahead on those, so at the moment we are particularly confident about the business plan going forward.
Mr Williams: Could I make one comment? The review that was done of the PETeC Centre last year was not done by Plastic Logic, it was done by Stuart Evans and David Monk acting on behalf of UKDL, where we were invited to pass comment, and they, very kindly, agreed to visit the very senior experienced people in the UK with tremendous business acumen and were able to prepare a detailed report that was submitted back through to PETeC and also through to us at UKDL. We expressed concern at the time that the business plan appeared to be predicated on focusing in the Far East to secure off-shore research programmes. We felt that there was a far greater need for focus in the UK, that the UK community would be more than enough to satisfy the business requirements of the PETeC Centre, and we were very concerned that there would be a loss of focus on the UK's lead, but it was very frustrating because we could see that the RDA places very strict sustainability issues on to the PETeC Centre, but the business growth from the UK has shown that the UK will be sustaining the PETeC Centre very strongly as it goes forward into the future.

Mr Perry: Can I make a couple of comments? First of all, we are setting our stall out to be a better than 50:50 chance of success. There is a risk-management process, we do have a technology and industry advisory group that guides us, UK Lighting and Displays, amongst other people, at present on that so people are very fully informed and very involved in what PETeC is doing and how it moves forwards. Secondly, on the commercial sustainability issue and drive, there are a number of reasons for doing that, but, obviously, there is the sustainability issue. The RDA is keen that we reduce our dependence on them, quite rightly, but it is also very important that we prove our capability on the international stage. The way I would like to phrase it is that we can do more good for the UK by proving that we are genuinely internationally capable than ranked really as well-meaning, gifted amateurs grown up in the north-east of England. I think the international competitive pressure that we sense is absolutely crucial in setting the standards and setting the ambition to which the centre can and will operate.

Q148 Dr Blackman-Woods: I am obviously very pleased that you are located where you are, because you are just outside my constituency, and I hope you are really successful, but we have had a previous panellist query whether it was entirely sensible to be located where you are. How would you answer that challenge? Why is it important that you are located at NETPark?
Mr Perry: There has been a strategic intent from the north-east to have an interest in printable and plastic electronics in the region. There are a number of significant initiatives which indicate that that is the right thing to do. The Siemens' facility at (?) unfortunately is now being closed down, but the skill-set in the region is also very significant. So, driving forwards off that strategic intent, the RDA has been very keen to establish the centre and it has followed on from that. The other point, you look at places like MIT and Harvard, and you are very often given and pointed at those as good examples, but having been there, the activity is within 100-mile radius of Harvard and MIT. If you draw a 100-mile radius around Leeds, you encompass an awful lot of the UK. I think it is very important that we stop thinking about the UK regionally and start thinking about the UK operating together as a whole. PETeC has a role in the north-east of England. Chris has already mentioned OMIC in the north-west. We have got the Cambridge IKC, we have got the Welsh Printing Centre, we are starting to assemble a national capability.

Q149 Chairman: Briefly, can you say whether you feel this is a good idea? Is it good use of government money to actually put in the PETeC centre and the Welsh Centre?
Professor Sir David King: Briefly, yes, I do.

Q150 Chairman: You would have more of it?
Professor Sir David King: We need more of it. Absolutely.

Q151 Chairman: It was not a foolish decision to put it in the north-east?
Professor Sir David King: No, but there is a real question around that. A good decision, but the question I have is in terms of RDA support and the different levels of RDA support for different parts of the country. Is the distribution the right one? I understand the political need to see that there is a more even distribution of development around the country, but we might lose a few development arguments around the south-east, because the RDA is relatively poorly funded. So, when it comes to a competition, the south-east is going to tend to lose out.

Q152 Dr Turner: PETeC is undertaking contract work for Samsung. Is this a harbinger of things to come? Is the plastic electronics industry about to go big in manufacturing in the Far East rather than in the UK? What other contract work have you got?
Dr Taylor: I will just put it into perspective. We are currently working with 30 institutions, 23 of whom are in the UK, at this early stage in our development. So of companies identified active in the UK, we are working with half of them already. The plastic electronics industry is going to become pervasive, and you can make an analogy, I think, to the ".com" industry. Most transactions today over the Internet are done by supermarkets, most trading is done by the existing players who have taken advantage of a new technology, but at the same time it has created opportunities for new business models to emerge, such as eBay. You can imagine that happening in plastic electronics. Plastic electronics is on the road map of all the big manufacturers, so they are below the surface, but in Korea, Japan, Taiwan they have plastic electronics road maps. They are going to incorporate plastic electronics in their products of the future. One of the unique things about PETeC and CPI, in competition with the Fraunhofers and the others, is we are very commercially networked, so we are privy to the road maps of the world's leaders. That is why we are doing business with them, to understand their needs, and so we are working with customers in the Far East to put UK solutions into their road map. In the future you will see, I have no doubt, the Far East manufacturing plastic electronics containing UK technology. You will also see emergent new models. You will see the Plastic Logics, the CBTs and the UK success stories. We have 23 UK initiatives and we have seven overseas initiatives, and that is partly a sign-posting exercise; it is partly a demonstration of our competitive strength in the UK, that we are able to licence UK technology abroad.

Q153 Dr Turner: Does that imply that you do not see a prospect of large-scale manufacturing in plastic engineering in the UK?
Dr Taylor: Not at all. The advantage of a sea-change in technology is its levels of playing field. The people out in Asia understand silicon very well; plastic is completely new to them. They are very

pragmatic people. One reason they succeeded in flat panel displays was their pragmatism in incorporating UK and US technology into their devices, and they are out doing that now and they will get the technology from wherever, whoever is prepared to co-operate, and they will pay handsomely for it. The UK benefits at the moment from the materials that go into the existing chain, and we will benefit in the future, but it does not mean to say that we cannot compete with that and that we cannot assemble the innovation. I think that model, the preparedness to go out there and be confident that we can compete abroad and engage and inform the UK sector of what it needs to do and help join that supply chain, is a winning formula.

Q154 Chairman: I am going to have to finish there because we have literally run out of time. There are a number of issues that we would like to write to you about, if we could. I wonder if we can finish this session, Sir David, by just asking you, as briefly as possible, to say what advice would you give to our committee for a recommendation in terms of this particular inquiry? What would you like to see us recommend?

Professor Sir David King: I think each of the issues that we have been looking at and discussing this morning (but you have been hearing evidence for longer) inevitably lead to the conclusion that government needs to provide much more focus for this range of activities. We discussed procurement, and I would very much hope that you would look at the procurement issue. We have discussed what other countries are doing, the Fraunhofer Institutes, for example. I think you see a nascent Fraunhofer emerging here, and so my interest is for you to take as a committee plastic electronics as an exemplar of what we can do in other areas. It is building rather well here, it could go much faster, with more support and that procurement issue, but what are the general issues that arise in terms of British manufacturing from this high-tech sector?

Q155 Chairman: On that note, can we thank you very much indeed, Sir David King, Chris Williams, Nigel Perry and Dr Tom Taylor. Thank you very much indeed.
Dr Taylor: Chairman, could we extend an invitation to the committee to come and see us? We would welcome to give you written evidence, but we would be very welcome to show you—
Chairman: We are intending to come to see you in September, if you can fit that in.

Witnesses: **Dr Richard Price**, Nano e-Print; **Mr Stuart Evans**, Plastic Logic Ltd; and **Dr Keith Rollins**, DuPont Teijin Films.

Q156 Chairman: If I can welcome our second panel this morning: Dr Richard Price from Nano e-Print; Mr Stuart Evans from Plastic Logic; and Dr Keith Rollins from DuPont Teijin Films; welcome to you all. I wonder if I could start with you, Richard, UK universities have spun out a number of plastic electronics companies. What has made the university sector so successful in supporting spin-outs? What do you think the Government could do to encourage more of it? We heard from Sir David King that there is a huge number, it is probably the most successful nation in the world, but what more can be done?
Dr Price: I think one of the reasons why the UK has been successful is that we have an extremely strong academic base, particularly in the materials sector, and this whole area is really predicated on material science. It is not to underestimate some of the challenges that still remain there, but certainly the likes of Plastic Logic and ourselves have benefitted from that expertise that has been built since the early 1990s when Richard Friend was doing his work at the Cavendish. In terms of spinning us out, I think certainly the work of the TSB and before that some of the DTI LINK programmes, bringing together different expertise, because this is a very complex area when you are trying to bring together materials with electronic design and various different processes, whether that be printing, coating and so forth, those targeted programmes and assisting in sharing that risk is very important. We have certainly benefitted from that under the TSB and the work that UKDL under Chris's leadership has done has been extremely important in building those relationships across the UK and also increasingly within Europe as well.

Q157 Chairman: Stuart, obviously Plastic Logic is an incredibly successful example of a spin out that has now gone off to Dresden as we were hearing a couple of weeks ago. What else do you think the Government could do to encourage that change from very successful university science through to successful implementation in terms of successful companies?
Mr Evans: The level of resources that goes into the core research seems to me to be about right and the main message one would want to give there is that that should continue and modestly grow. I think there are three other areas where you could imagine expenditure being useful. The first is in the whole process of getting ready for manufacturing, and that was touched on a bit by the PETeC guys; the second is building the factory, and the UK lost to Germany, and we might talk a bit about why that was; and the third is putting it into use, the whole role of procurement, SBRI and prototype projects. Just to deal with Dresden is it well-known that we did a global search on that—

Q158 Chairman: We have dealt with that with Herman Hauser.

Mr Evans: Indeed. I think in terms of customer readiness we are surrounded by paper. Electronic books and readers will be the first killer application in this space and I think it would be terrific to see government procurement initiatives to interact with our community so that you would have a single electronic book in front of you instead of all these pieces of paper you are about to throw away.

Q159 Chairman: Keith, when I came up to Teijin Films some time ago, before this was even on the horizon, I had a very interesting visit there. Clearly you are a huge multi-national company. How do you interact with small spin-out companies? Is your main objective to gobble them up and suck them of their life blood so you can make more profit?
Dr Rollins: No, I do not think that is the intent.

Q160 Chairman: But is that the outcome?
Dr Rollins: It is not the outcome either, no. Can I apologise for my slightly casual dress this morning, having returned from Korea and Japan yesterday for 10 days, it was going to help me get through this morning I think, so just bear with me. I think it is important to understand that from a business development perspective this is very much a global game, so you need to position yourselves with different kinds of customers with different needs. Interacting with a major Asian multi-national requires a different approach to interacting with a start-up at a Cambridge science park. We have made an investment over the last five to six years to work with those companies to try to develop material sets as an enabler to this industry, because clearly without a piece of plastic of the right quality and specification, et cetera, you are not going to develop and build a plastic electronics industry. In terms of the R&D investment that our business has been prepared to make, we have taken a pretty open approach to the way in which we work with those companies and, of course, what we have tried to do is to pick winners. I am delighted to say we started to work with Plastic Logic six or seven years ago. That is a good example of a winner and there is no shortcut to that; you have to develop those relationships and work with customers and understand their technology and translate that into a product which can allow them to grow their business. Our job—profitably of course—is to allow those companies to grow their business for the future.

Q161 Mr Boswell: I am interested, as we have heard this morning, in the interplay between intellectual property and the various players who may or may not own that who claim it and other players who may want to exploit it. Clearly there is an interest, and you have just touched on this, in having a fairly open structure but on the other hand you are going to have bits that you want to keep to yourself. Conversely multi-nationals may, to follow the Chairman's formulation, want to collar not just the manufacturing and take things away to manufacture but collar the IP which then becomes no longer available in the UK. It sounded from the contributions that you three gentlemen have made so far that you were reasonably relaxed about this rather mixed economy at the moment. Is that the message we should be getting from you? Would any attempt, as it were, to intervene by anybody, whether it be TSB, the Government, or otherwise, destabilise and do more harm than good?
Dr Rollins: Maybe just to qualify my comment about the openness, that was more in terms of our willingness to operate in different parts of the value chain to the ones we would normally occupy, because in this very immature industry it is very difficult to get established companies who perhaps have not recognised the opportunity here to invest and commit resources to develop the industry, so we have worked further down the chain, and part of the investment that we made in CPI four years ago was a strategy to allow us to do that. My comment on intellectual property is of course, like any technology developing company, IP is extraordinarily important to us. It is one of the critical reasons why people like 3M and Merck have a very good sustainability model in the LCD space, and clearly that is a model that any materials company will seek to develop.
Mr Evans: As to IP arrangements between Plastic Logic and DuPont Teijin Films, that is dealt with by we buy his substrate and pay him money, and that is a straightforward kind of arrangement. We are all conscious of the need for a very broad ecosystem here because this is a big task and whether it is in the UK or other countries I think the public purse continues to play an important role in enabling some of that and if the UK chooses to do less of it then others then it will eventually suffer the consequences. Short term I think we are funding R&D research about right. Then there is the getting into manufacture which the PETeC guys and others are talking about and then there are pilot projects that take what comes out of the factories in Dresden and other places and put it on the desks of people like you guys.

Q162 Chairman: Richard, is not the very purpose of your existence to encourage companies to actually go into the pockets of larger players?
Dr Price: In terms of university spin-outs—

Q163 Chairman: Is that not what you do as your job? How do you measure success?
Dr Price: You measure success by creating value and whether that is through an exit of a trade sale to a large global player, through an IPO or through generating sustainable revenues, there is a range of different options. When you go down the path of taking venture capital you are more constrained in your choices there but it does not necessarily mean that you are going to be acquired by a Samsung or Hitachi. Because of the possibilities that were touched on earlier about being able to enter into manufacturing or create various parts of the value chain within the UK, then it is not necessarily the case that this would go overseas. There are possibilities that UK companies over time could be acquiring each other.

Q164 Dr Blackman-Woods: Both Nano e-Print and Plastic Logic were spin-out companies based on venture capital. Did you look at any other funding possibilities, for example University Challenge funds? Was there anything else there or did you not look?

Mr Evans: For Plastic Logic our ambition was always such that the level of funding that it would take would be well beyond what was available initially from those kinds of resources. To hark back to what David King said, we are halfway through our journey. We have raised hundreds of millions of dollars and one of the key things to avoid the company being acquired is that public markets are opened. Some of our investors will eventually want to sell their shares and that is entirely reasonable but we do not want that to be a thing that forces the sale of the company. It is really important that whether it is on NASDAQ in New York or on AIM in London that there is an ability for some of the investors in Plastic Logic to make money at that stage. I tell everybody that an exit is not the end. Bill Gates is so rich because in the IPO of Microsoft he did not sell any shares, and that is the ambition that we have at Plastic Logic.

Dr Price: We are at a much earlier stage in our journey having just raised $1 million rather than several hundred.

Mr Evans: That is the hardest!

Dr Price: It is the hardest and of course we looked at a range of different options for funding. It is very difficult to get that funding particularly at the early stage when essentially, because of the nature of this industry, there is still an extremely high level of risk, it is still essentially in a research phase, albeit industrial research, and looking at other sources of funding other than equity investment was almost impossible at the time.

Q165 Dr Blackman-Woods: Richard, you mentioned earlier that you were getting funding from Technology Strategy Board. How important is that to your company?

Dr Price: It is incredibly important for several reasons. Firstly, it brings together consortia that would not necessarily have come together unless there was government support to share that risk. Secondly, it helps us in terms of our cash flow and enables us to further develop before we have to go back to the market for more investment. It also helps us build relationships with some of the knowledge transfer networks and to grow organically some of our networks within industry.

Q166 Mr Boswell: Just a little point, if I may, following this. Are you satisfied that there is adequate capacity in the UK for appraising these kinds of applications for funding for venture capital? I imagine for example if a small company were to go to a clearing bank they might have some difficulty in having a dialogue with them. At your sort of level and in your experience, is there somebody who at least knows what you are driving at and can give you if not necessarily the funding you require at least a sensible discussion about whether it is merited or could be considered?

Mr Evans: If I were to respond to that I think it is entirely unreasonable to expect clearing banks to be investing in plastic electronics at this stage. We have generally found that dialogues both with grant-making bodies like TSB or investors have been very reasonable; and I would want to pay tribute. In the UK, whether it was the DTI programmes or the current wave of TSB programmes, they are massively easier to work with than the Framework projects in Europe. With DuPont we have done a couple of projects and there have been three players and we were all complementary. We were in three Framework Six projects and each consortium had 20 players and the bureaucratic overhead was a nightmare, so there has been very much more successful state funding from these things here in the UK.

Q167 Dr Blackman-Woods: So you would conclude that the TSB is doing something that is quite unique, it is not duplicating something that is being done somewhere else in the UK?

Dr Price: Absolutely. I would echo Stuart's comments about European projects. They frightened the life out of us, quite frankly, with the complexity of the projects. They are just not appropriate for what we want at this stage.

Q168 Dr Blackman-Woods: Would a reformed SBRI programme be helpful to spin-out companies in your sector?

Mr Evans: Absolutely yes. I think there are two problems there. One is that this has been a promise that has been around for many years and those of us in the entrepreneurial community are extraordinarily sceptical about whether anything will happen; we await with interest. I think they play a really important role in enabling pilot projects and because they provide 100% funding, which is completely different to any other regime, they permit little companies like ours and Nano e-Print to do some different kinds of stuff, so it is a very welcome initiative and I do hope it progresses.

Dr Price: If you look at the difference between, say, CDT in the UK and the Universal Display Corporation in the States, the number of projects that UDC got was phenomenal from the US Government. Despite the success of CDT, I think they could have done much better by having additional support.

Q169 Dr Turner: Stuart, Plastic Logic has gone down the manufacturing route as a business model rather than developing IP and licensing it. Why is it that you have done that? What is your rationale? Do you see that as a greater potential in profit in the future?

Mr Evans: Absolutely yes. The journey we have been on is quite interesting. When we started the company we did view IP licensing as an attractive business model, but one of the things that we realised as we developed the company is that we were going to be first and we concluded that it was much better for us to be first because it was a very attractive profit opportunity, a very attractive opportunity to deliver great value and in our field—and you say this carefully—it is only £100 million to build a factory whereas if it is a 300mm silicon fab or Gen 8 Fab in Asia it is billions and billions of dollars. Writ large the manufacturing story is much more optimistic in the sector than you might imagine because you will have lots of small facilities being very successful and competitive and there is bound to be some in the UK if we wanted to; we only have to try.

Q170 Dr Turner: Richard, what model is your company going to adopt? Are you going to go to licensing or manufacturing? Do you think that one of the factors in it is the attitude of venture capital funders? Are they more like likely to be interested in funding an IP model or a licensing model or a manufacturing model?

Dr Price: Like Stuart, we started off with a licensing hypothesis, but we have quickly moved away from that, partly because it is a very difficult model to implement successfully. There are few examples of it. ARM is the classically cited example of a successful licensing model but they spend enormous amounts of money on their business development activities, so it is very easy to underplay licensing and to assume that it is straightforward. It actually involves incredible amounts of investment and to have licensees that are committed to your technology and implementing that and manufacturing that for you to get a return on your investment. The model would be to develop products or product components and that is much more attractive to the VC market. They prefer to invest in products and something where there is more control over the risk than through a licensing model.

Q171 Dr Turner: Do you anticipate doing your manufacturing in the UK or elsewhere?

Dr Price: At this stage it is too early to say. We would very much hope to do it in the UK. What has been refreshing is that we have a slightly different technology to Stuart's company and we have been able to work with existing players in the UK within the holographic industry. It has been encouraging that there is such a wealth of expertise in that field within the UK and also within parts of Europe, so I would hope that very strongly we could do that within the UK or, if not, the UK within Europe.

Q172 Dr Iddon: Keith, companies such as Merck Liquid Crystals, Chiso or Corning with the glass substrates have been highly successful in the LCD sector. Should we in the UK follow a similar pattern to that in this field that we are talking about this morning? In other words, are we going to be enablers or are we going to be producing devices?

Dr Rollins: I think the attractive thing about the space at the moment, because it is so early, is that all of those options are open. If you look at the materials history in the UK, it would be astonishing if a range of companies did not participate in just the way that Merck have done in LCD but in plastic electronics, so develop the technology, develop products associated with that, and either export or manufacture domestically closer to where device manufacture is taking place. You would be surprised if that did not happen. Almost certainly the technology development and IP licensing piece is going to happen, again traditionally a UK strength. It would be very surprising if that did not happen. I have always felt, as I know Stuart does, that there is an opportunity for the UK to contemplate being a device manufacturing community. That race is not yet won and the opportunity therefore still exists. I think the UK needs to have a very clear strategic intent in this area if it wants to occupy that place in the future. I often think about examples like the German photovoltaic industry—which is a very interesting story to reflect on—which in very quick terms, to go back in history 20 or 25 years ago, the German Government introduced a set of tariff schemes to encourage the adoption of photovoltaics. Germany would not be the first country necessarily to think about building a major PV centre but they did. The German PV industry today is the largest adopting country world-wide for photovoltaic devoices. It is an industry that employs half a million people and it is a multi-billion euro industry. That is the kind of prize that if we are ambitious and have a real strategic aim in this area is the big opportunity. The other stuff is going to happen, I think, but I think that is the big prize.

Q173 Dr Iddon: Stuart, we know full well the hows and whys of you ending up of all the sites you looked at, including one in South Wales, in Dresden—there was a can-do attitude there and the skills were there in that fine city—but do you think you will be able to use your products for assembly in Europe, in Germany in the Dresden area, or will you also be an enabling technology when you are manufacturing?

Mr Evans: We are intending to have Plastic Logic be a manufacturer of electronic readers so what we will make in the factory will be display modules that will be assembled into complete readers probably with a partner in Europe, but that is not finally determined, and is by and large a commodity purchase, with not great value added. I think it is a more interesting question where the second factory might go. Will it go next door to the one in Dresden; will it go somewhere in Asia; or might it come to the UK? I do not think the answer to that is clear, but it is not impossible it could come to the UK, I would have said.

Q174 Dr Iddon: It seems to me that the Asians have cornered final product manufacture whether it be a display screen in a satnav or a mobile telephone or whatever, and they are very reluctant to install manufacturing capacity in the West. Is that a big problem in this area?

Mr Evans: What you see there is maybe slightly misleading. It is very interesting to see the way, for example, the flat panel TV companies are doing more and more final assembly in Eastern Europe and that is the net result of having anchors in Asia. They have got so much invested in the gen eight fabs that they really cannot do anything about that but the other bits of value added they want to do close to the customer. So in the context of Plastic Logic in Dresden we are making the equivalent of what they make in the Gen 8 Fabs in Asia and the final assembly can take place in a wide range of different places, so I do not accept at all that it is a thing that cannot be done to our benefit. I think the product design of course is very interesting. We sometimes talk about Plastic Logic devices wanting to be like iPods but of course the designer of the iPod is a Brit. Jonathan Ive is the chief designer at Apple and he is a Brit. Whether you do it in California or whether you do it in the UK or Europe, if you looked at the mobile phone business, companies like Nokia make one million mobile phones a day and they are a European company.

Q175 Dr Iddon: When Keith Rollins told the Committee recently that you can develop technology in the UK and Europe generally but you have to manufacture in Asia; you would say he is wrong?
Mr Evans: Absolutely and I do not know that he said that, did you?
Dr Rollins: I do not think I did say that. I think what I said was this area offers the opportunity to break that paradigm.
Mr Evans: The point is you will manufacture everywhere because the product will be used everywhere and you are not forced to have a small number of giant plants. All we have to do is want to and try hard and we can have plastic electronics manufacture in the UK.

Q176 Mr Boswell: And it is worth being close to the market
Mr Evans: Absolutely yes.

Q177 Dr Iddon: I am glad we have qualified Keith's earlier comment.
Dr Rollins: I think the other comment I would make to that—because in the first session this morning there was a lot of discussion about barriers to implementation is—I think one of the great advantages that the Asian companies have because of the history of almost 20 years now of course is that in Tokyo, in Seoul, in Taipei, in a 30-minute taxi ride you can jump into the headquarters of the R&D centres for major electronic companies who are the supply chain champions for those industries. The US has something very similar; it is called the United States defense industry. Two years ago when they detected a gap in their capability around flexible displays, they threw, give or take, $50 million at the University of Arizona and set up a flexible displays early stage manufacturing facility. Again at the top of the pyramid there is an organisation that drives adoption and drives implementation of these technologies. I and a number of others in the submissions that we made to the Committee did make the point that, as Chris said earlier, the major electronics industry in the UK has gone but there is an incredibly important role that the UK Government can play in facilitating that domestic demand. I think that is a really important thing for us to think about and to consider if there are any opportunities to make that happen because if the UK Government or some procurement body, or whatever it is going to be, can sit at the top of that pyramid the supply chain will begin to assemble beneath that.
Mr Evans: If I could hark back to the theme you have asked about a couple of times which is the decision not to have this Managed Programme. I do not think that really matters in terms of the money because, by and large, government support financially has been broadly what was anticipated in the managed programme, but it is a missed opportunity to bring together the industry to lead itself into the future. I do not think that the PETeC guys are quite engaged with the stakeholder community in the way that would be ideal. You have got a very powerful cluster around Cambridge. We work quite closely together and Chris Williams has done a great job at building the UKDL into something cohesive, but there is a step further to go I think, and that would be a very desirable outcome, and I think if we had had the managed programme where essentially there had been a commitment to spend the money, which is being spent anyway, industry would have had more control over that and I think that would have been very helpful.

Q178 Ian Stewart: My interest is around skills and recruitment so the first question is are there skills shortages in relation to this in this work? If there are skills shortages, what can be done about that? Secondly, have you got problems recruiting in the industry? Do you recruit internationally and would you prefer local skilled workers?
Mr Evans: We have got the most people so maybe I could respond to that. When we had nine employees, six were foreign; when we had 20 employees, we eight nationalities. We thought that was fantastic. We thought that was really important but now we are nearly 100 people in Cambridge and I should think 70% are British. I would say, broadly speaking, the science skills—and it not easy—you can do because we have got such great universities producing great people. Engineers, the guys who know about what Chris erroneously described as the "boring bits" (and I think that is part of the problem; they are not boring for the right kind of people) we have hired people from Intel who are great semiconductor engineers but who know nothing about plastic electronics, and of course that is inevitable because there is no industry. I think it would be very interesting to see an emergence of a plastic electronics conversion course at some kind of UK institution that could take guys who were basically electronics engineers in yesterday's technology and make them electronic engineers in tomorrow's technology. There is a very nice precedent in the UK displaced masters programme which does something like that and I think that would be very, very helpful.

Q179 Ian Stewart: Can I just press you on that because that would be the next question. Would you prefer then graduates who had specific skills in plastic electronics or would you prefer graduates with more generalist skills?

Mr Evans: For us we want people who are graduates with five, six, 10 years' experience, so it is not so much what their first degree was, although obviously has to be some deeply technical degree, but when we hire them at age 28 or 30, we want them to have spent their time in the right industrial environment. We will do our bit to train them but that is where we would like some help.

Dr Price: Stuart is right that in terms of the science for the core research there are those skills available although we need to keep investing in those. I know certainly the University of Durham are putting together a doctoral training programme that they are helping to get funded for the next 10 years that would generate a continuing pipeline, in addition to the Cavendish pipeline that is very excellent at producing scientists. Alongside that, as we transition from the research into the development and manufacture, those skills are completely different to the skills you need to understand the fundamentals of plastic electronics and that is really where there is a gap at the moment.

Dr Rollins: Obviously our company is a little bit different to Richard's and Stuart's in terms of we will recruit from traditional material science, polymer chemistry, physics and then a variety of brands of engineers, and we recruit generally from the UK, and that suits our needs very well, quite honestly. In answering the broader skills question, again it is important to think about what is the end point in this game; what is the model within UK plc because that will dictate the skills set that is required of course. So if the end point in terms of UK plc is PETeC-type scale, that dictates a certain set of skills sets and so on. It is always going to be very multi-disciplinary for sure and maybe does need to be multi-national as well. If you are going to get a German PV industry in 10 years' time, then that is a large-scale manufacturing mind-set. It is a whole different skills set to the one that gets technology to a PETeC-type scale. I think you have got to answer that question before you really lay out the strategy that says what your people development part is to satisfy that need.

Dr Price: Going back to Stuart's point about their first nine employees, out of our first six we had four different nationalities, so it is a similar pattern.

Q180 Ian Stewart: Can I just move on to another aspect of training then. Would you prefer graduate training to include management skills or is that something you were saying, Stuart, that you would expect to do for yourself in the company?

Mr Evans: I think that is quite valuable early on. In Cambridge one of the most popular courses in the University is what they call Enterprise Tuesday. That is all about teaching young scientists about starting up their first company. It is fine that they know that but I want young scientists to know how to supervise people, how to write project reports, and how to do some of the basic blocking and tackling that represents the move from being a fantastic professional to being a young manager and then to be a great leader. So whether you do it in under-graduate degrees, I am not certain that is relevant; it is definitely relevant in post-graduate qualifications.

Dr Rollins: I think it is important the professional bodies provide some of that training as well. The Royal Society of Chemistry has a nice approach to that in which it delivers a mini general management training programme, I would call it, with elements around the finance, around project management, around people leadership, and I think that is a pretty valuable approach because in some senses it is the sort of programme that would have been delivered from some of the corporate organisations that perhaps are not quite present in the UK in the way in which they were at one time, and of course ICI is probably the highest profile example of that. That produced a stream of well-trained graduate and post-graduate scientists over a 10 to 15-year period some of whom would stay with that organisation and some of whom would take those skills more broadly across the UK, and clearly we will have lost that piece. I think it is important to keep that being delivered.

Q181 Dr Iddon: Do you think our electronics courses in universities are up-to-date? You are at the cutting edge of technology. Are they training people for your industry?

Dr Price: Perhaps I ought to start there. I think there is varying quality across the different universities but I know certainly at Manchester we are starting to introduce courses in plastic electronics and the more emerging aspects—nano electrics, plastic electronics—that have some relevance but the predominant course is still very traditional.

Dr Iddon: Too traditional; is that what you are saying?

Q182 Chairman: Nobody is listening, you can be as honest as you like!

Dr Price: Slightly too traditional I would say.

Dr Rollins: As a materials company it is not really something that we engage in too much so it is difficult for me to make any great comment on that.

Q183 Dr Iddon: You mentioned the RSE; are you principally chemists or across the science base?

Dr Rollins: I am a chemist by training but within the company we have a very multi-disciplinary group.

Q184 Chairman: Stuart, are you happy with the quality of electronics engineers?

Mr Evans: I would say that, broadly speaking, what you want is top-notch people with an excellent technical education, whether they do "Plastic Electronics 101" probably does not matter today; in 10 years it will look old-fashioned, but it is not a problem now.

Chairman: On that note, can I thank you very much indeed, Dr Richard Price, Mr Stuart Evans and Dr Keith Rollins, for your time this morning and thanks to my Committee.

Monday 3 November 2008

Members present

Mr Phil Willis, in the Chair

Mr Tim Boswell
Mr Ian Cawsey
Dr Ian Gibson
Dr Brian Iddon
Mr Gordon Marsden

Witnesses: **Rt Hon Lord Drayson**, a Member of the House of Lords, Minister of State, Department for Innovation, Universities and Skills, and **Lord Carter of Barnes**, a Member of the House of Lords, Parliamentary Under-Secretary of State, Department for Business, Enterprise & Regulatory Reform, gave evidence.

Q185 Chairman: Could we first of all apologise to our second group of witnesses this afternoon who are here as part of the engineering inquiry and the particular case we are looking at is plastic electronics engineering. We did have a vote halfway through the last session which delayed us but thank you very much indeed for your patience. We welcome this afternoon in his new capacity Lord Drayson of Kensington, the Minister of State at the Department for Innovation, Universities and Skills. We welcome you to your post, and I say that very genuinely on behalf of the whole Committee. We are very excited about your contribution particularly to the science agenda, and hopefully we will be able to talk to you about that in the future. We also welcome Lord Carter of Barnes, the Parliamentary Under-Secretary of State for the Department for Business, Enterprise & Regulatory Reform, who in fact has a foot in a number of ministries as part of his particular post. You are very welcome to join the Committee too, Lord Carter. I think it would be wrong of me, Lord Drayson, not to say that yesterday was a momentous day for engineering a long way away and I am pretty sure that you would have preferred probably to be in Brazil than in England, and I wondered if you would like to put on record a brief comment about the success of our Formula One engineering team yesterday.
Lord Drayson of Kensington: Thank you very much, Chairman. I am delighted to do so. I think we all went through several lifetimes in that race, but it is absolutely wonderful to have a British world champion in a sport, particularly in a sport where Britain leads the world. We are the leaders in motor sport and I think Lewis Hamilton is an absolute inspiration, his talent but also the way in which he and his family have developed that talent and the way he is such a wonderful ambassador for sport and such a role model for young people—and the way he took Glock on that last corner was brilliant.

Q186 Chairman: The fact that Glock was going backwards at the time helped. Lord Drayson, the origin of our interest in plastic electronics was Professor David King who, in his valedictory session with us, made it quite clear that plastic electronics technologies had a real chance to be a disruptive technology which would challenge silicon, which would be able not only to revolutionise certain aspects of technology but also be a huge winner for UK PLC. Do you agree with that?
Lord Drayson of Kensington: Yes, I do. I think it is an example of, as you say, Chairman, a technology which has the potential to make a very significant contribution within an industry which is in itself growing, to be a disruptive technology and one where the United Kingdom has a lead position in terms of the way in which the Government over quite a considerable period of time has supported the development of intellectual property. The key for us is to make sure that we turn that intellectual property strength and research strength into wealth and jobs in the United Kingdom.

Q187 Mr Marsden: I was interested to hear you give that endorsement, Lord Drayson, because it is quite true that when Professor King spoke before the Committee in December last year he was very enthusiastic about plastic electronics, but in our first evidence session Doctor Ian French of Philips said, "I think plastic electronics has potential in relatively small areas short term; and these areas would have to be very successful before it could be extended to much larger areas". What independent assessment have you made in government of the real potential of these things, or was the former Scientific Adviser just being over-enthusiastic when he came before us?
Lord Drayson of Kensington: I think when one looks at the assessments that have been made of the potential size of the market one always has to be very cautious. It is very difficult to predict the future size of the market and there has been wide variation in those estimates, some of the order of £15 billion. The best evidence that one can take for the independent assessment of this area of technology having a high impact is the fact that it has been successful in raising really quite significant amounts of venture capital funding. Plastic Logic, for example, raising upwards of $200 million in quite challenging market conditions I think is a pretty strong validation that the venture capital community regards this as an area of really quite high potential in the future.

Q188 Mr Marsden: That has been up to now for the future, but, given the difficult economic times and given presumably that the Government is not going

to want to bankroll this innovation entirely, what is the scope for the City of London to carry on making that sort of commitment?
Lord Drayson of Kensington: These are really challenging times for business generally, clearly, but if one looks at the opportunity for hi-tech, high-growth businesses in the context that those are the businesses which are going to deliver the growth in the future, it is very important both for the private and the public sector not to eat the seedcorn during a time of difficulty. The maintenance of investment in research and development through this period is going to be very important. I remember when I was running a science-based business through the last recession. You have to do two things. You have to focus on surviving but you also have to focus on making sure that you are in a strong position three years out when things will undoubtedly be in an upturn. The very fact that the financial sector is going through some really difficult times at the moment and there will be restructuring of funds means that I am actually quite optimistic that there will be a renewed look at venture capital investments as an alternative for hedge funds. I have already seen some anecdotal evidence that the way in which large-scale private equity management buyouts, the way in which hedge funds have taken such a large proportion of investors' money, have led to not enough being invested in venture capital in early stage development capital. Given that those opportunities no longer exist with the attraction that they had, I think that we can expect people to be looking at those again and that is why I am really quite optimistic.

Q189 Chairman: What is Government going to do to support that? Is it going to incentivise venture capitalists to get engaged at a time of downturn? That is the fundamental question.
Lord Drayson of Kensington: There is the need for the Government to look at the existing schemes that we have, to support investment in early stage high potential businesses and to look at the opportunity for increasing that support in partnership with industry during this period. This is a time when the risk/return equation can be changed, I think, in favour of these businesses, and we have to look quite imaginatively at our role in doing that. The Government already has a number of schemes which have proven to be successful, the small firms loan guarantee scheme, for example, and the enterprise investment schemes. We need to look at all of these and see whether or not we can do more to have an impact, particularly over the next year. The next six to nine months is going to be very important indeed for SMEs. The opportunity is there to work with the financial institutions to ensure that, particularly in the £200,000 to £2 million range of funding, we make sure that adequate capital is available.

Q190 Chairman: The Council for Science and Technology recommended earlier this year that the department should conduct a value chain analysis of the plastic electronics sector. Has that happened?
Lord Drayson of Kensington: That recommendation is something which we intend to follow up. Now that we have seen the example of, in particular, Plastic Logic getting to manufacturing stage, we are at that very important stage with this industry where the supply chain and the geographical location of that supply chain is going to have a big impact on the generation of a cluster in Europe, and so therefore we need to analyse what we can do to facilitate development of such a cluster around the centre which we clearly have here.

Q191 Chairman: When will this happen then?
Lord Drayson of Kensington: I do not have a timescale for the Committee today.

Q192 Chairman: Could you let us know?
Lord Drayson of Kensington: I can write back to the Committee and provide you with fuller details.

Q193 Chairman: Picking up from Gordon Marsden's point, we saw liquid crystal and amorphous silicon industry move abroad despite the fact that the inventions, the breakthroughs in science, actually occurred here. The question is, and I think this was the point that David King was getting at, why should we simply have the great ideas which are then capitalised and taken abroad rather than have major manufacturing of these things—and plastic electronics is a classic example—in the UK? What are we going to do about that?
Lord Drayson of Kensington: The Government over the last 10 years in my own experience as a science entrepreneur has done a really excellent job to transform the landscape around the commercialisation of intellectual property out of the universities and we have seen the creation of many more spin-out companies. That is a success; that is going well. We need to increase our focus now on how we make sure that a greater proportion of those spin-out companies grow to be world-class players. What we are seeing is a relatively recent change whereby it is beginning to be understood by innovators and entrepreneurs that a lot of these technologies, when they move from the laboratory to their first decent-sized manufacturing plant, require the skills of the late stage development to be right next door because the manufacturing itself is really quite uncertain. What we have seen is that other countries in competition with the United Kingdom have been really quite aggressive—and I saw it myself in the Ministry of Defence in aerospace—in seeing that they can backwards integrate by attracting to their particular country the factory for the next generation of manufacturing and then suck towards that supply chain the R&D. We need to be aware of that, the Government is aware of that, and we need to look at interventions to support those industries where we regard there to be—

Q194 Chairman: The two main companies in this area that you are talking about have both gone to East Germany, to Dresden, so we are losing that battle already before we start.

Lord Drayson of Kensington: I think that we need to take those examples as warning signs. In the biotechnology industry we saw this happen with monoclonal antibodies. This is something we just need to put a stop to.

Q195 Dr Gibson: One of the drivers of innovation you would have to consider I guess is public procurement. How important is that in your opinion? You have seen the summary, I guess. How important is it in driving innovation forward, in this sector particularly?
Lord Drayson of Kensington: I think the fact that the Government is spending approximately £160 billion a year gives it an enormous opportunity to make a positive difference. The recent announcement by the Government in response to the economic situation to change the terms of business from 30 days to 10 days is a reflection, I think, of the power that government procurement can have. The challenge here from my experience in the Ministry of Defence is that using government procurement to strategically develop the science base and innovation will require the civil servants responsible for that procurement to take risk and so there will always be a balance between the amount of risk you are prepared to take by trying a new innovation and the criticism which you may be subjected to if that risk-taking in a proportion of times leads to greater cost and more delays. I think what we need to do is to use the procurement budget and we need to learn the lessons which I think have been successfully applied in certain departments for this Government and apply a best practice across government. We are doing that. We are implementing innovative procurement plans from my department to do that to help departments to think strategically. We are also reforming the process by which we encourage those departments to use their procurement budgets to support SMEs and to support innovation. We are doing this but we need to do it on a bigger scale to have more impact than we have had to date. The SBRI scheme is an example where we have gone so far; we are now reforming that and it is part of my job to make sure the implementation of that is effective.

Q196 Dr Gibson: You will know, of course, of the success this has engendered in the United States, the generation of Silicon Valley and the fact that public procurement there has been a major factor. Millions of dollars have been put in there in terms of risk. They are prepared to take the risk, but our civil servants—most of us, I guess—are not prepared to take a risk with unproven technologies. It has to be pretty safe. Is that the British way?
Lord Drayson of Kensington: I do not think it is the British way. I think it is about putting in place the structures to allow civil servants to be able to make informed judgments to lead to better outcomes. We have great examples of where they have done this, things that have been done within the Department of Health, things that have been done within the Ministry of Defence where we have operated pilot schemes. An example in the Ministry of Defence was the Grand Challenge scheme where we put out a challenge for a military capability that we needed and we found that the scientific community responded brilliantly to that competition for ideas. These are schemes which we have tried as pilots. They have worked really well. We need to apply those across other government departments.

Q197 Dr Gibson: Do you think there are British companies that have not got a clue how to go forward to get public procurement? They sit there waiting for the phone to ring rather than getting out there and being Californian, I guess.
Lord Drayson of Kensington: We need to do as much as we can to help particularly SMEs to understand the process of government procurement and the necessary checks and balances that there have to be in the way in which public money is handled. We have seen good examples in certain departments where they have done that, but I think we have more to do in terms of making sure that across government, this best practice is used.

Q198 Dr Gibson: How about the SBRI schemes that we have initiated after the American model in health and defence? How are they progressing? How has anybody's life changed in this country because of new things that have come along?
Lord Drayson of Kensington: There are many examples of improvements to the quality of life through innovation, particularly in healthcare. That is another example of an industry where the UK is a world leader. We have reviewed the SBRI. We concluded that, although on the face of it it was showing that it was hitting its targets whereby departments were spending more than 2.5% of their budget supporting these sorts of projects, more can be done to make them more strategically connected to the strategic aims the Government has in addressing these key challenges. This is what we intend to do; this is what we are planning to do now, put a budget of about £100 million behind this whereby we are saying that we know we have got these challenges relating to an ageing population, relating to climate change. How can we help the departments when they are making decisions, for example in transport, in leveraging the investment that the Government has already decided to make, £100 million, for example, in low carbon vehicles, and that in the procurement decisions they are making in those departments, for example, when they go and buy vans for delivery, they are doing so in a way which supports innovation, for example, buying electric vans rather than diesel? These are examples where I think we can do more to make sure that strategic top-level decisions which are getting significant investment are followed through in the procurement practices in each of the departments.

Q199 Dr Gibson: Would you say that we were going to catch the Americans up with this kind of attitude to make things happen? Is that your ambition? The pieces are in place; you have just got to make it happen?

Lord Drayson of Kensington: I think we need to be ambitious and realistic together. Having had the opportunity over the past year to spend a lot of time in America and having myself built a company in Silicon Valley, I know the power that exists over there, but venture capital investors in Silicon Valley told me this summer that they recognise that whereas in the past they could literally go out of their office and on their doorstep was the science around the biosciences, the science around IT, the coming wave of technologies are not on their doorstep; a lot of them are in Europe, so therefore those investors have said to me that they need to go out into Europe, they need to develop links, and therefore I think this is an opportunity for the United Kingdom, I really do, to be this innovation bridge between Europe and the United States. The fact that we have this Anglo-Saxon business model is a real strength. We have very strong financial and public markets in terms of the way in which they are set up to foster the innovation process in a way that certain continental markets do not, and so I do think it is possible for us to see the next few years as an opportunity, providing that we are strategic in focusing on those areas where the UK really can develop a significant position.

The Committee suspended from 5.37 pm to 5.48 pm for a division in the House

Q200 Chairman: Before we were excitingly taken away to vote on this Bill, Dr Gibson was exploring the issue of procurement. You have given us the Government's line. I wonder if we could now talk about some real actions which are going to change things. If you look at the SBRI funding in the United States, witness after witness has told the inquiry, both in terms of oral witnesses and written witnesses, about the ability of US companies to feed from the huge amounts of resource which are available to companies. If you take the Universal Display Corporation, they repeatedly got grants of between $0.5 million and $1.5 million in order to be able to develop their technologies, and it is that that has enabled them to be ahead of the game. Can you point to a single company over the last 10 years that the Government through procurement has made develop from a small spin-out into a major corporation, just one?
Lord Drayson of Kensington: Yes, my company. Powderject was an example of exactly that, where the way in which the Government supported the recognition of the importance of the biopharmaceutical area in this country, both in terms of its ability to make a positive impact in terms of healthcare and the fact that in terms of the budget being around vaccine R&D, vaccine procurement, Powderject became the world's sixth largest vaccine company after 10 years from spin-out from Oxford University. I can give you that one particular example.

Q201 Chairman: Could you give me another?
Lord Drayson of Kensington: If it would be helpful to the Committee what I could do is write to the Committee and give examples, because I do believe that there are real examples, from a number of different sectors. I spoke about the sector which I know about in terms of my own experience and my own business, but I know from a defence point of view when I was Minister for Procurement in Defence that the Government's willingness to support innovation within defence was built upon the fact that there was a clear recognition of the link between military capability and investment in all R&D and innovation. The Chief Scientific Adviser from the MoD looked at the data and was able to correlate the impact that all R&D had had and was able to conclude that the military capability that we enjoy today was a function of the investment that we had made two decades ago. We do not have that data in other areas because we do not have that clarity of military capability.

Q202 Chairman: I think, to be fair, that you would except that the MoD is a slightly different beast from, if you like, plastic electronics, which is entirely in the private sector. The point that I am trying to make here is that Plastic Logic, for instance, which is one of the big spin-out companies from Cambridge, now has its headquarters in the United States, presumably because it wants to get into the action in terms of US procurement budgets. Do you feel that we are active enough in this particular space in order to be able to incentivise businesses to get government procurement to grow the business and to become world beaters?
Lord Drayson of Kensington: The way that the Government has identified the need to invest significant amounts of money into the stage of the development of a business, that very important stage of getting from really quite a small organisation to a significant organisation, depends upon those important initial orders and that important support for the late stage development of manufacturing. That has been recognised through the setting up of the Technology Strategy Board, a £700 million budget, on the basis of investment to identify those strategic areas that I mentioned earlier. In terms of plastic electronics, unlike, for example, low carbon vehicles, which is a need that society has clearly identified, at the moment with plastic electronics we are dealing with an enabling technology. It is not clear at the moment what product areas, what market areas, plastic electronics is likely to have the biggest impact on, so it is not possible for the Government to say today, "This is the area we think the technology could have an impact on", and therefore I think it is right the way in which the Technology Strategy Board has supported this area of plastic electronics with an investment of about £10 million a year because it is not clear what those key markets are going to be.

Q203 Chairman: Can I just follow that through with you? We were in Japan two weeks ago and Sony, Toshiba, Panasonic, Sharp are all involved in looking at organic LEDs sponsored with something like a £20 million or $30 million budget from the Japanese government, which is for prior development. It is this valley-of-death stuff, and then they can compete on product afterwards, and yet, when I visited PETeC up in Sedgefield during the summer, this is again a very exciting development, with TSB putting money in, the Government putting money in, the RDA putting money in, but if in five years' time they are not self-sufficient there is no more money from the Government. That flies in the face of what you are saying.

Lord Drayson of Kensington: I think you have identified the need for support to businesses to be of a scale which enables us to compete with other countries by being extremely aggressive in identifying these sectors and then targeting the next stage of development. We have seen this in various industries over the years. It is clearly an issue which is very alive in this particular emerging industry. I think that the initiatives that DIUS and BERR have put in place have taken us so far. What we need to do is look at what we can do to address that competitive situation which is very real and I accept exists.

Q204 Dr Gibson: I am just writing a piece about what use science and technology has been in the Ministry of Defence with all the money that has gone in and so on. Could there not be another way of doing that, that the government agencies put aside, like the Ministry of Defence, 2.5% of their research and development budgets like they do in the States to go back into a great big pot which can go to the small businesses? It is there and you are not grappling and fighting other groups to get that money. You have actually got it earmarked from the Ministry of Defence and others that benefit from it.

Lord Carter of Barnes: I very much defer to my ministerial colleague. This is his sector, but, looking in on this from the Department for Business and from my own sector, which is related because in some ways it is a pump-primer for technology innovation, it seems to me that much of your line of questioning is both timely and all in the same area. Our thesis is that there has been a significant and consistent development over the last decade particularly around the excitement with which educational establishments have embraced intellectual property and the commercialisation of intellectual property. There is then the next stage question, which is the scale of commercialisation and how you achieve that. From a practical perspective we have a number of leaders. I would not describe all those leaders as small but they are small by comparison with some of the international comparisons that you make. Nevertheless, some of them have got quite some scale behind them. In health or, if you want to look at it from an industrial point of view, in pharmaceuticals and in defence, the role of government at scale and of government as a customer at scale is very different from almost every other area of activity. The new Secretary of State in our department, Lord Mandelson, has made it clear in his Action Programme for Business that one of the things that he rightly wants to look at is what else should we do as we look to develop other strong industrial sectors in order to give ourselves more scale and more capability in these areas. The report is very timely and the line of questioning I think is very timely. Are we at a tipping point where we do need to be slightly more adventurous in the way in which we use procurement to allow us to go from where we undoubtedly are at the moment to the next level?

Q205 Dr Gibson: Do you think the brightest brains are going into that kind of enterprise or do they stay doing really interesting blue skies research?

Lord Carter of Barnes: My own view is that that has been a big change over the last 10 years. I do think in that area, or certainly in related areas, in hi-tech, digital technology businesses, we have, as Paul was saying, a real international competitive advantage and some outstanding examples of excellence across the piste, not just in plastics or plastic electronics technology but in lots of other related areas. I think there is an appetite there. I think the question is what can we do to the incentive mechanisms we have got to encourage people to take small to medium-sized ideas to scale businesses?

Q206 Dr Gibson: But I have heard these ideas being talked about in this country for at least 15 years. David Sainsbury was in your position, the same story, the same arguments, and yet here we are still trying to do it. What is missing?

Lord Drayson of Kensington: I think there has been real progress but that progress has been in parts of government. That though gives us the confidence about what works in government procurement to address the innovation agenda and to support the science base. The fact that I have been charged with setting up a new Cabinet sub-committee for science innovation, which has as part of its responsibility driving through this procurement agenda and using procurement in this way that the Committee has asked, I think is a recognition of the opportunity to make a bigger difference but also to do so in a way which learns from what works. What we have seen from the SBRI is that it is just not effective enough to give a government department a target of percentage. What you need to do is inspire both the civil servants within the Department but also industry to tackle a clearly defined problem. The answer is to identify those projects in those areas within each of the government departments where they are part of the bigger picture, addressing, for example, the impact of ageing, which has an effect on all government departments, or issues relating to climate change, and then to target the scheme to use innovative procurement in that department and hold those departments to account for their relative performance in carrying out innovative procurement across the piste.

Dr Gibson: I am very interested in what you say about civil servants, and I will shut up at this point, because some of my best friends are civil servants. I know quite a lot and they say they come up with very bright ideas—

Chairman: Name him.

Q207 Dr Gibson:— no, her, actually, and they get bounced because the ministers in the departments do not want to take them on. They spend an awful lot of time, these bright people, coming up with ideas, producing documents, and they just lie there because it starts to get into that maelstrom of argument between departments and so on, "My department is bigger and more important at the minute than yours". I do not know what Gus O'Donnell says in public; I know what he says in private, but a lot of young people are getting a bit miffed being in the Civil Service because they are coming up with brilliant ideas, they want to do it, but they get bounced. Is that true, do you think? Do you talk to civil servants about it? You may will them to do it but they find the whole structure within their departments inhibitory. Is that hypothesis true?

Lord Carter of Barnes: I defer to your knowledge and experience of dealing with civil servants. I certainly talk to civil servants a lot of the time but also it relates to what can we do going forward rather than historically, and you know this far better than I but my sense is that there have been a number of significant legacies, certainly from David Sainsbury's period, and one of those has been to get us to the stage we are at now in terms of the field of opportunity there is. If there is a silver lining associated with this current economic turbulence and international and domestic circumstance it is that there is an appetite across government—and I would include civil servants in that and certainly politicians—to look at other individual areas, other individual opportunities and see how we best align incentives, government involvement, government procurement and encouragement to allow us to take maximum advantage of that, and that is what we are seeking to do. At the same time as Paul is setting up a Cabinet committee I am trying to produce a report, the *Digital Britain* report. There are 14 projects working across government in eight government departments, all of which are trying to create a coherent framework for the digitalisation of the economy. If we could just align ourselves in a coherent way there that would be a significant generator of procurement activities from the public and the private sector. I sense with the ideas that you refer to, whether they are coming from civil servants or other people, that there is an appetite to listen to them right here and right now.

Chairman: I have got an appetite to listen to Dr Brian Iddon.

Q208 Dr Iddon: One of the sad things about this inquiry was to listen to the reasons why Plastic Logic went to Dresden, and the key factor seemed to be a "can do" attitude among the authorities in the city of Dresden. From approach and agreement in Dresden to a production plant took 18 months. It is no secret that they considered five sites, of which one was in South Wales. Do you think we have learned from that experience and if a similar company wanted to stay in Britain with a British discovery out of all the discoveries that came out of Cambridge do you think we could do it now in any region of our country, having learned about what has happened to Plastic Logic?

Lord Drayson of Kensington: I think we need to recognise that we do have an issue in this country culturally, which is that our real academic centres for science and engineering are often in parts of the country where those people not involved in those areas do not want anyone building a factory. I know from my own experience working in the bioscience sector that it was extremely difficult to persuade local authorities that the creation of a new hi-tech manufacturing facility for vaccines was something that they wanted to have in Oxfordshire. We need to recognise as a country that if we are going to have these high-growth industries of the future that often you need to co-locate the late stage development scientists with the early stage manufacturing and therefore we need to look again, I think, at the way in which we communicate to people the reality of modern manufacturing. We can build, we can be competitive in this country in the most hi-tech manufacturing in a clean way. I think there are plenty of good examples. I point to the Rolls Royce factory down in Goodwood as an example of a very modern factory which is a thing of beauty in itself, and that is not just me speaking as a manufacturing engineer. I do not think this is an easy issue to solve because it does boil down to the local attitudes within an environment, so we need particularly to look at the area around Cambridge, the area around Oxford and in London where we do have these centres of scientific and engineering experts.

Q209 Dr Iddon: In talking to the leading industrialists, particularly in Japan but also in China, they have a high on Britain as a possible manufacturing centre for the whole of Europe and perhaps beyond, companies like Hitachi and Sony and so on. They say they are attracted by the products that we produce in our universities and by the number of inventions, but, of course, set aside from that are the tax incentives and other incentives like the city of Dresden has offered Plastic Logic. Do you think we are ahead of the game in attracting companies into this country and, if not, how can we bring companies like Sony into the country?

Lord Drayson of Kensington: I will turn to my colleague here, but the data I think show that the United Kingdom has garnered a larger share than anyone in terms of inward investment within the EU. If you focus on a particular type though of inward investment, the area on which the Committee is rightly focusing is the area of investment for the early stage manufacturing of these big growth industries of the future. We need to recognise that other countries, such as Germany, Singapore I know within biopharmaceuticals, Ireland in the past, have put really quite enormous sums of money into attracting these factories to their region. I am optimistic because, as you say, the United Kingdom has what all of these global companies want. It is the know-how, it is the skills of the scientists and the engineers. What we need to do is make sure that we are leveraging that most effectively. I also think one thing which the Committee has not yet touched upon which I think is very important indeed is to make sure that internationally we have a level playing field such that when our hi-tech companies get to a point where they are publicly traded it is as easy for them to acquire a foreign based company, for example, in Germany as it is for a German company to acquire a UK based hi-tech company. It has not been that up to now. It is next to impossible for a UK company to acquire a German company because of their capital structure and the way their markets operate. I am not saying we should go into protectionism but we need to make sure that other markets are as open as our market such that our companies can grow by acquisition as much as theirs can.

Q210 Dr Iddon: Last October a company called OLED-T that was active in the plastic electronics field unfortunately had to go into liquidation because they were unable to access capital to take them through what this Committee calls the death valley from a good idea into a productive mode. Do you think that we have recognised plastic electronics as a rapidly developing area and supported it early enough? I guess the question I am really asking is, do we have a UK strategy for plastic electronics or is it something we have just ignored and let bypass us?
Lord Carter of Barnes: I cannot comment on the specifics of the particular company you refer to but my sense is yes, we do have a strategy both for the category and for some of the specific opportunities within it. You will have seen the department's publication from just over a year ago which laid out some of the charges and the obstacles. To slightly elide your last and that question, I think the evidence would bear out that we are as a country competitive in an attractiveness for inward investment sense globally, that for many of those large-scale international players we have the smarts and the skills, and, let us not forget, the legal, intellectual property, rule of law, flexible labour market environments, all of which are part and parcel of this. Having said all of that, there are going to be a lot of countries around the world, particularly as a result of what has happened to the financial markets, looking to gain competitive advantage in these new areas. The Technology Strategy Board in its new iteration again is probably the nearest thing to a determined UK strategy in this field. My sense is that that could be sharpened even further. It is somewhere between interesting and conspicuous. If you look at the five platforms they have chosen, most of those are ones where you have got government as a specific customer or potential procurer, and there is a question about how much more commercial they can be in their interest areas. All of these are pointing to a similar direction. As I say, the objective of the Department for Business is to take the early day work that was done in this, the work that was done on the manufacturing strategy, and pull that together in the Action Programme for Business and see what more we can do in order to build on the attractiveness that we already have. I would say this but I do think there is a connection to the work we are also doing in *Digital Britain* for many of the companies, particularly the things you refer to. One of the other things that attracts them to this market is that we are significantly ahead on digital television, mobile technology, wireless technologies, wireless applications, personal mobile display, all of which use an awful lot of the technologies that these companies are manufacturing for, so making us an attractive and vibrant market at consumer and individual retail points I think is also part and parcel of the same strategy.

Q211 Mr Cawsey: As we have done various inquiries in different sectors we have looked at, all roads seem to lead to Rome to me, and that is that if we are looking at cutting edge technologies and new manufacturing we will end up being worried about whether we have got the people with the skills and the training to move them forward in this country. There is concern that the UK is not training sufficient engineers to support the plastic electronics sector, and indeed, to go before that, there is more concern that the quality of applicants for graduate degrees in the disciplines that are relevant to the sector are insufficient in terms of both number and quality. I wonder what the Government is going to do to ensure that we have the right number of engineers and, more importantly, we have people taking graduate degrees in the relevant disciplines.
Lord Drayson of Kensington: Chairman, I think the Committee is rightly focused on a central challenge that faces not just the United Kingdom but most western countries. It is a problem that is faced, for example, by the United States, in that for many reasons not enough young people are choosing to study the stem science, engineering, maths subjects at school, not enough are taking those through such that they have the opportunity to become qualified to be scientists and engineers, and what we face are some really quite important shortages. This is recognised by the Government. The Government has put in place a number of actions at various levels. The Sector Skills Council I think is a very good example where it has identified those particular skills that industry feels it needs. A lot of effort has gone into recruiting more teachers into schools who have been qualified in the sciences because we know that that ability to enthuse is greatly enhanced by having a background in the subject itself. One of the things which I think has come out over the past year is that we have seen the data start to show that those measures that we have taken in schools and education have started to have an effect. We have started to see the early signs of an uptake in young people choosing these subjects but we need to do more. Our research this year has told us when we did a public attitude survey that young people do regard the teaching of sciences and maths at school as extremely important, they do regard them as well taught, they do enjoy learning them by and large. What is missing, which is really striking, is that young people do not understand how that translates into an effect on their potential careers and their parents do not understand. The failure is a failure by us to communicate to young people how, by studying these subjects, you have these opportunities open to you. This is something which I am very focused on in taking up my post. It is about providing more clarity to young people, setting out a vision for them where they can understand what they

can do with their careers. It is about improving careers advice through education, and it is about encouraging industry. It is a job for both the private and the public sector to do a better job of inspiring and communicating how you can have an absolutely wonderful life; you can really change the world by doing this stuff, and making it clearer to young people that the hard work that is required to follow your sciences through school, to then go on to university and do some really quite tough subjects, is worth it, and to persuade parents that supporting their children to do their maths homework and so forth is worth it because the career opportunities that are open to them are really magnificent, which they are. We are taking action in this area. We recognise the problem. We are seeing it is having effects, we are seeing it is working. What we also have to do is use the opportunity which exists because of the difficult economic circumstances. The Government is implementing measures to try and attract those people who are qualified in the stem subjects who went into the financial services sector and now are thinking, "What do I do with my life now?" to come back to science, to think about teaching physics within schools, to think about going back and doing that PhD which you decided not to do after your degree, to think about starting up a science-based business. The initial meetings which have been held, roadshows within cities, have been successful. This is something which we are going to roll out.

Q212 Mr Cawsey: I was interested in your point that it is not just an issue in the UK, and I am sure you are right in that, but do you not think there is a cultural problem in the UK inasmuch as engineering is seen as an oily rag sort of profession and not the same as accountancy and law or any of the other things that talented young people can go into? I say that because I was very taken by a session we did some time ago where somebody said that some young people had been surveyed and asked to name a famous British engineer and the most popular one was Kevin Webster, who is the mechanic on *Coronation Street*. Does that not show that there is this enormous gulf between what we want young people to aspire to and their very poor knowledge of exactly what these professions are?

Lord Carter of Barnes: The last time I heard someone ask that question the research came back with Bob the Builder, so it has moved up a bit. I think you touch on a very interesting cultural point. Again, if you look at it constructively, although it still validates your point, we have a highly successful service industry and an awful lot of it is a discussion about product technologies and product businesses and they are different. I do not think it is an either/or; I do not think anyone would want to trade one for t'other. We unquestionably have great success in the service industries. Indeed, television production is one of our great successes. Let us not knock *Coronation Street*. It is an enormously successful business as well as an enormously successful programme. The question is how do you align the curriculum and the employment incentives and the routes to success and scale for businesses so we have an equally developed culture of product obsession? Some of that I do think goes back to my colleague's comment about routes to exit for businesses. Part of the reason when you go to some of these other countries where you do have businesses built on an obsession around products rather than around necessarily the financial matrix is that it creates a culture which attracts people who themselves seek reward and satisfaction from building and innovating great new products. That is the next stage of development in this area but it is not, I do not think, at the expense of the service industries. I think it is about doing both side by side.

Lord Drayson of Kensington: Chairman, to use the example that you raised at the beginning, I think that if we take Lewis Hamilton and motor sport, we saw on Sunday the tremendous job that he did as the driver, but for him there are several hundred people who are the engineering back-up. You saw him talking to his race engineer and for those people watching it it needs to be pointed out to them that that was someone who was only in their twenties who has a very glamorous life, flying round the world, and is able to do that job advising Lewis about how to get the best out of the car because of what he studied at school, what he did at university and what he has gone on to do. We do have an image problem which we need to address. The problem is that people just do not understand how brilliant modern engineering really is. I see it as a personal mission of mine—I trained as an engineer—to be a champion for the engineering and science community both within government and outside and to really do something about this because it is a misunderstanding. From my own personal experience I have had an absolutely fascinating, exciting and rewarding life because I did maths, physics and chemistry A-levels and I went on to study engineering at university and then did a PhD and then went into business. I could not have done those businesses if I had not done all of that beforehand. We need to make that clear to young people.

Q213 Mr Cawsey: I agree with that. Just to move on to another aspect of training skills in this sector, I found it quite interesting that some of the firms that have given evidence to us say that as well as making sure they have got people who are trained to do the work and the research and all the rest, talking about mainly doing a lot of manufacturing, the other thing that is lacking is often straightforward management training. In other words, you train people to become an expert in whatever form of engineering it is they want to do but you want them then to be successful within the companies as well but they are not trained for the basic management techniques that any company will need to be successful. Is that an issue that the Government should help set the agenda on or is that really for industry itself to sort out?

Lord Drayson of Kensington: I think that is an issue that the Government can make a big contribution to. I think that the CASE awards, for example, for PhD students, are a great model because doing a

PhD means you are effectively your own boss for the first time in your life as a researcher. It is a great training ground doing the right sort of applied research for people to find out whether they would be happy being an entrepreneur. We have seen very effective models for spin-out companies where it has been a professor and a post-doc. The professor has worked with the post-doc to create new intellectual property but the professor has stayed as an academic and carried on teaching while the post-doc has then transferred to be the first managing director of the spin-out company, and with the right training and the right support they can go on to be very successful. You have to have that central focus for the science first and then train the management experience on top of it, and I think we have got the right focus in terms of the balance between the two.

Q214 Dr Gibson: How do you compare with MIT, for example, because we tried to recreate the MIT at Cambridge University, if you remember?

Lord Drayson of Kensington: I think that things like the Judge School have been really positive initiatives. We need to recognise that in some of these areas we are 10 years behind the United States and that just the scale effect does take some time to get going. We certainly saw that within the biosciences, for example. I think initiatives like the one you mentioned have been good ones.

Chairman: On that note, and given that there is another vote imminent, could I thank very much indeed yourself, Lord Drayson, and Lord Carter, for coming before us this afternoon. We have very much enjoyed having you both as witnesses and we apologise for the disruption halfway through.

Written evidence

Memorandum 118

Joint submission from the Department for Innovation, Universities and Skills, and the Department for Business, Enterprise and Regulatory Reform

The terms of reference for the plastic electronics engineering case study are as follows:

— The current and future roles of engineers in the field of plastic electronics

— The potential for plastic electronics in the UK/global economy

— How universities, industry, venture capital and Government are involved in the development of the UK plastic electronics sector, and

— Whether the UK engineering and manufacturing sector are set up to handle growth in this area or other areas like it

Background

1. The term "Plastic Electronics" is used to describe the branch of electronics encompassing semiconducting organic molecules, including polymers.

2. There is a great deal of interest and excitement around plastic electronics at the moment as the discovery of electronic properties from new "plastic" materials has opened up the prospect of electronic circuits manufactured using relatively cheap, additive printing processes on flexible surfaces; something inconceivable using conventional silicon-based electronics. The ability to create plastic electronics circuits on flexible substrates will enable the creation of a whole new range of products that will open up new markets to complement rather than compete with those currently dominated by Silicon. Early applications could include rollable displays for compact mobile devices, and "electronic newspapers"—flexible displays that are as comfortable and natural to read as paper, and can download a book or pick up the latest edition of a newspaper. Another exciting potential application is solar power—organic solar cells have the potential to generate energy at much lower cost than current devices.

3. The UK has been at the forefront of much of the pioneering research in this exciting new area whilst also playing host to many of the key companies throughout the supply chain. This puts the UK in a strong position to develop new products and exploit commercial value from the technology

The current and future roles of engineers in the field of plastic electronics

4. Engineers are employed within the academic base and in companies throughout the supply chain of this emerging industry. Academic roles cover technical areas from chemical synthesis to theoretical modelling and from material analysis to electronic device development and measurement.

5. The task of engineering organic materials exhibiting semiconducting properties into manufacturable devices and products has been taken up by engineers primarily based in industry. This work involves the development of novel materials processing technologies using deposition techniques more closely aligned with the printing industries than those normally associated with semiconductor manufacturing methods.

6. Designing and manufacturing plastic electronics devices is currently at a stage where knowledge and understanding of the manufacturing processes employed is still a requirement of device designers. At present, the development of specific devices is taking place in parallel with the development of manufacturing processes required to reliably and repeatably produce those devices. This dictates a multidisciplinary engineering approach requiring very close working relationships across the supply chain from materials and substrate suppliers, process equipment manufacturers, device designers, and systems engineers. Close collaboration between specialists in each of these fields can be greatly advantageous. The UK is well represented with companies in many parts of this supply chain and benefits from a well developed network to assist with the flow of knowledge and information between interested parties.

7. The Plastic Electronics Technology Centre (PETeC) is being established at Sedgefield as a national prototyping operation, providing world class facilities and services to a UK-wide network in plastic electronics. PETeC will be developing manufacturing processes compatible with pre-production volumes, when fully functional later in 2008, and, as such, be able to help bridge the gap between the small scale laboratory demonstrators and high-volume production runs required for marketable products. The Centre should be very beneficial to small companies looking to develop products based on plastic electronics.

The potential for plastic electronics in the UK/global economy

8. While solid market outputs are expected within 2–3 years, products incorporating Plastic Electronics such as the displays of several mobile electronic appliances (mobile phones and MP3/MP4 players) are already in the marketplace generating revenue. These are significant markets and there is an expectation that as the technology matures and improves in performance, it will rapidly penetrate into higher-value markets. These are likely to be complementary to conventional silicon-based electronics while allowing the prospect of developing flexible circuitry for use in areas like flexible displays (sometimes referred to as e-paper), electronic RFID labels, intelligent packaging, biosensors, disposable electronics and intelligent textiles. Current predictions by market analysts include:

— ID TechEx: Plastic electronics £15 billion by 2015; up to £125 billion by 2025.

— Intertech: 40% (by area) of flat panel displays will be flexible.

— NanoMarkets: £3 billion plastic electronics markets by 2009, and total market will grow to £12 billion by 2012.

These figures are highly speculative however, as the technology and associated products are at an early stage of their evolution and market reports for disruptive technologies/markets are notoriously inaccurate when compared to those for what have been termed "sustaining innovations".

9. In a recent report entitled "Strategic decision making for technology policy", the Council for Science and Technology (CST), the UK government's top-level independent advisory body on science and technology policy issues, identified Plastic Electronics amongst its 6 priority technology areas that could produce real returns for the UK within a five-year timeframe.

How universities, industry, venture capital and Government are involved in the development of the UK plastic electronics sector,

10. Plastic Electronics is a rapidly developing area in which the UK has an exceptionally strong academic base and a number of companies throughout the value chain with leading positions in developing and marketing early products. The UK community is well networked, with the UK Displays & Lighting Knowledge Transfer Network (funded by the Technology Strategy Board) providing a useful focal point for relevant UK interests throughout the supply chain, which comprises organisations developing, producing and supplying the following:

— Materials/Substrates—the fundamental building blocks for plastic electronics products;

— Processing Equipment—the equipment necessary to prepare raw materials for subsequent manufacturing steps;

— Manufacturing Equipment—the equipment necessary to deposit processed materials onto substrates;

— Device Design—activities associated with understanding the interactions between the substrates, materials and layers to realise functional devices;

— Device Manufacture—the sequence of manufacturing process steps required to assemble functional devices;

— Device Testing/Equipment—techniques and equipment required to measure device performance characteristics;

— Device Integration—the bringing together of devices into higher level sub-systems and systems;

— Product Design and Integration—the integration of devices and systems into marketable products.

11. The strength and representation of academe and UK industry across the supply chain is in part the product of past investments by the former Department of Trade and Industry (DTI), the Technology Strategy Board, the Engineering and Physical Sciences Research Council (EPSRC), the Regional Development Agencies of England and the Devolved Administrations of Northern Ireland, Scotland and Wales[1]. The investments include:

— Funding for more than 50 projects in the area amounting to over £25 million in grant under DTI LINK programmes and more recently through collaborative R&D activities funded by the Technology Strategy Board (with support following specific calls for research on the subject of plastic electronics). These projects have also helped the development of an infrastructure of businesses supplying organic electronics materials and equipment, with notable clusters around Cambridge and the North East

— An announcement to establish a £10 million Plastic Electronics Technology Centre (PETeC) in Sedgefield, by One North East in late 2006, supported by £2 million DTI/Technology Strategy Board funds (due to be completed in June 2008)

[1] The Technology Strategy Board and the Research Councils will be submitting a detailed memorandum to the Committee.

— Funding for UK participants in European Framework Programme 6 projects, and successful lobbying of the European Commission by DTI to include plastic/organic electronics as a key theme in Framework 7, with €63 million allocated to this area across Europe in the first year of the programme

— EPSRC supporting the fundamental science, technology and engineering that underpins research into plastic electronics, and pre-competitive research that will position the UK to most effectively develop and exploit technology advances in the area. Current EPSRC portfolio of funding with direct relevance to the field of plastic electronics is £68.2 million, including £2.6 million for skills and training. EPSRC funding is provided, for the major part, directly to universities as research or training grants, a great number of which are collaborative with industrial partners and other relevant stakeholders, and

— Funding for the National Measurement System Innovation R&D programme, which has recently supported a £1.5 million project on plastic electronics metrology at the National Physical Laboratory (NPL). NPL work in the piezo and particle size measuring areas for example, is necessary to underpin the novel manufacturing technology (precision ink-jet printing) required for Plastic Electronics.

12. Much of the Plastic Electronics development work being pursued in the UK and the rest of the world is based on developing and exploiting intellectual property. Some fundamental materials patents have proved to be valuable not just from the licensing revenue they earn but also as an asset to attract interest from venture capitalists and institutional funders. Companies not owning fundamental patents are developing IP portfolios based on process and manufacturing technologies; these can be equally important but are, arguably, difficult to protect. The UK's academic and industrial communities benefit from a generally enlightened attitude towards the value and worth of intellectual property in all its forms.

Whether the UK engineering and manufacturing sector are set up to handle growth in this area or other areas like it

13. Government (national and regional) and delivery partners have a process of ongoing dialogue with industry, including the engineering and manufacturing sectors, to ensure that they are well placed to take advantage of opportunities like this.

14. In the near term, following a process of consultation, DIUS will launch its Science and Innovation strategy, which will set out an ambitious agenda for the UK's innovation policy.

15. The upcoming BERR Manufacturing Strategy Review will look to set out a manufacturing vision for the UK and a clear set of priorities that will need to be taken forward. A key role for the review will be in assessing how the reforms set out by "World Class Skills", which emphasised that the answer to the UK's future skills needs lies in creating a demand driven system in which the skills and training provided are determined by the needs of employers, can most effectively be carried through to ensure that the skills needs of the manufacturing sector are met. Sector Skills Councils have a key role to play in this agenda.

16. The National Skills Academy for Manufacturing (NSAM) will provide industry specific development programmes for trainers and assessors, which it will accredit against the new national standards. It will train employees and managers to work closely together with training providers in the supply chain to ensure that the skills of the entire manufacturing workforce are lifted. The scope of the Academy will be broadened to include schools and Higher Education. By 2012 it will be supporting the learning and skills needs of 40,000 people per annum. Electronics is one of the four leading sectors for NSAM.

17. The Government is also substantially expanding the Apprenticeships Programme. By 2013 the government will have introduced an entitlement to an apprenticeship place for all school leavers who meet the entry criteria. Apprenticeships for older learners are being expanded as well. Apprenticeships offer the chance to acquire high quality, technical skills through the practical experience of working with an employer while achieving a nationally recognised qualification.

18. The national Engineering Apprenticeships programme is one of the largest, with 17,000 young people currently enrolled on level 3 courses. Continued employer engagement will be vital to further expanding the programme.

19. The new 14–19 Diplomas will provide an opportunity for employers to recruit people who have demonstrated an understanding of and a commitment to their industry. Diplomas give employers a key role in the development of curricular and allow learners to combine theoretical study with practical experience. SEMTA in association with other SSCs has played an important role in developing a new diploma in Engineering, which will be taught for the first time in September 2008. A diploma in manufacturing will be introduced in September 2009.

20. A key aspect of our enabling the UK to compete globally in the high technology sector is to develop our skills in Science, Technology, Engineering and Maths. To this end:

— DIUS is investing 12.7 million (2005–2008) in STEMNET—the Science, Technology, Engineering and Mathematics Network, which has a UK wide network of 53 SET Points to encourage the take up of these subjects

— DIUS is investing 12.7 million (2005–2008) in STEMNET—the Science, Technology, Engineering and Mathematics Network, which has a UK wide network of 53 SET Points to encourage the take up of these subjects. 18,000 Science and Engineering Ambassadors (SEAs) are supporting school science activities, offering mentoring and careers advice and acting as positive role models

— Steps have also been taken to improve the number and quality of science teachers. 3,390 people started to train as science teachers last year (2006–07), up from 2,590 in 2000–01, and

— The Government is committed to improving the recruitment, retraining and retention of physics and chemistry specialist teachers so that by 2014, 25% of science teachers are specialised in Physics, and 31% in Chemistry

21. The Technology Strategy Board will launch its strategy for the upcoming CSR period shortly. It has been established to play a cross-Government leadership role, operating across all important sectors of the UK economy to stimulate innovation in those areas which offer the greatest scope for boosting UK growth and productivity. Following the CSR 07 settlement, the Technology Strategy Board was allocated a budget of over £700 million, and the Research Councils and RDAs have also committed £120 million and £180 million respectively for collaborative working with it. The leadership role assigned to the Technology Strategy Board will enable it to use its investments to create critical mass and coherence so that UK business has greater clarity and is better able to access the most relevant support available.

22. Joining up the activities of the main funders of innovation is vital to the future success of the UK if we are to compete globally. The technology and innovation priorities the Technology Strategy Board identifies, in conjunction with its stakeholders, will provide a focus to co-ordinate activity across the UK. This will include not only support for research and innovation, but also the use of other levers of the innovation landscape such as innovative regulation, intellectual property rights, standards, metrology and procurement. By working across the whole of the economy opportunities are opened up to transfer knowledge between different sectors. This helps develop an understanding of how innovation differs across the economy and sectors. Approaches can then be tailored to suit differing needs.

23. The BERR Electronics and IT Services Unit is working with the key businesses, the Technology Strategy Board, UK Trade & Investment, the regions and other agencies to ensure that there is a coherent strategy for pulling the advances in plastic electronics technology through to exploitation in the UK.

March 2008

Memorandum 119

Submission from Nano e-Print

EXECUTIVE SUMMARY

— Plastic electronics offers great hope for low-cost electronics, ultimately towards ubiquituous electronics.

— The UK is a major global pioneer of organic semiconductor materials, electronic devices and processes, with companies such as Plastic Logic, Polymer Vision, Merck, Nano ePrint; centres of excellence such as OMIC, PeTEC; and a wealth of academic excellence in Cambridge, Manchester, Imperial, Durham, Sheffield and many other universities.

— Rapid growth is predicted for the plastic electronics market over the next 10–15 years. The UK can maintain a leading global position given the wealth of printing knowledge still retained and can even expect to be a key manufacturing base in this field.

— Nano ePrint Limited is a spin-out company from the University of Manchester and is venture-capital funded. Nano ePrint is developing a new electronic device which can overcome some of the limitations with current plastic electronic devices and enable more complex functionality.

— True innovations are those which generate revenue—the plastic electronics industry needs to quickly focus on products that capitalise on the excellence knowledge base. These must align with the general trends for technology convergence.

— Continued government support at all levels will maintain the excellent academic body of knowledge whilst also allowing new companies to grow and major companies to continue their involved in the UK and within the industry.

1. *Introduction*

1.1 Plastic electronics offers great hope for low-cost electronics, ultimately towards ubiquitous electronics. These possibilities include potential applications such as:

— Thin, flexible displays eg maps, e-books, retail labels

— Disposable sensors eg temperature, food quality

— Smart packaging eg wireless stock-control, link to internet for promotional purposes

— Smart tickets, eg print-on demand, access control

— Brand protection, eg low-cost covert security features

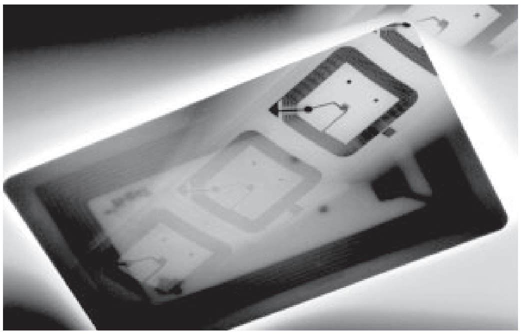


Figure 1 (above): High-frequency RFID label, which could be incorporated into bank cards, tickets, etc.; (left): Schematic of a printer – ultimately this type of equipment could be developed for production of plastic electronic labels or documents.

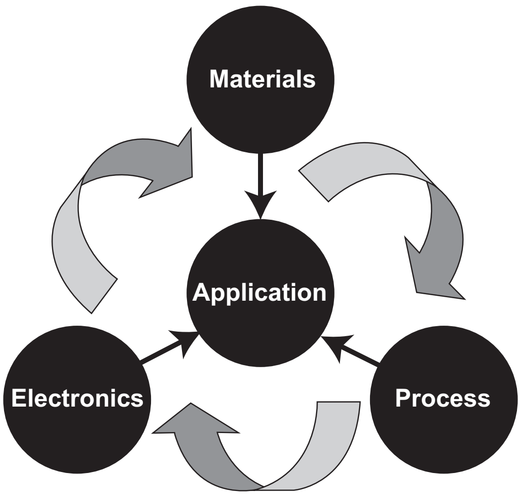


Figure 2 – Plastic electronics unites areas of materials, electronics and processing (such as printing) into new applications.

2. *Why it is important to the UK*

2.1 The UK is a major global pioneer of organic semiconductor materials, electronic devices and processes, with companies such as Plastic Logic, Polymer Vision, Merck, Nano ePrint; centres of excellence such as OMIC, PeTEC; and a wealth of academic excellence in Cambridge, Manchester, Imperial, Durham, Sheffield and many other universities.

2.2 OLEDs

The plastic electronics industry is currently dominated by OLED displays which are already established in various applications (MP3 players, mobile displays). OLED technology was pioneered by Kodak (US) and Cambridge Display Technology (CDT, UK). Other companies such as OLED-T, Opsys (acquired by CDT) and MicroEmissive Displays (MED) have been developing OLED related technologies during the past 10 years. Whilst production of displays is still focused around Asia (MED is a notable exception), particularly Taiwan and Korea, the UK has received value in terms of investment and commercial income from the development of OLEDs. Revenues for OLEDs were $600 million in 2005 (Displaybank) and predicted to reach $1 billion in 2008 (OIDA).

The UK is still a leading pioneer in OLED technology.

2.3 Flexible displays

These displays can be produced on flexible plastic, metal or even paper substrates. Typically, people discuss the use of polymer semiconductor materials which are developed into electronic diodes, transistors and circuits. However, this also encompasses the use of traditional semiconductor materials and novel methods for their deposition and/or processing on flexible substrates.

2.4 Plastic Logic, based in Cambridge, pioneered the area of functional electronics which could be produced by spin-coating a polymer semiconductor. This has now been developed into a process for e-readers (electronic books, newspapers) and moving towards manufacture. Polymer Vision, spun-out from Philips, has developed a display which can be rolled-out of a mobile phone (below)—production of this product will take place in Southampton.

2.5 RFID

Radio-frequency Identification (RFID) is a wireless recognition technology that has the ultimate potential to replace the barcode. There are some 15 trillion barcodes in existence, which presents a sizeable addressable market in the future. The UK is a leader in the adoption of RFID (for stock-control, baggage-handling, library applications).

RFID Label used for identifying clothing such as suits

2.6 The biggest barrier to further adoption of RFID is cost. Current products use silicon chips which are attached to an antenna (aerial). This process has fundamental limits both related to the cost of the silicon chip and "pick-and-place" production. Plastic electronics offers the potential for all-printed or "chipless" rfid, which can drive a radical cost reduction down to the levels demanded by industry. Many commentators believe that Si-based RFID can never achieve lower costs than 5–8c, whereas industry demands 1c for item-level tagging. The latter can only be achieved by a high-throughput, low-cost printing process such as plastic electronics can enable.

3. *The marketplace*

3.1 Rapid growth is predicted for the plastic electronics market over the next 10–15 years. The UK can maintain a leading global position given the wealth of printing knowledge still retained and can even expect to be a key manufacturing base in this field. Excluding OLED, the market is estimated to be $2 billion to $10 billion p.a. by 2010 (Sources: Plastic Logic, IDTechEx, Nanomarkets, Samsung SDI). Growth thereafter is predicted to be very strong with figures of at least $20 billion p.a. by 2015 being typical (Nanomarkets predicts the market to reach $19.7 billion by 2012). The key drivers for the industry are its ability for low-cost items with added flexibility. iSuppli predicts flexible displays to become a $340 million market by 2013, with Plastic Electronics being a dominant force (over 50%). Many commentators, including some leading players, predict even bolder growth to over $1B by 2012. Plastic electronics needs radical cost savings compared to Silicon to achieve these sales volumes.

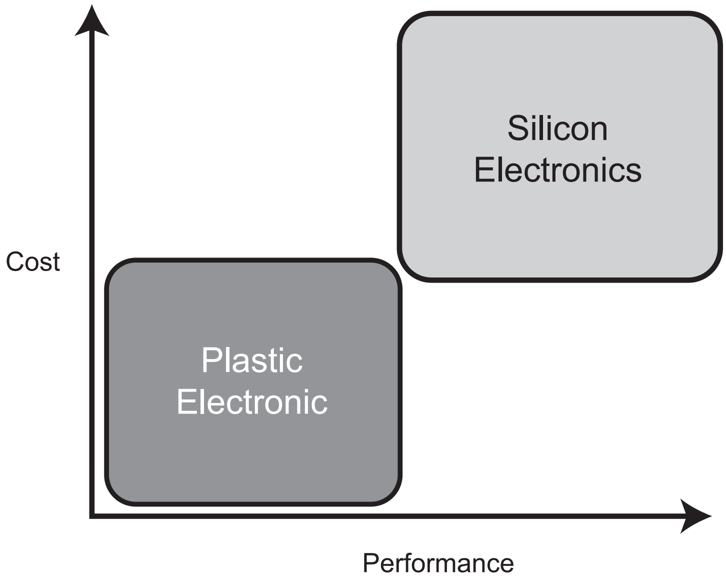


Figure 3—Plastic electronics vs. Silicon electronics: lower-cost & lower-performance.

4. *Nano ePrint Limited*

4.1 Nano ePrint Limited is a spin-out company from the University of Manchester and is venture-capital funded. Nano ePrint is developing a new electronic device which can overcome some of the limitations with current plastic electronic devices and enable more complex functionality.

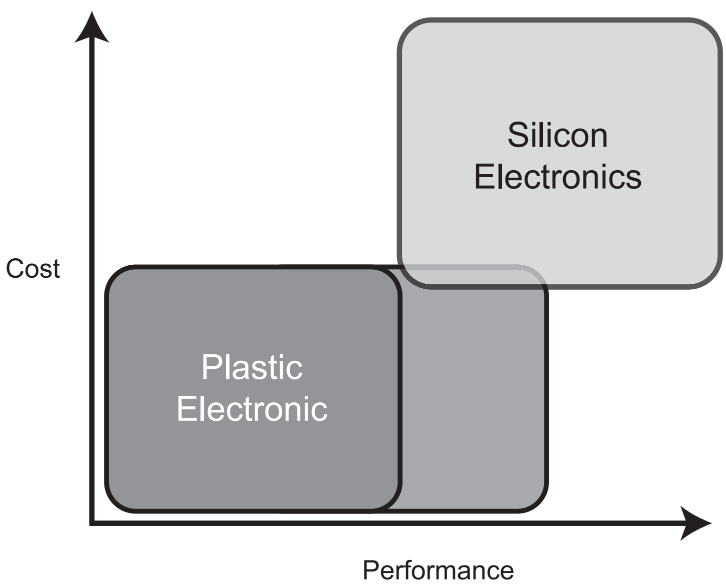


Figure 4—Nano ePrint electronics vs. Silicon electronics: lower-cost toward same performance.

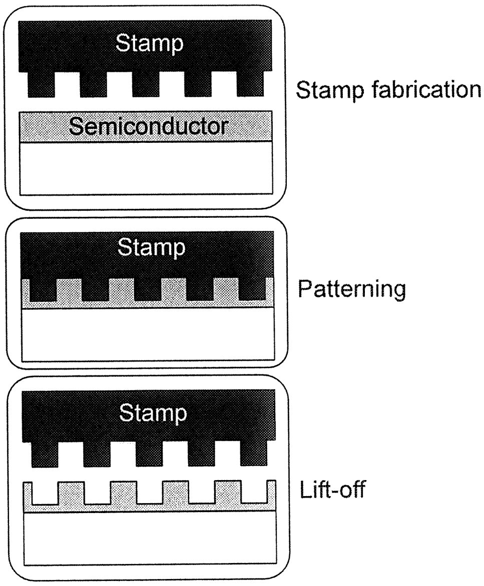
4.2 Nano ePrint's technology is based on a new electronic device design with the following features:

- — Planar diode/transistor
- — One-step patterning
- — Avoids complex alignment
- — Lower losses
- — High speed (10s MHz)
- — Simpler to interconnect

4.3 This enables printing of electronics to be achieved by a simple, one-step process avoiding many of the multi-layer processes required for conventional electronic device designs.

4.4 The printing process used is embossing, which has been well-developed for applications in security printing, such as holographics. Many of these features are used on passports or as brand protection products:

Figure 1 - process of embossing; (1) production of stamp (using lithography or engraving); (2) pressing stamp into soft polymer film; (3) removing stamp to leave patterned surface with features of electronic device



4.4 The printing process can be integrated into existing printing facilities for production of electronically-enabled labels. Brand-protection is a major international problem (approx. 6–8% of world trade is counterfeit goods).

5. *What the future could be?*

5.1 True innovations are those which generate revenue—the plastic electronics industry needs to quickly focus on products that capitalise on the excellence knowledge base. These must align with the general trends for technology convergence.

5.2 These cover a number of areas, such as:

5.2.1 Enhanced consumer experience—"informercial". These could include advanced electroluminescent lighting for advertisement; interactive retail displays with product information; smart packaging linked to promotional offers (eg via the internet). These types of product help to develop brand affection and customer loyalty—this provides the real value to the end-user (rather than the technology itself).

5.2.2 Security and brand protection. Counterfeit goods are a major global problem—plastic electronics offer the capability to embed covert security features by printing. Simple authentication devices could also be used for identifying shrinkage/theft or also linked to customer habits (ie loyalty/targeted marketing).

5.3 It is believed ultimately that plastic electronics will enable a whole series of new applications based on the potential for low-cost printed electronics. These are currently limited by people's imagination and one should expect to see marketing-led innovations being driven forward as the industry matures.

6. *What is needed?*

6.1 Continued government support at all levels will maintain the excellent academic body of knowledge whilst also allowing new companies to grow and major companies to continue their involved in the UK and within the industry.

6.2 Commercial investment, particularly VC, needs to be increased and further efforts should be undertaken to make this industry more attractive to such investors.

6.3 Manufacturing and prototyping facilities such as the Printed Electronics Technology Centre (PeTEC) in the North-East are laudable activities. Grant-aid/assistance for SMEs to develop their own manufacturing capabilities is important if the UK is to maximise its return-on-investment.

March 2008

Memorandum 120

Submission from the Engineering Professors' Council

The Engineering Professors' Council represents the interests of engineering in higher education. It has over 1,600 members, who are all either professors or Heads of Engineering Departments, virtually all the UK universities, which teach engineering are represented. It has as its mission the promotion of excellence in engineering education, teaching and research

Introduction

1. Plastic Electronics is the general term for the branch of electronics that deals with devices made from organic polymers, or conductive plastics (as opposed to silicon) and their integration with inorganic semiconductors. The UK is exceptionally well placed to develop this technology as it already has a first class academic base in this area as well as several key industrial players. It is also leading in the early commercialisation of first generation plastic electronic applications.

A. *Current and Future Roles of Engineers in the Field of Plastic Electronics*

2. Organic light emitting diodes (OLEDS) for application in lighting and displays lead the way in the plastic electronic field with OLEDs emerging as a strong contender for application in various fields. Their introduction has been slower than anticipated by some because of the competitiveness of other technologies, but they are a growing market and many analysts predict that they will capture a significant share of the Flat Panel Display/TV market over the next five years. The ability to integrate electronic functionalities into a range of non-conventional substrates can also enable new products, such as flexible, light-weight and unbreakable displays, for applications such as electronic newspapers or electronic books. Such flexible displays are one of the early important applications of plastic electronics with significant market potential.

3. However plastic electronics offers more than just the above applications. If reel-to-reel manufacturing process can be made mature, there is the potential for a large range of products involving both electronic and optical components to be manufactured at lower costs with more rapid lead times. More novel applications can also be considered as part of the distributed electronics field ie large area electronics with local intelligence and added functionality encompassing areas such as "chip-on-flexi". These applications would include intelligent packaging and RFID tags, distributed and conformal electronics (eg in automotive applications, large area sensors, imaging applications), smart power management, e-skin, wearable electronics, smart windows including antenna for wireless communications, medical sensors and inorganic and organic thin film solar cells on plastic substrates and foils.

B. *The Potential for Plastic Electronics in the UK/Global Economy*

4. The present research base in the UK is extremely strong with a number of world-class university groups (including Cambridge, Imperial, Liverpool, Durham, Oxford, Manchester) as well as a wide reaching commercial sector including Cambridge Display Technology (CDT), Plastic Logic, the Merck Research Centre at Chilworth, Sumation, OLED-T, Kodak European Research, Plastic ePrint Ltd., together with an ink jet printing cluster including Xaar, Xennia and others and, in the North East, the Plastic Electronics Technology Centre (PETeC) and DuPont Teijin.

5. Plastic electronics has great potential for the UK in that substantial manufacturing can be achieved with much less capital costs than in conventional electronics and hence new participants who are technically leading can have major commercial impact, provided they can respond rapidly to the market. The UK will also be able to build on its strong competence in circuit and consumer product design. Companies currently operating as fabless silicon chip companies will be able to apply their competence to plastic electronics as manufacturing capacity becomes available.

6. It is also clear that a sustainable development and a lower energy economy can also emerge from this sector's growth and maturing business development but the availability of appropriately trained staff for manufacturing is a possible constraint, given the loss of the training solution previously offered by large electronics companies.

7. So, as shown above, there is certainly potential for UK to be world-leading. As well as expertise in organic materials the UK has relative strengths in both the printing industry and in pharmaceuticals (in terms of molecular engineering competence) that may be transferable into plastic electronics. However we must act quickly and focus on commercial aspects if we are to be successful.

8. There are practical limits on the size of investment that can be achieved in the UK in the short term. However because of the potential market opportunities and technical feasibilities, we believe that the following deserve special consideration as areas in which the UK should seek to play a major role: Lighting, flexible displays, intelligent packaging (eg RFID), and medical sensors. Displays for public information and outdoor and indoor deployment, reflective or emissive have huge market potential, which is as yet untapped.

C. *How Universities, Industry, Venture Capital and Govt are involved in the Development of the UK Plastic Electronics Sector*

9. The Government via the EPSRC and DTI (now BERR) have made several calls relating to Plastic Electronics including the Carbon Based Electronics (EPSRC) initiative and the DTI -funded Plastic Electronics: Materials Processing and Systems Integration programme. The Cambridge Integrated Knowledge Centre (CIKC), recently set up to provide a platform Technology for Molecular and Macromolecular Materials, is an excellent example of University /Industry interaction in the Plastic Electronics area. The funding for the Centre from both EPSRC and Industry is approximately £14 million over five years.

There are several other examples:

10. The Plastic Electronics Technology Centre (PETeC) is a national centre currently under construction at NETPark in the North East of England for the development of plastic electronics technologies. The Centre will make available access to capabilities around substrate preparation, materials formulation, device modelling, process development and process integration using advanced printing techniques such as inkjet, screen printing or web-based printing. The range of applications for these technologies is extremely broad, but PETeC, in response to industry interest, is initially focusing on displays, photovoltaics, lighting and medical sensors- Partners include Durham County Council, County Durham Development Company, County Durham Economic Partnership, One NorthEast, The Northern Way, DBERR and the European Commission.

11. The UK Displays and Lighting Knowledge Transfer Network (UKDL) was set up by the DTI (as was) to cover Displays, Lighting and Backlighting in all aspects from fundamental materials development through to applications for specific end users. They cater for technology from the point of its invention to the time when it must be refurbished, recycled or safely disposed of. They are the home of Plastic Electronics, Flat Panel Displays and Solid State Lighting in the UK and organize activities in order to strengthen the community. They aim to support the disparate needs of the Displays and Lighting communities in the UK including SMEs, OEMs and Academics from Science Base through Manufacturing and Standards and into strategic End User markets.

12. The Welsh printing Centre set up in 2006 is a world leading research centre focusing on investigating printing and coating as a manufacturing process. The Centre enjoys access to industrial printing facilities and also works closely with all components in the supply chain, including ink, substrate and machinery suppliers. Research into image transfer mechanisms is undertaken on all of the high volume printing and coating processes. It has particular expertise in screen, flexographic, offset, gravure, rotogravure, digital and pad printing.

13. There have also been numerous start-up companies based on plastic electronics—the two most high profile (both from Cavendish Labs in Cambridge) being CDT (recently acquired by Sumitomo Chemicals) and Plastic Logic who have recently decided to locate a $100M factory in Dresden due to substantial support from that region in Germany.

D. *Are the UK Engineering and Manufacturing sector set up to handle growth in this area or other similar areas?*

14. The UK has the skills but there is a concern that these are fragmented. There is significant potential for the UK to establish a world leading position in specific areas as plastic electronics evolves into a mainstream technology, comparable with that in the 1990s when the UIK optoelectronic industry produced 20% of the world target market. However the UK is not able to meet all market opportunities in this space. For example, although the UK has many of the individual components and there is potential for UK SMEs to capture value from early technological leads, the value chain is dispersed and we lack system integrators of

sufficient scale to generate sales for suppliers. Impediments are seen as not on the technical side but are related to coordination and allocation of resources. The UK must focus on specific areas where there are clear addressable routes to market.

15. There are potential focussed routes in which it could be possible to establish commercial production in the UK within 5 years, for example by involving the healthy traditional print industry that already exists together with great expertise in ink jet printing (eg Xaar, Domino etc) and strengths in molecular engineering from the pharmaceutical industry that may be translatable into this arena. These could also make use of pilot manufacturing facilities that are being put in place at PETeC.

16. To provide a secure market and therefore a strong business case for investment, the UK should engage in a detailed study of technical and commercial opportunities taking into account its existing strengths. On this basis resources should be targeted on ensuring that existing public funded activities are operating in a coordinated manner to provide a coherent technical infrastructure, and that there is a set of economic conditions to allow UK industry developing in this field to perform fully in global markets. Careful consideration should be given to the most appropriate method for developing such policies.

17. As part of this activity, it would be expected that initial focus might be given to smaller volume larger margin commercial opportunities, but routes should be developed to determine the potential development of larger market opportunities. Policies should explore routes to encourage industrial partnerships to encourage growth of investment and output, and also where appropriate due consideration should be given to the use of standards or policies, for example in environmental related activities, to encourage the uptake of the technology. Finally, consideration should be given to the use of UK government procurement to encourage the UK industry base. Examples might include, for example, the NHS acting in the medical arena as a customer for diagnostic sensors for MRSA, or in homeland security there could be a requirement for RFID tags or biometric sensors that would provide the market pull to drive the development of the technology.

18. Given their successful use elsewhere, tax incentives for capital investment in SME and large enterprises should be considered, along with the tax position of equipment donations to university as well as targeted R&D tax relief could be examined. The investment climate and tax regime in the UK is not favourable for manufacturing industry in this technology compared with that in other countries. This is important as establishing such a manufacturing base would be critical to enable UK to create and sequester wealth from this technology. The level of government support is not competitive with that offered by other countries for the development of plastic electronics. The Plastic Logic experience provides a good example where their factory will now be situated in Dresden whereas all the initial research and development work was of course carried out in the UK.

Summary

19. In summary the UK has a long history in the field of plastic electronics and has led the way in many aspects. It possesses a vibrant knowledge base and translating this into wealth creation should be a strategic imperative for the UK economy.

March 2008

Memorandum 121

Submission from the Royal Academy of Engineering

0.0 The following response has been produced in consultation with Fellows of The Royal Academy of Engineering and their associates with expertise in the area of plastic electronics. Plastic electronics technology offers new opportunities in the development of displays, sensors, printed batteries, photovoltaics, lighting and signage and organic tags and labels. The main thrust of the response is that plastic electronics constitutes a great opportunity for UK industry and engineering. This is an opportunity that can be grasped or lost. The UK Government needs to take decisive action to support the development of this industry in the UK, from research to manufacture. This is an area where the Government needs to create a strategy to ensure that plastic electronics can develop into a thriving UK industry. This strategy should ensure that funding is available and that action can be taken swiftly when opportunities arise to begin manufacture in the UK.

1. *The current and future roles of engineers in the field of plastic electronics*

1.1 If the UK is to develop a plastic electronics industry then engineers will be central to this field. Hence, as the field grows, there will be an increasing number of roles and opportunities for engineers. It is key that the UK has the right engineers to fill these roles, and currently the UK does have many of the requisite engineering skills. Electronics exploits skill sets that exist in the UK but which have been underexploited since the '80s. These skill sets are semiconductor electronics and materials science combined, and process engineering. The growth of the plastic electronics industry in the UK would present significant opportunities for these engineers.

1.2 It is important to note that currently there are two methods being developed and used for manufacturing plastic electronics. One is based on the method of deposition and removal of material that is used in the manufacture of silicon electronics. The other is a novel method of printing electronics. The comments under the points below might differ with respect to which of these methods is being considered.

Research

1.3 The field of printed plastic electronics began very much upstream in the university sector. Many of the breakthroughs in the development of printed electronics are a product of the work of researchers from the Cavendish laboratory at the University of Cambridge. There are other strong research groups in plastic electronics in the universities of Oxford, St Andrews, Durham, Manchester and Sheffield and Imperial College London.

1.4 There are considerable further research opportunities for engineers in the UK. For example, several UK research groups including the Cavendish Laboratories are pursuing early stage research in using plastic electronics to produce cheap solar cells. This and other possible developments in the plastic electronics field mean that there will continue to be future roles for engineers in research.

1.5 However, it is important to keep a broad definition of "engineer" in mind here. A lot of the research in this area began in physics rather than engineering departments. But this is a reflection of the fact that physics departments in the UK are heavily involved in applied science (the Cavendish laboratory in particular). This contrasts with, for example, the US, where work of this nature would certainly be in an engineering department, most likely such as materials science and engineering. Hence, it is important not to draw to sharp a distinction between UK engineers and physicists when considering the plastic electronics sector (or other sectors, for that matter).

Development

1.6 The UK has had great success in developing plastic electronics to bring them to the point of manufacture. The companies Plastic Logic and Cambridge Display Technologies are spin outs from the University of Cambridge and have been enormously successful in bringing printed electronics to the point of manufacture. Dupont Teijin films based in the north east has also done valuable work in the area of "planarization"—the smoothing out of films so that they can be used as a substrate for printed electronics. The Plastic Electronics Technology Centre (PETeC) has been recently established in the North East to assist in prototyping and promoting commercialisation.

Manufacture

1.7 Philips and its spin-out Polymer Vision developed methods for producing plastic electronics based on traditional processes for manufacturing silicon semiconductors, by means of deposition and removal of material rather than printing. The company Innos, a spin-out of the University of Southampton, won the contract to manufacture plastic electronics in this way. Innos had set up a fabrication facility with a state-of-the-art cleanroom, using fabrication facilities previously used for producing silicon semiconductors. This was attractive to Polymer Vision as the high specification cleanroom would allow manufacturing in higher quantities. This allowed Polymer Vision to continue development of plastic electronics to bring them closer to the point of manufacture, focusing on yield improvement and finalization of the product. Innos has now been bought out by Polymer Vision but the manufacturing facility remains in Southampton.

1.8 The traditional methods of manufacturing used by Polymer Vision meant that use could be made of existing plants which produced silicon semi-conductors and the expertise which came with them. It takes little work to develop these in order to produce plastic electronics by the same methods; therefore there is some room for manufacturing to grow in the UK in this area.

1.9 In the realm of printed electronics, the UK has been successful in the first phase of taking science and early stage engineering to the point of manufacturability. However, Plastic Logic is now entering the manufacturing stage, but will be basing its manufacturing overseas in Dresden. There are a number of reasons for this. First, there is a workforce with relevant experience in Dresden, as demonstrated by the success of the large process facility operated by AMD there, whereas it is unclear what companies Plastic Logic would recruit from to get manufacturing staff in the UK, with the diminishing semiconductor volume manufacturing base. Second, it was possible to move very swiftly in the process of setting up a plant (a point which will be returned to below).

1.10 In the case of both Plastic Logic and Polymer Vision there have had to be collaborations with overseas companies for financial support and manufacturing. Although such collaboration brings benefits, it does mean fewer roles for UK engineers in product development and manufacturing. While these firms are based in continental Europe they are only providing limited employment opportunities for UK engineers (though the fabrication facilities in Southampton set up by Innos and now run by Polymer Vision provides employment for some UK engineers). The UK produces many skilled process engineers who are employed across the globe and it would be of great value to develop opportunities for them to be employed in the UK, contributing to the UK economy.

2. *The potential for plastic electronics in the UK/global economy*

2.1 Plastic electronics have the potential to transform the UK and global economy tremendously, having as big an impact as the development of silicon. At this point plastic electronics is not a mass technology but is still "waiting to happen". However, performance has now been demonstrated showing that its potential is very strong. This means that we are now on the brink of a sea-change in how electronic devices/products are marketed. Plastic Logic's electronic paper is moving closer to market with US investors currently placing bets on this. There is strong international interest in this technology and manufacturing interest in Asia is gathering pace.

2.2 Plastic electronics have the capacity to transform electronics generally. If printed circuits come to maturity it would be possible print circuits straight from a computer. This would have a profound impact on prototyping, making it significantly easier. Normally UK start-ups have to manufacture overseas, but this would allow easy small-scale manufacture of prototypes. This could change the paradigm of electronics manufacturing, having smaller production lines instead of large manufacturing centres based overseas. It could potentially see the return of high-tech manufacturing to the UK.

2.3 There is certainly the potential for some degree of change to the current manufacturing paradigm. Although capital for manufacture in this area is substantial, it amounts to hundreds of millions rather than billions. The logic which forced silicon manufacture to be focused in small areas does not apply in this area, hence there is potential for manufacture in Europe—producing value chains in design, manufacture and marketing.

2.4 The development of plastic electronics will also facilitate the growth of pervasive electronics. It provides opportunities to develop products that use plastic electronics—consumer products including devices that you can wear. There is great potential in the UK to establish companies based on the end products that use plastic electronics.

2.5 The UK is in the lead in this area—ahead of the US. It could lose this lead if opportunities are not grabbed, in which case the potential for plastic electronics to boost the UK economy would be lost.

3. *How universities, industry, venture capital and Government are involved in the development of the UK plastic electronics sector*

Universities

3.1 The role of universities has already been described—though it is important to look beyond engineering departments in universities. As explained, physics departments in the UK have greater involvement than they might in the US due to their focus on applicable research.

3.2 Universities have so far been very successful in setting up spin out companies to develop this area. This should be encouraged to continue—perhaps in particular setting up a company to develop solar cells based on plastic electronics.

3.3 At the moment the area is well serviced by students, mainly from physics and chemistry. However, it would be beneficial to set up specialized teaching courses in this area to serve the industry as it grows. The University of Southampton is currently training PhD students in this area.

Industry

3.4 Traditional industry tends to be risk averse therefore relying on existing players in industry to develop plastic electronics would mean that little headway will be made in these new areas. However, Merck, which has based its R&D activities in this area in Southampton, is an exception to this.

Venture capital

3.5 Venture capital has a major role to play in developing the plastic electronics sector. USD120 million of venture capital was raised to set up Plastic Logic's manufacturing facility, a very significant investment.

3.6 Venture capitalists will invest large amounts of money when an industry is becoming established, but not when it is still at the research stage. Venture capitalists cannot invest in an area unless there is an exit in the next three to seven years. Government often tends to support the early research stage, but sometimes with not enough finance to get a company from start-up to the state where venture capital will become involved. This is an area where it would be helpful for Government to work with venture capital funding to support the development of plastic electronics from research through development to manufacturing. If the gap persists, then more companies will have to go overseas and the opportunity for the UK will be lost.

3.7 University venture funds can be of great benefit—eg, Cambridge Challenge Fund[2], Imperial Innovations and similar at Oxford. However, there is still need for strategies to fund research through development to manufacture.

Government

3.8 An important role of the Government is to create the right environment for venture capital to make investments—in terms of the right tax environment and supporting the development of the UK skills base. Government funding also plays its part, through what were the DTI schemes and the European Framework. However, such funding is rarely a catalyst for new work, and tends only to fund already likely to be taken up. UK Government funding contrasts with Darpa funding in the US which seems to constitute a swifter, less bureaucratic system which is more effective in supporting novel research.

3.9 Generous and swiftly available Government support paved the way for Plastic Logic to set up its manufacturing base in Dresden. Dresden is, like Wales, a development area and therefore there was local support for a plant there. When setting up a plant (especially in a Greenfield site) the time lapse between agreement and finishing the plant is critical; in Dresden, only 15 months after the money being handed over the factory is almost ready to go. One North East supported the development of PETeC in County Durham, but this project has moved ahead far less swiftly. If it is felt that the UK should try to develop manufacturing strengths in plastic electronics then the UK Government and the RDAs need to consider how they can make decisive and swift funding decisions, to support the swift build of facilities, to attract manufacture within the UK.

4. *Are the UK engineering and manufacturing sectors set up to handle growth in this area or other areas like it?*

4.1 In terms of the traditional methods of producing semiconductors adapted for plastic electronics, there is the capacity for manufacturing in the UK. Hence the only real manufacturing currently done is by Polymer Vision at Southampton, using a site which was home to the oldest fabrication facility in the UK (though all of the equipment presently used there is new). There are other disused "fabs" that have the facilities, the equipment and the knowledge to allow fabrication here. These should be exploited to a greater extent.

4.2 However, in terms of printed electronics there is not currently the capacity to manufacture in the UK. Large-scale manufacture of products is likely to continue to be based overseas but there is potentially a role in the UK for the development of small specialized devices where design is important. In principle, however, plastic electronics presents an opportunity to change manufacturing paradigms, bringing manufacture back to the UK. The committee may find it useful to explore the possibility and likelihood of such a change.

4.3 In order for growth in this area it is vital that the UK has the requisite human capital. The UK has started to attract skilled people in this area and it needs to continue tempting people from overseas as well as fostering UK engineers. It must also retain its best students who have come into the UK university system from around the world. It also needs to invest in the training of skilled clean room technicians, which are a scarce resource in the UK, but essential for the manufacturing of plastic electronics.

March 2008

Memorandum 122

Submission from the Technology Strategy Board

Executive Summary

1. The Technology Strategy Board welcomes the case study into Plastic Electronics Engineering by the Innovation, Universities and Skills Committee. This emerging technology offers a great prospect for the UK to exploit the critical Intellectual Property and knowledge that it possesses to generate wealth in the global market.

2. In recognition of this, Plastic Electronics has been identified by the Technology Strategy Board as an important part of one of five technology pillars in the draft Electronics, Photonics and Electrical Systems Strategy. The Technology Strategy Board will consider seriously further investment to exploit the UK's lead in plastic and organic electronics to develop a sustainable base for wealth creation.

3. To date, Technology Strategy Board Collaborative Research & Development competitions worth £48 million including Plastic Electronics in the technology scope have been conducted. The total value of Plastic Electronics projects that are running is over £52 million, representing over £25 million committed

[2] Though it is important to note that this fund was *not* used by Cambridge Display Technologies or Plastic Logic.

investment by the Technology Strategy Board at least matched by funding provided by business. The Plastic Electronic Technology Centre (PETeC), which opens in Summer 2008, benefits from a further £2.06 million investment by the Technology Strategy Board, in addition to the funding from One North East.

4. The Technology Strategy Board financially supports the UK Displays and Lighting Knowledge Transfer Network, which is an active champion for the field. Previous networking support of the Plastic Electronics sector has been through the Flexynet Link Programme, which later grew and evolved into the UK Displays and Lighting Knowledge Transfer Network.

The Technology Strategy Board

5. The Technology Strategy Board was established in July 2007 as an Executive non-Departmental Public Body sponsored by the Department for Innovation, Universities and Skills. Our vision is for a world in which the UK is a global leader in innovation and a magnet for innovative businesses, who can apply technology rapidly, sustainably and effectively to create wealth and enhance quality of life. We will promote and invest in technology-enabled innovation:

- For the benefit of business,
- To increase sustainable economic growth,
- To improve quality of life.

6. We will invest with partners including Regional Development Agencies, Devolved Administartions and Research Councils in new ideas, build networks, promote knowledge exchange and provide leadership. With a wide remit covering the whole of the UK economy, the Technology Strategy Board will have to make choices as to where we invest. We will do so using the following criteria:

- Does the UK have the capacity and capability to develop and exploit the technology or innovation?
- What is the size of the global market opportunity?
- Is the idea ready? Potential for impact and timescale.
- Is there a clear Technology Strategy Board role?

7. We will evaluate our investments to inform future decisions. We will consider further investment in the exploitation and commercialisation of Plastic Electronics against these criteria.

Introduction

8. Plastic Electronics is an emerging field that has the potential to disrupt the world of electronic circuits and flat panel displays. It has been identified by the Technology Strategy Board as an important part of one of five technology pillars in the draft Electronics, Photonics and Electrical Systems Strategy.

9. The ability to utilise flexible substrates instead of the traditional rigid glass structures or silicon in certain applications, will lead to a paradigm shift in product and end-use capability as well as manufacturing processes with roll-to-roll processing, now a real possibility. The development of Organic Semiconducting Materials is also recognised by the Technology Strategy Board as a significant enabler. Although several UK companies are leading the way to exploit this field there is still work required to fulfil the potential.

10. The basic manufacturing technology, both for the use of organic semiconductors and for the creation of electronics on flexible substrates, is printing. The UK publishing industry is particularly well established, so there is considerable capacity and skills base to draw upon. The development of functional inks carrying organic semiconductor materials, metals and barrier materials has been driven in large part from the UK academic base, and their integration into the manufacturing process is now well underway.

Current and Future Roles of Engineers in the Field of Plastic Electronics

11. This need for continued technical development is recognised by the Technology Strategy Board and is why further support and investment is being seriously considered. Additional technical challenges relate to the compatibility between materials (including wet shelf life), device geometry, processing—especially the manufacturing proposition, which could well be roll-to-roll as described above, and general issues of developing manufacturing capability.

12. Some of these challenges require genuine scientific advances in the laboratory but all of them require an investment of engineering effort. A joined up approach is required from electronic engineering and materials engineering through to manufacturing and process engineering, recognising that some of the solutions will originate from academia. It is the integration of solutions from these disciplines which will lead to systems and products which can then service the global market.

13. It should be recognised that a valid commercial proposition also exists for the individual material, component or production technology suppliers that can provide solutions to address these challenges and win in the global market.

14. If appropriate advances can be made to make printed electronics a commercial reality, this will also open up the field to a new skill base in the printing community who would not normally associate themselves with electronics. This means that it is not only traditional skill sets that are required but the innovative application of skills from other fields as well. This prospect is particularly exciting, because of this cross-cutting applicability.

Potential for Plastic Electronics in the UK/Global Economy

15. The worldwide market for organic and printed electronics is estimated to rise from $1.18 billion in 2007 to over $48 billion by 2017[3], and technology analysts speculate that these new markets could be valued in the hundreds of billions of dollars within 20 years. One substantial opportunity is in the flat panel display component market, for which a UK capability study has been conducted in the past[4]. Recent data show the market exceeded $94 billion in 2006 and will grow to nearly $200 billion in the next ten years[5]. Currently this is based on silicon deposited on glass, but plastic substrates and organic semiconductors aim to penetrate or displace parts of this. For example, the e-paper market is predicted to reach $2 billion by 2012 and then double again in the subsequent two years[6].

16. It should also be recognised that the first applications of Plastic Electronics will not necessarily be the high end display market, even though some Far East companies have recently launched or announced thin displays based on Organic Light Emitting Diodes (OLED). In fact the first market opportunities could well come from those requiring short lifetime such as advertising displays or cheap giveaways from fast food outlets or garages etc. This is one of the reasons why Plastic Electronics is full of opportunities and the UK needs to identify and exploit these emerging markets, in parallel with the further development of the wider industry and technology for traditional applications.

17. In a field that is often referred to as Organic PV (PhotoVoltaic), Plastic Electronics also offers the possibility of cheap, flexible solar cells and a market of $2.3billion is predicted to emerge for thin film and organic semiconductors as they penetrate portable applications and low cost installations in the built environment[7]. Similar rapid market penetration is predicted for plastic RFID tags and other cheap disposable electronics, whilst the use of organic electronics in lighting applications leads to an emerging market for OLEDs that has been forecast to exceed $400 million by 2010, with strong continuing growth to over $6 billion in 2015[8, 9].

18. The uptake of these Plastic Electronics devices in the market promises a wealth of new application possibilities, providing a platform for software and service innovations, improving operating efficiency in retail and logistics, and penetrating into sectors as diverse as transport, publishing, medical devices and domestic and consumer electronics.

How Universities, Industry, Venture Capital and Government are Involved in the Development of the UK Plastic Electronics Sector

19. To date, Technology Strategy Board Collaborative Research & Development competitions worth £48 million including Plastic Electronics in the technology scope have been conducted[10]. The total value of Plastic Electronics projects that are running is over £52 million, representing over £25 million committed investment by the Technology Strategy Board at least matched by business.

20. The opening of the Plastic Electronic Technology Centre (PETeC) in Sedgefield, in the summer of 2008 will provide an open access facility to allow new companies to enter into this exciting new field and create working prototypes, which is why a £2.06 million capital investment in this centre was made by the Technology Strategy Board, supplementing infrastructure investment support from One North East. This centre will provide a focal point for developing manufacturing processes leading to commercialisation of the technology, and for building a skills base in the North East and nationwide to support it.

21. The Technology Strategy Board has also invested in networks to nurture and grow the field of Plastic Electronics; the UK Displays and Lighting Knowledge Transfer Network grew out of the Link Programme called Flexynet. UK Displays and Lighting are champions for Plastic Electronics in the UK, and provide a forum within which this community can meet and cross-fertilise ideas, to encourage innovation in the field.

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3 IDTechEx, Organic and Printed Electronics Forecasts, players and Opportunities 2007–2027.
4 Flat Panel Displays in the UK—a guide to UK capability. Logystyx Ltd for DTI. Aug 05.
5 OIDA Global Market Optoelectronics Industry Market Report and Forecast. October 2007.
6 www.optics.org reporting on "E-Paper Markets: An Eight-Year Market And Technology Forecast" which is available from NanoMarkets.
7 Thin Film and Organic PV: New Applications for Solar Energy. NanoMarkets 2006.
8 OIDA Global Market Optoelectronics Industry Market Report and Forecast. October 2007.
9 Nanomarkets.
10 The following competitions have been run by the Technology Strategy Board and by the Department of Trade and Industry before that: £4 million, April 2004, Displays; £8 million, Nov 2004, Optoelectronics and Organic Electronics; £14 million, Apr 2006, Organic Electronics, Displays & Solid-State Lighting; £7 million, Nov 2006, Plastic Electronics and Displays; £5 million, Apr 2007, Plastic Electronics; £10 million, Nov 2007, Advanced Lighting, Lasers & Displays.

As well as providing knowledge transfer opportunities for the UK community, they also work with UK Trade and Investment as ambassadors for the UK capability to overseas companies and organisations, to provide new export or inward investment opportunities.

WHETHER THE UK ENGINEERING AND MANUFACTURING SECTOR ARE SET UP TO HANDLE GROWTH IN THIS AREA OR OTHER AREAS LIKE IT

22. There are also over 30 companies with benchmarked world-class R&D in Plastic Electronics, these range from home grown companies to multi-national players. UK organisations hold much of the knowledge and critical IP, along with leading positions in developing and marketing early products.

23. The UK also has an exceptionally strong academic base, with several 5-star university departments, such as the Cambridge Engineering (Centre for Advanced Photonics & Electronics) and Cavendish Laboratories, and Imperial College and Southampton having world class activities. EPSRC has taken a lead in supporting university research in this area, with several large grants to develop the UK capability.

24. Support and investment is required to help the growth in this area. However this is not just a case of providing money to the sector. In fact some of the bigger questions relate to how it is possible to extract wealth from the public and private investment. This might be through a new manufacturing proposition, or technology licensing or the supply of the constituent materials, components or processing equipment. Further work with the community and key stakeholders is required to explore these ideas and identify the UK route to wealth creation from Plastic Electronics technology.

25. This is where the Technology Strategy Board will work with the emerging Plastic Electronics industry and other stakeholders such as the Research Councils (eg EPSRC) and Regional Development Agencies (eg One North East), to make sure that all of the support is joined up. If new sectors are to embrace the opportunity that Plastic Electronics offers an appropriate out-reach programme needs to be conducted to educate the existing sector. Knowledge transfer is of utmost importance. It is also important that the correct technology barriers are addressed for the good of the wider community, and also that the manufacturing proposition for the sector is identified and exploited to ensure that the investment today, provides great payback in the future.

SUMMARY

26. The Technology Strategy Board welcomes the case study into Plastic Electronics Engineering by the Innovation, Universities and Skills Committee. The emerging industry offers a great prospect to for the UK to exploit the critical Intellectual Property and knowledge that it possesses to generate wealth in the global market. The Technology Strategy Board is seriously considering further investment to exploit the UK's lead in plastic and organic electronics to develop a sustainable base for wealth creation.

March 2008

Memorandum 123

Submission from the Cambridge Integrated Knowledge Centre

EXECUTIVE SUMMARY

1. Plastic Electronccs Engineering is both a radical opportunity and founded in technology and science developments securely vested in the UK's competency. For UK government to assist the translation of that opportunity into wealth creation in the UK it is essential that the engineering discipline is engaged and advanced through a coherent strategy. It is necessary to consider both the contemporary developments in engineering as well as the radical new developments and this requires a sustained policy intervention to ensure that the stakeholders are all engaged in the process. It is important that the deliverys of trained resource and the transfer of skills from other sectors is considered along side the science and technology developments. In the main body of this submission these points are discussed in greater detail.

Introduction

2. The Cambridge Integrated Knowledge Centre in Advanced Manufacturing Technologies for Photonics and Electronics (CIKC) brings together research activities on molecular and macromolecular materials in the Engineering and Physics Departments of Cambridge University with the expertise of the Judge Business School, the Institute for Manufacturing and the Centre for Business Research to create innovative knowledge exchange activities spanning research, training and exploitation. With funding from EPSRC of £7 million over five years and £5 million from industrial sponsors, CIKC will orchestrate the creation of a centre of excellence in the field of low temperature and additive processing for the fabrication

of products in the fields of distributed electronics, flexible electronics, displays and communications. The Mission of the Centre is to provide the business and technical expertise and infrastructure to enable those with exploitable concepts to achieve commercial success.

3. CIKC was founded to respond to the need for industry to develop advanced manufacturing for the new technologies labelled as "Plastic Electronics", a technology vector derivative of distributed electronics and flexible circuits. The imperative is to enable paradigms using new macromolecular material systems, and to create valid exploitation models for these innovations. Developments in the molecular engineering of polymers, advanced liquid crystals and nanostructures, are having a disruptive impact on fields such as microelectronics, displays and communication systems with the introduction of new low cost processes allowing components to be fabricated on flexible substrates (or conformally on non-planar surfaces). This technology thrust is accompanied by societal needs to lower energy and environmental impact of manufacturing processes. In turn, it reflects industry needs to lower capital investment and operational costs of their manufacturing technology. Coupled to market demand for integrated products and mobile life-style enhancing (knowledge and "infotainment" economy) products this is a market disruption and segmentation event of great commercial significance. The penetration of soft materials into the electronics and photonics markets has already begun, and with a market estimate measured in $10s of billion per annum, the UK must capitalize on its strength in the basic science as well as build the engineering base to support the emergent industry.

The Engineering Discipline in "Plastic Electronics"

4. Engineering is fundamentally the translation of the science base into application driven technologies. In the context of "Plastic Electronics" it is the primary role of engineering to provide proofs that technology demonstrations of the emergent propositions may be exploited in applications plausibly of commercial potential.

5. In the current expressions of the technology, engineering has a role to see that the new technology can be prosecuted on manufacturing platforms and that the devices may be integrated into production streams which have viable yields. In some of these applications the developmental role of engineering will be to translate the propositions onto existant tool-sets and to provide the evolutionary propositions which develop those platforms and processes to enable immediate adoption of the technology. However, in the near and mid-term this must be coupled to development of new paradigms enabling of the future tools and processes that will achieve the production efficiency gains expected to derive from these innovations. Thus at least these two streams of endeavour are required:

> 6. Functionally complex integrated products (such as mobile phones and flexible displays) are already adopting the new materials and process technology and herein the process and materials developments need to be married to the existing CMOS and flexy-circuit paradigms.
>
> 7. Elsewhere radical new products and processes are being created which have no precedent in contemporary industrial deployment and here we must develop the manufacturing technology as well as the fundamental proofs of "fitness-for-purpose".

8. Looking forwards, engineering as an interdisciplinary science will continue to innovate and create new propositions and scientific proofs relevant to this field. We can see this most clearly in the exploration of novel materials and processes for photovoltaic technology. It is to be expected that this early exploration will also have relevance to the broader thrusts in electronics and photonics.

9. The engineers required must span the disciplines which will provide businesses the human resources they require. A minimal expectation must be that due regard is given to the need for production expertise, manufacturing management (operational and supply-chain), science and technology professionals and personnel with hands-on experience with the new and emergent tools and methods. The implication is that training and re-training opportunities must be created which are both theoretical and academic as well as hands-on and practical. The balance to be struck here will need to sustain both the demands of industry and the need to develop educational and research infrastructure. Thus: secondary and tertiary level education planning and resource; post-graduate opportunities and support; continuous professional development and knowledge exchange and dissemination are all required.

UK Economy: Potential impact of plastic electronics

10. Plastic electronics can integrate electronic functionalities into a range of non-conventional substrates, and in this way will enable new products, such as flexible, light-weight and unbreakable displays, for applications such as electronic newspapers or electronic books, POS displays, and eventually wall-sized TV displays. OLEDs are already emerging as a potential alternative to liquid crystal displays, although the introduction has been slower than anticipated by some, and many analysts predict that it will capture a significant market (for example, DisplaySearch predicts OLED displays as a $5 billion market by 2009).

11. Flexible displays are one of the early important applications of plastic electronics with significant market potential ($10 billion by 2010 according to Samsung), others areas include lighting (NanoMarkets predict $1.5 billion market share by 2014), solar cells, intelligent packaging and RFID tags and medical

sensors. In each of the areas there is already strong commercial interest. Overall projections for the printed and plastic electronics industry as a whole range up to $250 billion by 2025. Many applications for plastic electronics can be considered as part of the broader field of distributed electronics ie large area electronics with local intelligence and added functionality encompassing areas such as "chip-on-flexi".

12. Plastic electronics has good prospects for the UK economy in that substantial manufacturing can be achieved with much less capital costs than in conventional electronics and hence new participants who are technically leading can have major commercial impact. The UK will also be able to build on its strong competence in circuit and consumer product design. Companies currently operating as fabless silicon chip companies will be able to apply their competence to plastic electronics as manufacturing capacity becomes available. A healthy traditional print industry already exists as well as great expertise in ink jet printing (eg Xaar, Domino etc) and together with strengths in molecular engineering from the pharmaceutical industry there may be opportunities to translate these competences into this arena. Europe is currently in a successful position in mobile phones, lighting, photovoltaic and automotive areas and a UK plastic electronics industry has the opportunity to play into these markets.

13. It is difficult to predict the likely UK market share, but we note that the UK optoelectronics industry reached a 20% world market share and this would appear to be realistically achievable. Clearly there is significant potential for the UK to establish a world leading position as plastic electronics evolves into a mainstream technology. However the UK is not able to meet all market opportunities in this space. It must focus on specific areas where there are clear addressable routes to market.

Current UK involvement in development of plastic electronics

14. The UK has an extremely strong research base with a number of world-class university groups (including Cambridge, Imperial, Liverpool, Durham, Oxford, Manchester) as well as commercial sector research (Merck Chilworth Research Centre, DuPont Teijin Films, Toppan Printing and Kodak European Research). It is also leading in the early commercialisation of many first generation plastic electronic applications through companies including CDT, Plastic Logic, Elumin8, OLED-T, Pelikon, Plastic e-Print. These companies have successfully raised large amounts of venture capital funding, frequently from overseas; most notably Plastic Logic raised $100 million in January 2007.

15. The EPSRC has supported scientific research though several calls relating to plastic and carbon based electronics as has the Technology Programme (most recently with an indicative £5 million call). Several Knowledge Transfer Networks (in Displays and Lighting, Photonics and Electronics) are in place to facilitate interaction between firms (and with academia) in this technology area. The Plastic Electronics Technology Centre (PETeC) in Sedgefield represents a major investment (primarily through One NorthEast and European Regional Development Fund) to put in place pilot manufacturing facilities. CIKC can also play a role facilitating liaisons between value-chain participants and engaging directly in process and design development for the fundamental components. Other research centres with important roles to play in developing this area in the UK include the Welsh Centre for Printing and Coating at Swansea University and the Organic Materials Innovation Centre at Manchester University.

Is the UK well positioned to handle growth in plastic electronics?

16. There is certainly potential for UK to be world-leading. UK has developed many of the individual component technologies and there is opportunity for UK SMEs to capture value from early technological leads if these can be translated into successful products. However, the value chain in the UK is dispersed and SMEs lack strength to be vertically integrated without a major customer to drive the market. Partnering with large system integrators will be important for these SME in order to enable the route to market. A sideways transfer of competence from the printing and/or pharmaceutical industries would also be a good model.

17. There is a need to establish better links between companies using intermediary institutions, such as the Knowledge Transfer Networks and the CIKC, as "virtual systems integrators" to create places where interactions between components of the supply chain can be facilitated to ensure a strong technology pipeline and produce a continuous flow of innovations. Funding of institutional mechanisms to encourage partnership and collaborative developments may provide greater leverage than supporting a large number of individual projects.

18. To provide a secure market and therefore a strong business case for investment, there needs to be a final customer in place for the technology. UK government procurement could be used to encourage the UK industry base and provide the market pull to drive the development of the technology.

19. The UK has the skills base to support commercialisation of this technology, however the availability of appropriately trained staff for manufacturing is a possible constraint given the loss of many skilled engineers in manufacturing as well as the training solutions previously offered by large electronics companies. Initiatives to address this should be supported.

20. Globalisation and the pace of market change demand a different clock-speed for emergent industry which poses a challenge to the UK financing which has traditionally not been highly geared. Risk awareness and preparedness for early stage investment is much greater in the USA. UK investment sector has shown a reluctance to fund the capital investment required to advance technology businesses into manufacturing and has thereby favoured knowledge services/licensing approach which does not offer the same potential value to the UK. Improving the investment climate for to set up in the UK is critical to enable the UK to create wealth from this technology.

21. In order to capture the significant opportunity in plastic electronics the UK needs to put in place well-articulated policy initiatives to provide the investment climate to encourage national or overseas manufacturing industry to locate facilities in the UK and in addition focus on grants to enable knowledge exchange and research targeted at wealth creation.

Conclusion

22. In total the opportunity for the UK in this field is very strong. Perhaps more telling to the UK economic future is that this is a field where the infrastructure planning has already been well advanced by initiatives such as the: Cambridge Integrated Knowledge Centre (and the Cambridge regional technology cluster); the Welsh Centre for Printing and Coating; the Plastic Electronics Technology Centre; the Organic Materials Innovation Centre at Manchester University; The UK Knowledge Transfer Networks (in particular the UK Displays and Lighting KTN) and a strong base in Universities and SME endeavours. Thus from the perspective of the economic future this is an opportunity for the nation to create a manufacturing base of large commercial potential. The societal benefit from this can be drawn from environmental gains, reduced energy use, the employment of staff and wealth creation.

March 2008

Memorandum 124

Submission from cintelliq Ltd

Since its formation in 2002 cintelliq has been tracking the commercial and technical activities of the organic semiconductor and organic electronics industries. cintelliq provides information services and technology consulting to the organic semiconductor industry. cintelliq is responsible for providing the following services:

— free weekly newsletter to the industry (OSA Direct);

— bi-monthly journal (Organic Semiconductor Industry Journal);

— quarterly report on patents covering organic semiconductor and organic electronic technologies (Organic Semiconductor Patent Analyst) first published in March 2004;

— annual conferences since 2003 (OSC-03, OSC-04, OSC-05,OEC-06,OEC-07,OSC-08); and

— consulting activities—projects for many of the major companies in the organic semiconductor/ electronics industry- project include—patent analysis, market evaluation, due diligence, analysis of government funding and VC investments.

cintelliq limited is based at St John's Innovation Centre, Cambridge, UK.

Prior to founding cintelliq Limited I have spent much of my career identifying, selecting, acquiring and exploiting new technologies. This includes working for:

— Cambridge Display Technology the inventors of light-emitting polymers.

— Cambridge Consultants (Arthur. D. Little) where I was directly involved in providing strategic and operational advice to clients dealing with the commercialisation and impact of emerging technologies. Key experience gained—developing technology and product roadmaps; technology intelligence; technology due diligence and reviewing strategic and operational options of R & D groups.

— Institute of Manufacturing (University of Cambridge) where I was involved in developing tools and techniques for auditing technology management processes.

Academic qualifications are—a BSc in Physics, MSc. Digital Systems and an MBA from Manchester Business School.

1. *The UK needs to rapidly increase UK engineering and manufacturing capability in "plastic electronics" if it is to retain its current world class position during the next phase of industry growth*

— The UK has developed a significant IP position in both OLEDs and Organic transistors.

— However, despite the UK holding a key IP position in fundamental OLED technology all manufacturing of displays has migrated to the Far East.

— The majority of UK and European organisations involved in "plastic electronics" are typically small companies who have spun-out from either university labs or large companies. The staffing of these companies are primarily scientists, and there are few staff with engineering or manufacturing disciplines.

— Compared to the Far East the UK, and Europe, has few significantly large product focused organisation developing "plastic electronics".

— In the Far East the situation is radically different. The top ten organisation developing organic electronics are large and well known—Sony, Samsung, Epson, Toshiba and other. They have the ability to quickly refocus internal engineering and manufacturing resources on to the commercialisation of "plastic electronics".

— The consequence is that in the UK and Europe there is a shortage of engineering and manufacturing expertise with direct knowledge of "plastic electronics" to assist in the next phase of industry development.

— Without such engineering and manufacturing capability the clear lead already obtained in "plastic electronics" in the UK and Europe could be eroded and eventually lost.

2. *"Plastic Electronics" is important to the UK*

"Plastic Electronics" is important to the UK for the following reasons:

— Over the past 20 years the UK has developed a world class position in organic semiconductor and organic electronics. Including both materials know-how and process know-how

— The "plastic electronics" market is expected to be worth between several billions of dollars and several hundred billion dollars over the next 5 to 20 years.

— More than $1.3 billion invested by Governments and VC investments (Europe and US) for the period 2000-Q1 to 2007-Q2

— The largest ever single VC investment ($100 million) in Europe was made to finance the world's first large-scale manufacturing facility being built by Plastic Logic (UK) in Dresden

— Polymer Vision, a spin-out from Philips, has built its first manufacturing line for organic transistors in Southampton

— The world's first substrate supplier to both Plastic Logic and Polymer Vision is DuPont Teijin Film based in the UK

— The UK has a growing number of companies who are actively participating on an international level in "Plastic Electronics"—this include Cambridge Display Technology, Plastic Logic, Merck (UK), DuPont Teijin Films, OLED-T, Novalia, and CENAMPS

— The majority innovation in the UK on "Plastic Electronics" is predominantly being developed by starts-up and key research projects in universities

3. *"Plastic Electronics" worldwide is important*

3.1 Over the past 20+ years there has been much research and development worldwide on a new class of electronics that takes advance of organic materials with semiconducting properties. These organic semiconducting materials can be formed in to individual electronic components—leds, transistors, photovoltaic, lasers, memory and sensors.

3.2 By combining these individual components into arrays and circuits new products and applications can be created these include—ultra-thin displays, flexible displays, eBooks, solid-state lighting, solar cells, memory and RFID.

3.3 The technology will lead itself to the development of low-cost and disposable electronics for consumer applications.

3.4 Products made from these devices can result in lower-cost, more energy efficient, more environmentally friendly, and because these devices are constructed from thin films (100nm or less) will use less materials.

3.5 These new devices can be manufactured by adopting not just conventional vacuum deposition techniques but also a wide range of printing techniques such as ink-jet gravure, and flexo-graphic.

3.6 In terms of maturity it has been said that the "organic semiconductor" industry is probably at the same level of maturity as the silicon industry was around the late 1960s or early 1970s.

NOTE: The term "Plastic Electronics" are used frequently by the press. However, it is important to point out that many other terms are used to describe the same range of components, products. This includes the terms:

— Plastic electronics.
— Printed electronics.
— Polymer electronics.
— Organic electronics.
— Organic semiconductors.

cintelliq uses the terms "organic semiconductors" and "organic electronics".

3.7 The size of the opportunity: Organic electronics is still very much an emerging technology, and there are hundreds of companies worldwide that are currently developing innovations in new materials, new devices and new processes to realise new products and new applications. Forecasted market sizes vary but it is expected that over the next 5 to 20 years the overall value of the market could between a few billion dollars to several 100 billion dollars. While the size and timings will vary the key point to note is that there is a growing consensus that there is a sizable market ahead.

3.8 The first segment of this market to begin commercialisation is OLED based displays. In 2007 sales of OLED based displays reach about $500m (DisplaySearch, Mar 2008).

3.9 Organic Electronics sales are not yet established with several companies developing manufacturing facilities.

3.10 The most commercially advanced are transistors. Initial applications of organic transistors are as backplane drivers of e-paper products.

3.11 Two companies poised for commercial launch of e-book applications

— Plastic Logic, based in Cambridge, is currently building their production facility in Dresden, and expects first commercial products during the early part of 2009.
— Polymer Vision, based in The Netherlands, will begin production this year at their manufacturing facility in Southampton.

3.12 These two production facilities are the first commercially available of organic backplanes in the world, and OLED will commercialise these include—RFID, solar-cells, memory, sensors and lighting.

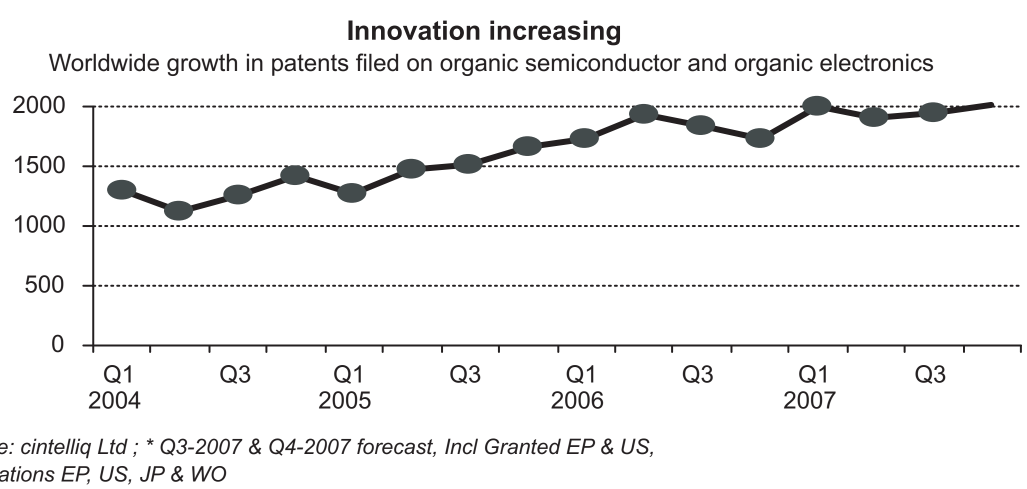
3.13 Over the course of the next five years more applications based on organic electronics.

4. *Organic Semiconductor Patents 2004–07*

4.1 Patents are a key indicator of technological innovation. The number of granted and application patents published on organic semiconductor and organic electronics has grown steadily each quarter since 2004-Q1.

Figure 1

ORGANIC SEMICONDUCTOR PATENT FILING—2004-Q1 TO 2007-Q4



Source: cintelliq Ltd.

4.2 Prior to 2005 only EP, US and WO where fully classified. Since 2005 all EP, US, WO and JP the patents were fully classified. The following analysis is based on patent data for the 30 month period 2005-Q1 to 2007-Q2.

4.3 Intellectual property (IP) is being filed worldwide across the full range of organic electronic devices—led, transistors, photovoltaic, lasers, sensors and memories are being developed.

Table 1

ORGANIC SEMICONDUCTOR PATENTS—2005-Q1 TO 2007-Q2: DEVICES

	Organic semiconductor based devices							
	OLED	*Organic Electronics*						
Priority Region	*LED*	*Transistors*	*Photovoltaic*	*Laser*	*Other Sensors*	*Total Memory Cell*	*Other*	*Total*
Europe	1133	184	79	3	23	89	304	1,815
US	1826	225	136	25	22	173	365	2,772
Far East	9,942	772	118	18	33	113	705	11,701
Total	**12,901**	**1,181**	**333**	**46**	**78**	**375**	**1,374**	**16,288**

Source: cintelliq Ltd

NOTE: There have been academic studies on the differences between Japanese patent filings strategies and European/US patent filing strategies. One of the findings is that Japanese companies tend to file patents with narrower claims, whereas European and US companies tend to file patents with broader claims. The result is that Japanese companies may file more patents whereas European and US companies may file fewer patents for similar inventions.

4.4 Organic semiconductor patents can also be classified in terms of the intellectual property they seek to protect. Again these can be divided in to two distinct groups—materials related patents and process related patents.

Table 2

ORGANIC SEMICONDUCTOR PATENTS—2005-Q1 TO 2007-Q2: MATERIALS AND PROCESS

	Materials			*Process*				
Priority Region	*Material*	*Substrates*	*Encapsulation*	*Patterning*	*Deposition*	*Device Structure*	*Fabrication*	*Both Other*
Europe	747	28	75	56	68	454	162	225
US	946	23	152	64	175	749	256	407
Far East	2,999	246	718	256	653	2,695	1,631	2,503
Total	**4,692**	**297**	**945**	**376**	**896**	**3,898**	**2,049**	**3,135**

Source: cintelliq Ltd.

4.5 Combining the two previous tables makes it easier to compare and contrast the differences between priority regions.

Table 3

ORGANIC SEMICONDUCTOR PATENTS—2005-Q1 TO 2007-Q2: DEVICES VS MATERIALS AND PROCESS

Priority Region		*OLED*	*Organic Electronics*	*Both*	*Total*
Europe	Materials	566	95	189	850
	Process	405	235	100	740
	Both	162	48	15	225
US	Materials	739	176	206	1,121
	Process	757	342	145	1,244
	Both	330	63	14	407
Far East	Materials	3,284	321	358	3,963
	Process	4,260	662	313	5,235
	Both	2,398	71	34	2,503
Total		**12,901**	**2,013**	**1,374**	**16,288**

Source: cintelliq Ltd.

4.6 OLED dominates the patent landscape, but this is only to be expected as it was first to be discovered/invented in the late 1980s. Eastman Kodak discovered small molecule based OLEDs around 1985 and Cambridge University discovered polymer based OLEDs around 1988. Cambridge Display Technology was founded in 1992 to exploit polymer based OLEDs.

4.7 OLED IP (Europe): Europe has developed a strong IP position in materials and device structures. However as virtually all OLED displays are manufactured in the Far East namely -Taiwan, Korea and Japan—this is where the majority for the process related IP has been developed. This can be seen in the number of process related patents filed in the Far East compared to Europe.

4.8 The early work in the UK on polymer based OLED devices has enabled a strong IP position in fundamental polymer based OLED IP.

4.9 Only two of the top ten European assignees manufacture end user products—Osram and Philips (displays and lighting). The remaining assignees are either material suppliers or licensing companies.

4.10 These top ten assignees account for 64% (715/1,123) of the European OLED patents.

Table 4

TOP TEN EUROPEAN PATENTS ASSIGNEES—2005-Q1 TO 2007-Q2: OLEDS

Assignee	*Materials*	*Process*	*Both*	*Total*
Cambridge Display Technology Ltd	55	60	18	133
Koninklijke Philips Electronics NV	29	65	32	126
Merck Patent GmbH	88	6		94
Covion Organic Semiconductors GmbH	76	4		80
Novaled GmbH	20	42	9	71
Philips Intellectual Property and Standards GmbH . . . Koninklijke Philips NV	15	29	11	55
Thomson Licensing SA	6	20	15	41
Osram Opto Semiconductors GmbH	20	20	1	41
Ciba Specialty Chemicals Holding Inc	39			39
BASF AG	34	1		35
Total	**382**	**247**	**86**	**715**

Source: cintelliq.

NOTE: Philips files patents under different assignees, if combined they would rank 1st(181); Merck acquired Covion and combined would rank 2nd (174) and CDT would rank 3rd (133)

4.11 OLED IP (Far East): Like Europe the Far East has developed a substantial amount of OLED IP, the majority of this IP is focused on process innovation. This is not surprising as the majority of OLED based displays are manufactured in the Far East.

4.12 In contrast to European assignees many of the top ten Far East assignees manufacture end user products (displays). They are all household names—Epson, Samsung, Sanyo, Sony, LG Electronics and Canon. There is only one materials company listed in the top ten Far East assignees—Idemistsu Kosan.

4.13 These top ten Far East assignees account for 52% (5,222/9,965) of the Far East OLED patents.

Table 5

TOP TEN FAR EAST PATENTS ASSIGNEES—2005-Q1 TO 2007-Q2: OLEDS

Assignee	*Materials*	*Process*	*Both*	*Total*
Seiko Epson Corp	130	733	391	1,254
Samsung SDI Co Ltd	204	491	286	981
Semiconductor Energy Lab Co Ltd	246	356	194	796
Idemitsu Kosan Co Ltd	289	106	15	410
Sony Corp	75	137	169	381
Fuji Photo Film Co Ltd	214	106	31	351
Sanyo Electric Co Ltd	71	146	111	328
LG Electronics Inc	79	143	55	277
Konica Minolta Holdings Inc	151	75	10	236
Canon KK	124	61	23	208
Total	**1,583**	**2,354**	**1,285**	**5,222**

Source: cintelliq Ltd.

4.14 Organic Electronics IP (Europe): Europe is clearly developing a substantial IP position in Organic Electronics with respect to both the US and Far East.

4.15 This is predominantly driven by developers of transistors and memory devices. Infineon is currently ranked 1st, however this will change in the future as Infineon quietly withdrew from developing organic electronics a few years ago.

4.16 In the UK Plastic Logic is developing organic transistors for use in e-Paper applications.

4.17 Memory devices are important but often not widely noticed. Thin Film Electronics (SE) has been active since the late 1990s.

4.18 It is worth noting that Cambridge University is the only academic assignee to appear in the top ten.

4.19 The majority of the Merck patents listed were developed in the UK at the Merck Southampton facility.

4.20 Top ten Far East assignees account for 262/677 = 39%

4.21 There is a greater emphasis on Process IP (device architecture, fabrication, deposition and patterning) than observed in OLED IP.

Table 6

TOP TEN EUROPEAN PATENTS ASSIGNEES—2005-Q1 TO 2007-Q2: ORGANIC ELECTRONICS

Assignee	*Materials*	*Process*	*Both*	*Total*
Infineon Technologies AG	22	29		51
Thin Film Electronics ASA		27	20	47
PolyIC GmbH	1	18	10	29
Plastic Logic Ltd		24	5	29
Siemens AG	4	21	2	27
Koninklijke Philips Electronics NV	5	11	5	21
Konarka Technologies Inc	3	15		18
Merck Patent GmbH	10	2		12
Cambridge University Technical Services Ltd	3	7		10
Samsung SDI Co Ltd		9		9
Cambridge Display Technology Ltd	2	6	1	9
Total	**50**	**169**	**43**	**262**

Source: cintelliq Ltd.

4.22 Organic Electronics IP (Far East): The Far East, like Europe, is actively developing Organic Electronic IP. As with OLED there is a greater focus on process IP rather than materials IP. Again the top ten assignees are predominantly large well-know manufacturers of consumer products.

Table 7

TOP TEN FAR EAST PATENTS ASSIGNEES—2005-Q1 TO 2007-Q2: ORGANIC ELECTRONICS

Assignee	*Materials*	*Process*	*Both*	*Total*
Samsung Electronics Co Ltd	30	57	3	90
Konica Minolta Holdings Inc	52	29	2	83
Semiconductor Energy Lab Co Ltd	3	65	9	77
Samsung SDI Co Ltd	9	63	5	77
Canon KK	21	32	3	56
Seiko Epson Corp	3	48	3	54
Ricoh Co Ltd	22	24	1	47
Matsushita Electric Industrial Co Ltd	10	33	2	45
Sony Corp	7	28	5	40
Sharp Corp	11	17	4	32
Total	**168**	**396**	**37**	**601**

Source: cintelliq Ltd.

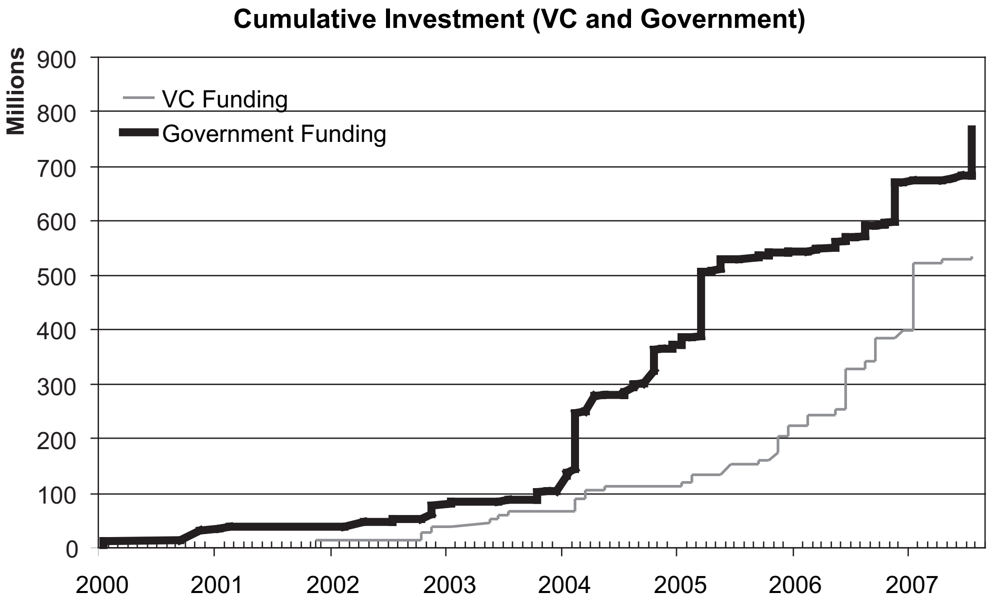
Top ten assignees account for 601/1769 = 34%

5. *Investments*

— It is also worth briefly mentioning Government funding and VC investment in organic electronics. More than $1.3 billion invested by Governments and VC investments (Europe and US) for the period 2000-Q1 to 2007-Q2

Figure 2

CUMULATIVE INVESTMENT IN ORGANIC ELECTRONICS—2000-Q1 TO 2007-Q2



Source: cintelliq Ltd.

March 2008

Memorandum 125

Submission from Plastic Logic

1. Summary

Plastic electronics[11] exemplifies Lord Sainsbury's theme of being engaged in a race to the top. The sector has already benefited from significant government support which has been well earned and well spent, and is completely justified by the stunning global opportunities for the UK in plastic electronics. In our submission, we: (a) encourage continuing support from EPSRC, TSB and others; (b) comment on some implications for UK engineering; (c) express concerns about the PETeC project; (d) encourage renewed efforts to introduce an effective SBRI program; (e) propose an important role for government in supporting pilot projects; and (f) remain optimistic about the prospects of UK manufacturing. All in all, we need to run not just fast, but faster.

2. Introduction

Plastic Logic (www.plasticlogic.com) is the leading UK SME in the plastic electronics sector. It spun out of Cambridge's Cavendish Laboratory from research by Prof Sir Richard Friend FRS and Prof Henning Sirringhaus. The company raised US$50 million during 2000–06 to develop its technology, and a further $100+ million in 2007 to build its first factory in Dresden, Germany. Funding has been led by UK-based Amadeus Capital Partners. Other financial investors include Oak Investment Partners and Tudor Investor Corporation, both multi-billion dollar US-based funds. The company's corporate investors include Bank of America, BASF, Dow Chemical, Intel, Mitsubishi and Siemens. It has also received financial support from the UK's TSB, via R&D tax credits and from German/Lander governments, as well as the European Commission. Plastic Logic's first target market is "take anywhere, read anywhere" electronic readers that are wirelessly connected and will incorporate flexible active matrix displays that are thin, light and robust. This enables a reading experience closer to paper than any other technology.

3. Plastic Logic has always thought of itself as a global company that happens to be based in Cambridge, rather than a British company that operates internationally. So by the time we had 20 employees, we had eight nationalities. We saw this as a strength and cause for celebration, rather than as a problem. According

[11] Other terms meaning broadly the same as plastic electronics include: organic electronics; polymer electronics; printed electronics, flexible electronics and TOP (Thin-film Organic and Printable) electronics.

to The Financial Times (14 March 2007), Plastic Logic has the best chance of becoming a £1 billion company among UK university spin-outs. The company occupies 20,000 sq ft on the Cambridge Science Park, including clean rooms/prototype line. UK headcount is nearly 100, of whom 70% are highly qualified technical staff. It continues a close scientific collaboration with the Cavendish Lab.

4. This submission on behalf of Plastic Logic has been prepared by Stuart Evans and Dr John Mills—brief biographical details are at Annex A and illustrate their experience in plastic electronics.

5. The Story So Far

The UK plastic electronics community comprises SMEs, multinationals and academic groups. It has already received, and values highly, significant government support over the years. This has included longstanding EPSRC support of the science base[12] as well as more recent TSB funding of collaborative R&D projects and a very effective Knowledge Transfer Network in Displays and Lighting (www.ukdisplaylighting.net). However, plastic electronics exemplifies Lord Sainsbury's theme in being engaged in *The Race to the Top*[13] and we absolutely agree we have to run fast. Plastic electronics is an area in which UK science remains pre-eminent on a global scale. Early commercial efforts (like Plastic Logic) are very significant, with high prospects of success. But UK plc mustn't become complacent. Independent data from IDTechEx shows 200 organisations in the US, 140 in Asia and nearly 250 in Europe active in plastic electronics. Fortunately, the nature of the industrial opportunity means manufacturing is not inevitably destined to migrate to Asia or the USA as is discussed further in paragraph 18. In terms of national competitiveness, it's clear that all the key governments are providing significant support to their local plastic electronics communities—the UK must continue to do likewise if it wishes to sustain its strong early position. In other words, we need to run not just fast, but faster.

6. Scope of, and opportunities in, plastic electronics. This is an emerging global industry based on most if not all of the following

- New materials (solution-based semiconductors, both organic and inorganic; printable metals etc)
- New processes (solution processing, printing, laser patterning etc; while trying to avoid mask alignment, high temperatures and vacuum processing)
- New flexible substrates (plastic, paper or thin stainless steel—all with no or minimal encapsulation; replacing rigid glass or silicon substrates)

The leading groups are pragmatic and not purist, and most first generation approaches are hybrid in some way. The eco-system to support this new industry is complex and still forming. Fortunately, the UK already has a significant presence across many elements of this.

7. The promise of plastic electronics is innovative, compelling products in attractive markets:

7.1 The first significant product categories are (a) electronic-paper readers, books and newspapers; and (b) OLED televisions. Initial products are based on rigid glass substrates, with flexible displays just around the corner.

7.2 There is increasing activity in photovoltaics and solid state lighting. The "green" agenda and government subsidy to consumers all over the world are key drivers in these markets.

7.3 There is other significant activity in batteries, memory, sensors and RFID

8. Plastic electronics also offers low manufacturing costs without massive manufacturing investments. Manufacturing is viable in much smaller scale facilities that conventional multibillion dollar 300mm silicon fabs or gen 8+ display fabs. They are not simply smaller scale but less capital intensive. As a result of lower economic barriers to entry, we will see multiple plastic electronics mini-fabs all over the world. Near to customers and markets, they will be well suited to rapid turnaround, short run length manufacturing. Of course, plastic electronics is not as far down the experience curve as conventional electronics so this adds to costs in the early days. To draw an analogy from another market, the steel industry faced significant disruption in the seventies/eighties with the emergence of mini-mills that were superior to conventional massive integrated steel works in product categories like reinforcement bars. Exactly the same will happen as plastic electronics matures and mini-fabs become commonplace—they will give glass- or silicon-based fabs a run for their money.

9. It's not easy to assemble credible independent perspectives on the scale of the plastic electronics opportunity, although it's much easier to assess the competitive strength of the UK. IDTechEx are the leading independent experts and their latest report[14] estimates worldwide industry revenues of $5 billion by 2011, $48 billion by 2017 and up to $300 billion by 2027. The Council for Science and Technology's November 2007 report Strategic Decision Making for Technology Policy[15] recommended plastic electronics

[12] eg http://www.epsrc.ac.uk/ResearchHighlights/TenYearsOfAchievement/PolymerOptoelectronics.htm
[13] Lord Sainsbury of Turville's October 2007 report The Race to the Top is available at http://www.hm-treasury.gov.uk/media/5/E/sainsbury—review051007.pdf
[14] Organic & Printed Electronics Forecasts, Players and Opportunities 2007–2027. www.idtechex.com
[15] Available at http://www.cst.gov.uk/cst/reports/files/strategic-decision-making.pdf

as one of only six new technologies that are crucial to UK's future prosperity and proposed it should receive preferential investment from public funds. As the CST detailed in its report, this is in part due to the very strong base already established in the UK.

10. The Role of Engineers

From a business perspective, the boundary between scientists and engineers is fuzzy. However, as Plastic Logic has evolved we started by hiring more scientists than engineers but now hire more engineers than scientists. This is not surprising as we have moved from [mostly] invention to [mostly] exploitation. Most scientific hires have come from academic groups that work in or around plastic electronics (including of course, the Cavendish Lab—for a spin out, hiring top PhDs is a wonderful way to increase the effectiveness of Knowledge Transfer) so in a sense they were relatively experienced. On the other hand, very few of our engineering hires come with significant experience in plastic electronic as there are so few companies and the industry doesn't really exist yet. With a greater concentration on gritty real world engineering problems like reliability/yield, and growing requirements to manage supply chains and procurement, the need for technology-savvy managers/executives increases. This has several implications for UK engineering that are relevant to the Committee:

10.1 Training qualified engineers in plastic electronics. A Master's level "plastic electronics conversion" course would be very helpful and could build on the Displaymasters course that has been run in recent years. The goal would be to assist experienced electronics engineers learn how plastic electronics is different.

10.2 Encouraging university engineering/industrial research collaborations in reliability, yield, failure mode etc would assist plastic electronics companies improve manufacturing operations. If academic groups have access to plastic electronics devices made in state-of-the-art industrial facilities (rather than university labs) they are more likely to generate breakthrough insights that will improve manufacturing effectiveness.

10.3 There are engineering skills in UK industries other than electronics (such as Bio/Pharma/Oil) that could very usefully be brought to bear on plastic electronics.

11. Support from EPSRC & TSB EPSRC funding in this sector runs around £20 million per year, and TSB funding over recent years has totalled around £48 million. Results have been impressive in terms of scientific/technological accomplishment as well as the development of a strong cadre of UK plastic electronics experts. It is tremendously important this level of support is sustained

12. Plastic Electronics Technology Centre (PETeC). Taking into account all the various strands of public sector financial support, this is easily UK plc's largest project in plastic electronics and we all hope it will become a successful flagship. It has struggled to define and articulate a compelling vision of how it will benefit the UK plastic electronics community as a whole. It proposes IP (Intellectual Property) arrangements that many SMEs will find unacceptable. Not surprisingly, it has struggled to build widespread stakeholder support. It completely changed its strategy from May 2007 (when the CST team visited) to November 2007 (when a team from UKDL visited). The latest strategy has a significant financially-driven focus on contract research for a small number of giant Asian electronics companies. We assess its chances of success in its current strategy as approximately 50/50 but are even more concerned about the lost opportunity to support a fledging UK industry. We encourage the Committee to challenge the various public sector funding sources to ensure PETeC delivers a positive outcome for the UK plastic electronics community and becomes a well deserved flagship.

13. Small Business Research Initiative (SBRI)

The Sainsbury Review supported a much more significant role for SBRI along the lines proposed by Anne Campbell and David Connell[16]. We understand the government has accepted Lord Sainsbury's recommendation. And as we finalised this submission, it appears the government's latest innovation white paper is also supportive.

14. It is widely recognised that the equivalent US Small Business Innovation Research (SBIR) program has been very successful. It has awarded over $12 billion since 1982 to various small businesses through a 2.5% set-aside of US government agencies' extramural R&D budgets to provide 100% funding to "small business concerns to engage in Research/Research and Development (R/R&D) that has the potential for commercialization". The US program has both Phase 1 grants (typically $100k for proof of principal over six months) and if successful can be followed by Phase II grants (typically $750k over two years). It's crucial that SBIR provides 100% funding (unlike TSB collaborative R&D support or general tax credits), especially for small businesses operating in early stage/immature sectors (like plastic electronics) while continuing

[16] Available at http://www.cbr.cam.ac.uk/pdf/SBIR%20Full%20Report.pdf

Research is as important as more downstream Research & Development. SBIR has also helped many small companies onto the first rung of the lucrative US government procurement ladder. Indeed the sustained scale of the program is evidence of a closer and more intimate relationship between small business and government than we see in the UK.

15. Universal Display Corporation (one of the key US start-ups in plastic electronics) has won approximately 10 Phase II awards in flexible displays and solid state lighting, and reports SBIR has been very useful in enabling the company to launch new initiatives as well as providing a good external validation that is appreciated by the investment community. Other beneficiaries of SBIR in the plastic electronics sector include Kent Displays (flexible display), Imaging Systems Technologies (flexible plasma display), eMagin (OLED microdisplay), and Dimension Technologies Inc (3D display).[17]

16. The UK SBRI has had several false starts. As a result, those of us from the SME community will be sceptical until we see real evidence of something happening. After all, the 2.5% SBRI target has to come from somewhere (we understand it is not new money) and it's natural to expect a stiff rearguard battle from existing stakeholders. Nonetheless, we consider it is an important initiative for plastic electronics (and indeed the wider SME sector). We hope the Committee can be persuasive in the right places to facilitate a fresh start.

17. Government Support for Pilot Projects

The public sector is already an important consumer of the products and system that will be disrupted by plastic electronics—paper, printing, energy and lighting among others. We assume there must be somebody responsible for reducing government energy consumption and purchases of paper and printing but no-one in the plastic electronics community knows who they are. We would very much like to see government support for early pilot projects on a relatively large scale. Projects with electronic readers for book/newspapers etc and new forms of energy and lighting would all simultaneously benefit the governments as a customer and be widely welcomed across the supplier base. It may already be too late for the 2012 Olympics to use plastic electronics for lighting, heating and cooling, but it's not too late to equip the 25,000–50,000 journalists and officials with wirelessly connected electronic readers so we can have a paperless Olympics. Other pilot projects can start well before that—the new Plastic Logic factory has a capacity of 1 million readers per year.

18. Potential for UK-based Manufacturing

As stated in paragraph 5, the nature of the industrial opportunity means manufacturing is not inevitably destined to migrate to Asia or the USA, especially as the concept of mini-fabs for plastic electronics becomes well established. Plastic Logic's 2007 decision to build its first factory in Dresden illustrates this very nicely and comes after a word-wide competition in which New York State and Singapore were runners up. The triumph here is that we put the factory in Europe, and not Asia or the USA. However, it also illustrates there is a race within Europe, and it's now arguable that Germany is nudging ahead of the UK for the number 1 spot in plastic electronics. Nonetheless, at the same time as the Plastic Logic decision, Polymer Vision (a Dutch spin-off from Philips) announced its manufacturing partner was to be Innos in Southampton, and subsequently Polymer Vision acquired Innos. The large electroluminescent display in the First Class lounge at BA's new Terminal Five was manufactured by Elumin8 in the UK. And Pelikon has manufactured electroluminescent displays used in high-end Universal Remote Control Units at its factory in South Wales. All in all, there is still significant potential for UK manufacturing of plastic electronics. The Committee should encourage UKTI, RDAs and other government bodies to seek out and support plastic electronics manufacturing projects in the UK. After all, the only way we can be certain of never having any UK manufacturing of plastic electronics is by not trying.

19. Emerging Value-added Opportunities

As plastic electronics technology matures over the next few years, display modules and other sub-assemblies will become available from several different sources both in the UK and internationally. As with the existing semiconductor industry, we expect there will be significant opportunities for fab-less business models in plastic electronics that could in due course be worth 20% of the market.

March 2008

[17] Personal communications from Mike Ciesinski, CEO of the United States Display Consortium; and Dr Michael Hack, Vice President, Strategic Product Development, Universal Display. See also www.nsf.gov

Annex A

A1. Stuart Evans is a co-founder of Plastic Logic and was its first CEO until his retirement in 2006; he was Vice Chairman 2006–07. He now pursues a portfolio career, including being a Board Member for EEDA, the Regional Development Agency for the East of England. He is a regular speaker at plastic electronics industry events in UK, USA, Europe, China and Japan; a member of the Advisory Board of the UKDL KTN; an honorary member of the board of the Plastic Electronics Foundation and was named "Printed Electronics Champion" by IDTechEx in recognition of his word-wide success as an evangelist for a new industry. He originally worked for IBM and McKinsey & Co but has been a serial entrepreneur since 1984. He has an MBA from Harvard Business School.

A2. Dr John Mills is Plastic Logic's Chief Operating Officer responsible for a team of over 100 in Research, Development and Manufacturing; he also leads the company's approx £50 million capital expenditure program in building a prototype line in Cambridge and the first manufacturing facility in Dresden. He was the company's first senior technical manager when he joined as VP Engineering in 2002 after seven years in product development management at Domino, a leading industrial ink jet printing company. He has a PhD in Semiconductor Physics.

Memorandum 126

Submission from Silvaco Data Systems

How universities, industry, venture capital and Government are involved in the development of the UK plastic electronics sector.

Silvaco data systems (Europe) Ltd., is an SME located in Cambridgeshire specialising in developing complex numerical simulation software for inorganic and organic semiconductor materials and technologies. The software that we develop is targeted at semiconductor technology device processing and device design, which is called Technology Computer Aided Design (TCAD) as well as complex circuit design (SPICE). Our customers are global and to serve them we have 14 offices around the world.

The UK office represents one of only three offices where the development of original software takes place. The other two locations are California and France. The local accent is on development of TCAD software.

The skills requirements for developers involved in this field are tough and stringent. Developers must have a high level of education and training in mathematics (numerical techniques), Physics and/or Electronics. They must also be highly knowledgeable in modern programming techniques. All the technical staff in the UK are educated to PhD level. In order to locate such skills the company scouts nationally and internationally. The current UK team is made up of staff who have joined us from well known research groups in Vienna, Cambridge, Oxford and others. Due to the skills shortage in this area over 60% of the technical staff are not native to the UK.

Apart from the usual supplier/client type relationships with our customers, we collaborate with a number of companies both locally and nationally, such as Cambridge Display Technology (CDT). Many of these collaborations are supported through the Technology Strategy Board. These activities help enrich and expand our collaborative partners technology portfolio and our suite of software tools. Without such collaboration our ability, as a supplier of design, modelling and simulation software to support the UK organic and inorganic semiconductor industry would be severely limited.

We also collaborate with a number of academic research groups around the country. For example the Department of Applied Mathematics and Theoretical Physics at the University of Cambridge helped us develop key aspects of our software over the last two years.

We must expand our local team to capitalise on the expansion in the organic and nanotechnology emerging design markets, an area in which we excel. However, we are continuously struggling to find new developers to fill our vacancies. Although we have strong historical links with many research groups in the UK and advertise both locally and nationally we believe that the current skills shortage could hinder the UK plastic electronics industry.

A national strategy aimed at addressing the skills gap in first class basic sciences education and training is what Silvaco calls for. We believe that the UK has traditionally excelled in design activities. Silvaco can serve the national and international design needs to exploit the alternative plastic electronics emerging markets.

March 2008

Memorandum 127

Submission from Logystyx UK Ltd

Executive Summary

Plastic Electronics embraces inorganic as well as organic electronics and is a new approach to assembly and device architecture offering greater manufacturing flexibility. It is also known as Organic Electronics or Flexible Electronics, a reference to the substrate, ie not glass or circuit board, as well as the production process.

(i) *Current and future roles of engineers in the field of Plastic Electronics*

(a) Currently the majority of professionals involved in Plastic Electronic industry are from the disciplines of chemistry, physics and materials science as there are still many basic science problems to overcome.

(b) The early adopters are currently moving to pilot production. There is a need for: process engineers; production engineers; device designers; equipment designers; printers; packaging engineers. There needs to be training for engineers in management of the supply chain and production disciplines.

(ii) *Potential for Plastic Electronics in the UK/global economy*

(a) UK is global leader in Plastic Electronics. To maintain its position, resources are needed to compete against the large international organizations that will inevitably move into the field.

(b) PE will not replace all traditional electronic markets but will generate new markets eg Third World, and replace parts of other markets eg e-print.

(c) Incentives are necessary to encourage large UK companies that stand to lose their historic business to the new technology such as: colour graphic printers; printer manufacturers. Plastic Electronics offers expansion for chemistry-based industries such as pharma who are used to dealing with nano-materials and have management structures already in place.

(iii) *How Universities, VCs, Industry and Government are involved in the development*

(a) The future success of Plastic Electronics hinges on the coordination and collaboration of Government, VCs, Universities and Industry.

(b) Government, through the Technology Strategy Board, has been instrumental in facilitating Collaborative Research and Development. So far there has been support of £48M. This needs to continue as a Managed Programme to guarantee funds are available to address technological hurdles at the optimal time.

(c) Many of the companies involved with Plastic Electronics have initial UK VC or Business Angel investment. Where there is dependence on co-development, it can be difficult to leverage additional investment and pressure from those investors for short-term profitability can cause SMEs to drop out of the sector and their expertise is lost.

(d) Universities are heavily involved in materials development for Plastic Electronics. However, their role could be increased and their excellence further exploited if the RAE could be adapted to include accreditation for scientific solutions to commercial problems. The current system acts as a disincentive.

(e) To ease the burden for capital expenditure for SMEs, Open Access laboratories for sample analysis, prototyping and pilot production are a boon.

(f) To retain manufacturing in the UK, thought needs to be given to incentives. Companies that will not be profitable for several years look to maximize grants eg Dresden and other EU priority areas. Established companies look for tax holidays eg Singapore and other Far East countries.

(iv) *Whether the UK engineering & manufacturing sectors are set up to handle the growth in this area or others like it*

(a) The talent is certainly available in the UK but the difficulty has been in raising additional funds in the UK for growth over the "dip" period moving from Small to Medium or Medium to Large Enterprises as the infrastructure has to be in place for a while before profits can be realised eg both CDT and Plastic Logic had second round financing from USA VCs.

(b) There needs to be some retraining of corporate teams to understand new disciplines and new market behaviour. Mechanisms need to be in place to reduce the pain of overheads during the transition to the new technology.

(c) UK has expertise in: roll-to-roll manufacturing and machine design; plastics; colour graphic printing; newsprint; small scale manufacture of electronic billboards; stringent packaging requirements eg food and medical industries; printer design including ink jet.

Case Study: Plastic Electronics Engineering

1. *Current and future roles of engineers in the field of Plastic Electronics*

1.1 The various disciplines of Engineering (electrical, electronic, RF & microwave, mechanical etc) will become increasingly important over the next five years as the platform of technologies that form "Plastic Electronics" moves towards volume production.

1.2 The bulk of the work in this sector has been by physicists, chemists and material scientists. They have developed the current materials and delivery processes etc, and proven the principles of device architecture. Now the technologies must move from laboratory and development onto the production floor. Scaling up both the complexity of the devices and the volumes required in manufacture is intimidating but not insuperable and should be under the control of the Engineering sector in the UK.

1.3 To date, there has been little engagement with the "conventional" electronics community during the development of Plastic Electronics. The material sets and production processes are so radically different that there is little commonality or compatibility with the design rules for conventional electronics. New rules must be learnt. It is suggested that PE technology today is equivalent to early stage development of the silicon industry in the 1950's. The rate of advancement of PE technology and growth of the industry will potentially be much faster than silicon, as it operates in a much more multi-disciplinary world. Where there has been engagement at University or Company between the chemists, physicists and traditional engineering disciplines, the contribution is significant.

1.4 The prototype devices made at various companies and university laboratories around the UK now need to be integrated into "real" systems, where the plastic electronics devices form part of a wider electronic system. This will require traditional electronic engineering skills to be developed so that standard electronic components (silicon-based) can be integrated with Plastic Electronics devices to affect this interoperability. Over time the percentage usage of Plastic Electronic and Silicon Electronic devices within any particular application will shift towards plastic as the performance characteristics of Plastic Electronic circuit elements improves.

2. *Potential for Plastic Electronics in the UK/global economy*

2.1 Plastic Electronics will disruptively impact every aspect of conventional living across the globe over the next decade. It will allow completely new technology-centric solutions. There are a number of third-party Market Research forecasts available that predict rapid growth of value of the PE marketplace to multiple billions of US Dollars globally within the next decade.

2.2 A "reality check" on the validity of these claims is simply provided by comparing the current global value of the Electronic Displays market (~$120 billion) and the global Lighting market (~$100 billion) with the value of the European paper and card market (~$400 billion). The ability of PE to make significant inroads into many areas of the conventional paper products suggests that market take-up and growth may be even faster than initially predicted.

2.3 During the next five years, we will see the emergence of:

— Intelligent food packaging: plastic or paper with printed gas or chemical sensors linked to printed circuitry and display elements on the food packaging container or wrapping material to indicate if the contents has started to go "off". A real time indicator of actual food quality could cut food wastage costs and reduce food poisoning through incorrect storage.

— Smart tags printed on paper or plastic substrates will be remotely addressable to track location and ownership. This enables RFID to become more widely used than at present.

— Intelligent ticketing printed on low–cost biodegradable substrates will reduce the costs of implementing ticketing systems like Oyster, and allow mass roll-out of the technology to a wider application base. Importantly, it will allow added value functionality to be integrated into tickets similar to conventional tickets encouraging use of the technology without alienation of the existing users.

— Electronic newspapers and e-books will radically change the face of publishing and content delivery. By creating electronic reading devices on truly flexible substrates, the current multiple printed page publications that dominate our reading habits will be changed beyond all recognition. Books and newspapers will be changed to allow readers to buy one or more electronic readers of different sizes (we speculate A5 will be used for typical electronic "book" applications and A4 for electronic newspaper variants.) As content may be delivered wirelessly to these devices, we speculate that there will be additional competition between content providers on device price and airtime subscription packages. The cost model would be similar to conventional mobile phone "packages" that "sell" a phone handset to the consumer at a fraction of its actual production cost, with profit coming from the airtime deals.

— Plastic Electronic retail signage will continue to develop from today's small volume usage, where colour graphic posters are overlaid with printed electronic elements, to become sophisticated devices printed on large area biodegradable substrates.

— Printable lighting will facilitate a radical change to room design. Within large units (houses, offices, etc) the emergence of printable lighting technologies using Inorganic or Organic Electroluminescent material will allow "lighting tiles" to be printed using modified conventional roll-to-roll volume printing techniques. These tiles may then be expanded upon to allow "printed electronic wallpaper" to be created, whereby individual light sources are replaced by the ability to light complete walls within any room. This will allow mood lighting and lighting for health to be implemented in a wider range of applications.

— Plastic Electronics can reduce national energy usage. One of the key benefits of this nascent technology is that we can assemble different circuit functions on to a single substrate material. Alternative power generation (photovoltaic) can be printed and then coupled to a printed battery, which will then drive printed circuitry. This will allow a new generation of self-powered devices to be created that never need to be connected to a mains-derived power supply.

2.4 The above examples illustrate some ways in which PE will impact upon our daily lives in the UK. It is not an exhaustive list, but it is important to note that the platform technologies that comprise PE can be imported into existing manufacturing processes within UK. The manufacturing processes for PE are low-temperature, energy efficient processes that can segue into other industries such as food packaging, colour graphics printing, pharmaceuticals, life sciences, aerospace, automotive etc.

2.5 We predict that many of the early adopters of PE will not be conventional electronic companies but will be printers, packaging companies, materials handling companies and similar who adopt PE to add value to their existing material sets/processes/products etc. This offers an opportunity to industries facing threats from low cost competition based in China and India, and adds value to their existing product portfolios with access to new market applications.

3. *How Universities, VCs, Industry and Government are involved in development*

3.1 The majority of initial scientific discoveries underpinning the PE industry have come from UK University laboratories. The early exploiter companies commercialising these technologies are also spin-outs from the same University Departments eg CDT, Plastic Logic from Cavendish and Nano ePrint from Manchester University.

3.2 The pioneering research at Universities has grown organically across the UK. We now have complementary clusters of activity in Manchester, Cambridge, London, St Andrews, Strathclyde, Bangor, Swansea, Oxford, Hull and elsewhere. This activity covers developments in materials, manufacturing processes, device architecture and device production.

3.3 Most of the activity continues to be within physics and chemistry departments, but we are now beginning to see substantive engagement with electrical/electronic engineering and mathematics (for modelling). This trend needs to increase, and we need proactive investment support from EPSRC to accelerate this process.

3.4 EPSRC can supply this support through existing funding mechanisms provided that it becomes a strategic topic of support, and this support is supplied consistently through their funding mechanisms eg EPSRC has funded a significant number of responsive mode projects in this sector, but they have declined to support UK Displays & Lighting KTN's request to be an agent for Industrial CASE studentships. This is a serious failure to ensure consistent support to a target sector.

3.5 There will be an increasing need for skills training and retraining at undergraduate, postgraduate and technician level to allow the available pool of manufacturing-quality personnel to increase with market demand. This training is being partly addressed by courses run by Liverpool, Swansea and the multi-University DisplayMasters programme. There will be insufficient capacity to meet predicted future demand, and the academic requirements will need to be spread over a much wider University base. This will require consistent support and co-operation between EPSRC and Government through DIUS and the TSB to achieve timely implementation of programmes that will result in the skilled labour pool being available to match market demand.

3.6 Government has been significantly involved in the nurturing and development of PE. Through DTI's support for collaborative R&D through the LINK programme, and then the Technology Programme, Government investment was consistently applied to support the initial basic and applied research, and latterly the move from applied research towards development for production. The Technology Strategy Board has continued support and aspects of funding for PE have been included in recent competitions of their CRD programme.

3.7 However, this funding model is not consistent, and there is no guarantee at present that the specific requirements of the community would be met under the new thematic scheme of project targeting that has been implemented by the TSB.

3.8 In 2006 DTI, in concert with UKDL KTN, engaged with the UK PE community to develop a comprehensive analysis of the sector's opportunities for growth, and to understand the specific needs for targeted support. This resulted in a detailed proposal for a Managed Programme that would ring fence £50 million funding exclusively for R&D investment into PE over a period of up to five years. The proposal was centred on the premise that the PE community is best positioned to assess its own progress and to identify its own needs for short- and medium-term research activities. It was planned that an investment panel comprising a representative selection of companies and academics would identify the particular technology hurdles that needed to be addressed at any time, and would run a mini-competition to solicit project proposals against those topics. The Panel, together with DTI would agree projects to be selected for support, and the projects would then be funded under the normal rules. This proposal was very well received at but coincided with the split of DTI into DIUS & BERR. The structural change prevented the proposal for a Managed Programme being taken forward.

3.9 We strongly recommend that a similar proposal for a Managed Programme to support the PE community with ring fenced R&D funding be adopted.

3.10 Government has also been involved, primarily through DTI/TSB and the RDAs and DAs in investing in regional facilities to operate Open Access process development and prototype production facilities supporting start-ups and SMEs in their early stages. Two centres will form the initial support for the UK:

(a) Welsh Centre for Printing and Coating (WCPC) based at Swansea University. This facility has expertise in preparing and characterizing functional electronic inks and pastes, and a variety of sheet-fed and roll-to-roll printing processes. Support is offered in material design and process development for "proof of principle" demonstrators, early product prototypes and small volume pilot line demonstrators.

(b) Plastic Electronics Technology Centre (PETeC) based at Sedgefield and Centre for Process Innovation (CPI) based at Wilton. The CPI facility is already open and trading, and its sister facility PETeC is due to open later this year. PETeC will offer a comprehensive range of materials technology and process development support activities for start-up's, SMEs and OEM companies.

3.11 These two facilities are supplemented by facilities primarily funded by EPSRC such as the Cambridge Integrated Knowledge Centre (CIKC) and the University of Manchester Organic Materials Innovation Centre (OMIC).

3.12 Together, the five centres form the fledgling platform of support for early stage Plastic Electronics activities, and it will be essential to ensure consistent funding to them to allow their activities to be focused on UK-based activities rather than have them search for additional offshore sources of revenue. The funding conditions for each of these centres requires that they seek to achieve self-sustainability in the relative short-term (two to five years). This requires a focus on revenue generation that seriously detracts from their primary aim of supporting and encouraging UK entrepreneurial activity.

3.13 The engagement of the various types of VC funding with PE is inconsistent at present. VCs such as Amadeus are strongly involved with early stage developments (eg CDT and Plastic Logic) but there are no general funds operating in this area yet. It remains difficult for start-up or SME companies operating in PE to access early stage funding. If it is practical for Government to offer long-term tax incentives to VCs offering financial support to this nascent market, it is likely that the barriers to involvement in this sector would melt away.

4. *Whether the UK engineering and manufacturing sector are set up to handle growth in this area or others like it*

4.1 Many parts of the required infrastructure for the UK to benefit from commercial exploitation of PE are already in place.

4.2 We have manufacturers of inorganic and organic materials in the UK who will be positioned to meet domestic demand and supply into global markets. We have manufacturers of substrate materials (metal foil, paper and plastic including fully biodegradable plastic on which PE devices will be built) that can readily meet UK, European and a significant percentage of predicted global demand.

4.3 We have manufacturers of production equipment (laser-based, conventional printing presses, ink jet printing equipments and sub-assemblies, vacuum deposition equipment, patterning process equipments etc.)

4.4 One strongly beneficial factor is that many of the Companies that form the infrastructure for materials and equipments have existing domestic and global markets for non-electronic applications in areas that are likely to be early adopters of the Plastic Electronics technology such as Colour Graphics Printing, Food Packaging and processing, Pharmaceuticals, Retail packaging etc.

About the Authors

Logystyx UK Ltd is a two-person consultancy specialising in Display Technology. The partners have been active in this market sector for 32 years and 26 years. Since 2004, they have monitored 33 Collaborative Research projects for DTI (LINK and Technology Programme) and for TSB (Technology Programme) in the fields of displays, solid state lighting and plastic electronics. In 2003 they were instrumental in setting up Flexynet, a networking group for organisations in the Plastic Electronics sector. They are founders of the UK Displays and Lighting KTN through their company UK Displays Network Ltd and Flexynet is now a major sub-group within UKDL KTN.

March 2008

Memorandum 128

Submission by UK Displays and Lighting KTN

Executive Summary

The UK is recognised as a global leader in Plastic Electronics. This leadership spans the development of innovative materials, low cost deposition, high precision patterning and additive printing processes. This impressive range of activities across the supply chain underpins the UK activity in Plastic Electronics and it is vital to maintain and build upon this position as the industry moves forward.

The UK Displays & Lighting Knowledge Transfer Network (UKDL) is 100% funded under the Technology Programme and currently has more than 750 profiled Members from more than 500 UK Companies and 85 University Departments. Of the 750 Members, more than 650 have registered that they are currently active in, or are likely to become active in, Plastic Electronics.

Third party market predictions vary but it is generally agreed between them and the Plastic Electronics Community that Plastic Electronics will become a £10–50 Billion global industry by 2020.

1. *Current and Future Roles of Engineers in the Field of Plastic Electronics*

1.1. The UK has significant engineering expertise in market applications in materials development, low cost deposition, high-speed precision patterning and additive printing processes. This is complemented by a number of highly developed and successful device design companies employing skilled electronic engineers. This skilled engineering resource is currently pushing forward key technology enablers in plastic electronics by developing the materials, manufacturing equipments and processes required by the industry.

1.2. Plastic Electronics (also known as Organic Electronics and Printed Electronics) is a young industry with very few players with >20 years industrial or business experience. There is a shortage of senior management team skills for companies looking to implement high-volume production (including buyers, QA, production, maintenance, operations). Following the reduction of the defence industry in the '90's and the move offshore of consumer electronics manufacturing, the UK's conventional electronics industry has contracted and fragmented into a mainly SME structure. There is certainly no lack of skilled chemists/material scientists/printing engineers but full exploitation requires the introduction of industrial personnel and processes from other industries (eg food packaging, pharmaceuticals, graphics printing) to address remaining difficulties such as encapsulation and volume substrate processing.

1.3. As the industry progresses towards volume production, engineers will be required to develop processes to ensure that manufacturing is robust, reliable and repeatable. Solving issues of accuracy and registration where multiple thin layers of material are deposited on top of each other on flexible substrates will be key to ensure high yields and optimal production rates. New methods of on-the-fly measurement and diagnostics will have to be developed and applied.

1.4. The UK has a very active KTN (UKDL) with clear vision based on Members input of the technical and commercial hurdles to be overcome. Training of engineers is a key element of the KTNs activities. Gaps in the skills base must be addressed early on in order to ensure a fully trained workforce. An example of this is the requirement to train printing engineers in electronics and materials science and conversely training electronics engineers in the limitations and opportunities offered by printing technologies.

2. *Potential for Plastic Electronics in the UK/Global Economy*

2.1. The implementation of Plastic Electronics manufacturing in the UK will have positive Societal impact and will enable new market creation.

2.2. Job creation—Plastic Electronic devices can be manufactured by companies already active within the printing industry. This will result in job sustainability and expansion, as today's products become enhanced with the added value contribution that Plastic Electronics brings. In addition, the cost of entry to manufacturing for new companies wanting to manufacture Plastic Electronic devices is significantly lower than for comparable conventional electronic devices. This will encourage more companies to be established as the range of product opportunities develops.

2.3. Waste reduction—the production of waste during the manufacturing process of Plastic Electronic devices is significantly reduced by using ultra-thin layers of materials and innovative patterning and additive printing techniques.

2.4. Environmentally friendly—new biodegradable substrates and functional materials are being developed to create consumer electronic and medical Plastic Electronic devices that will fully decompose after being discarded.

2.5. Energy Reduction (1)—Plastic Electronic devices need less energy to be used in their manufacture as all stages of assembly use low-temperature processes.

2.6. Energy reduction (2)—Plastic Electronics technology allows multiple functions to be assembled on a common substrate. Photovoltaic cells can be integrated with power storage, electrical circuitry, sensor and display elements to create "self powered" devices that are "energy neutral" and require no connection to mains power. This off-grid functionality will reduce the national demand for energy generation and distribution.

2.7. Intelligent Medical Devices—disposable printed medical sensors for use by GP's and/or the general public will be commonly available at low cost. Flexible patches are being developed, based on organic light emitting diodes for localised Photodynamic Therapy for the cure of certain skin cancers.

2.8. Intelligent Food packaging—printed sensors embedded within food packaging will allow the consumer to ascertain if the food or liquid is "off" irrespective of the sell by date. More sophisticated devices will allow information on the product history in terms of temperature and time during storage and transport to be displayed to the consumer.

2.9. Electronic wallpaper—large area printed electronics can be used to augment conventional advertising posters and displays with an animated electronic cartoon. Designers can employ these flexible panels to invoke novel lighting scenarios to enhance buildings and public spaces.

The list above highlights the breadth of applications made available by Plastic Electronics; this is by no means an exhaustive list but is indicative of the UK/global potential.

3. *How are Universities, Industry, Venture Capital and Government involved in the Development of the UK Plastic Electronics Sector?*

3.1. The UK Government, through the DTI and latterly the TSB, has acknowledged the strategic importance of Plastic Electronics with regular investment in basic and applied research. Since April 2004 Technology Programme funding into Plastic Electronics and related topic areas amounts to £48 million. This has been matched and exceeded by industry. Private equity investment into UK companies active in Plastic Electronics exceeds £140 million over the last five years. The largest-ever single VC investment ($100 million) in Europe was made to finance the world's first large-scale manufacturing facility being built by Plastic Logic (UK) in Dresden. Government funding is also available for prototypes and proof of principle projects, but a significantly stronger mechanism is required to fund pilot production lines.

3.2. A small number of RDA, DA and Research Council funded Centres of Expertise focused on Plastic Electronics have formed around the UK and are rapidly developing their capabilities. Examples include Cambridge (CIKC), Manchester (OMIC), London (IC, QMU, Brunel), Swansea (WCPC) and the North East (PETeC, CPI). Each of these Centres is attracting a number of SME and start-up companies to locate within the vicinity. This "cluster" model allows for progression throughout the entire value chain from the development of new materials to device integration, prototyping and on to low volume production. These skills centres act as an important catalyst for new SME companies who wish to be involved in the Plastic Electronics industry.

3.3. Following the reduction in defence spending and the moving of much of the UK's consumer electronics manufacturing offshore, the UK's Electronics sector lost most of its OEM companies and fragmented into a sector driven mostly by SMEs. Driven mainly by UKDL and the Collaborative R + D programme many of these SMEs are now forming collaborative partnerships. It is widely recognised by the Plastic Electronics community that the industry will not progress unless skills and resources are pooled. There is some involvement with larger companies and this will develop further over the next 1–2 years as global leaders begin to see the value in investing in the industry.

3.4. There is a continuous need for high quality research into topics such as material processing and device reliability. These topics are often perceived as mundane and do not generally benefit a University's RAE rating, so are often ignored. Urgent public funding of QA/reliability research activities is required in order to strengthen the knowledge and resource base to match that of our major competitors in Japan and Korea.

3.5. Academic Members of UKDL have commented that with few exceptions, they seldom get to perform research work on state of the art materials and devices, or to use the latest metrology equipment. They are concerned that their research activities can go largely unnoticed by industry, which may not readily interpolate the improvements that would be seen if the work was based on the best available materials/

equipments. There is a need to encourage more "open relationships" between emerging technology Companies and Universities in order to address this issue. Public funding is also required for developing adequate analysis tools, instrumentation and data analysis equipments to strengthen resources at this critical primary research level.

3.6. As Plastic Electronics moves towards commercial exploitation it will become necessary to develop greater involvement in KTN activities from Commercial Managers and Directors of potential Suppliers, Integrators and End Users to encourage wider commercial comprehension of the opportunities offered by Plastic Electronics.

4. *Are the UK Engineering and Manufacturing Sectors Set Up for Growth in Plastic Electronics?*

4.1. The UK has a strong heritage in manufacturing across a broad range of application areas, and still maintains a very strong global position in industries such as Pharmaceuticals, Oil, Printing, Life Sciences, etc. To fully exploit Plastic Electronics it is vital to engage these key stakeholders to attract funding to and from them in order to encourage their engagement with the diversification and added-value product enhancement opportunities offered by Plastic Electronics. The skills and experience available in existing industries may be suitable to rapidly address many of the "move to production" issues faced by the current Plastic Electronic community.

4.2. It is certainly possible to use the existing skills base (eg from Bio/Pharmaceuticals industries) where there is an existing infrastructure for big business (>£100 million turnover, >100 employees). This will require provision of training and/or retraining for these engineers and managers in the new disciplines required within Plastic Electronics.

4.3. There is currently insufficient industrial investment at UK Companies to develop the indigenous industry at a rate that allows the UK to become world leading in production rather than just research. For example, Bayer GmbH has analysed the market success of Elumin8 (a very small UK SME) in creating innovative printed posters that combine colour graphics with electronic cartoon circuitry as an overlay. Bayer has identified this to be a significant market opportunity and has invested €26 million to build and equip a 5k m^2 clean room as a strategic move to "dominate the printed Electroluminescent display market". UK SMEs will be under great threat from such well-financed competition seeking to walk in and exploit their innovative groundwork. This places a greater emphasis on the creation and protection of IP to preserve the integrity of UK ideas, but it also indicates a need for Government to motivate UK Industry to seek to exploit these opportunities directly.

4.4. There is an incorrect perception within the UK (and journalists in particular) that the UK is no longer a Manufacturing country. It was noted that the UK is actually the 6th largest worldwide manufacturer by value, yet a recent survey of Journalists indicated they thought UK would be around 31st. The Technology Strategy Board, UKDL (and Government) need to make greater representation and implement wider promotional activities to change the public mindset and perception about the UK as a Manufacturing base and not just a service industry culture.

4.5. When early stage Plastic Electronic companies move to initial production there is a tendency to move out of the UK because of the extensive cash incentives currently on offer from EU countries in Eastern Europe. It is further noted that when moving into sustained profitability, such Companies can benefit from a move of their manufacturing base to the Far East where they are offered significant tax incentives (eg 15 years tax free in Singapore). A change to the Company Tax regime in Europe in order to match that of the Far East and develop a level playing field is required in the longer term. Since global multi-national Companies already minimize tax payments as a matter of standard practice for their operations within the UK, the impact to Treasury would probably not be that great. In the short-term, the role of the Centres of Excellence should be expanded to allow them to engage with pilot production volumes of Plastic Electronic devices. This will considerably delay the timing in which a start-up company must plan its next move to production, and will also significantly reduce its initial capital equipment expenditure requirements—a strong incentive for supporting start-up and spin-out companies during turbulent financial times.

4.6. It is also recommended to establish a Government-supported production facility that can act as a volume fabrication facility for a number of UK Plastic Electronic companies. By allowing such companies to operate a "fabless" production model within the UK, reaping the benefits of innovation exploitation will be greatly enhanced, and the cost for new entrepreneurs to enter the market will be reduced. De-risking this early stage exploitation will greatly increase the rate at which Plastic Electronics concepts and designs are created and delivered to the wider market place.

4.7. It is noted by UKDL Members who have created early stage production facilities within other EU countries that the UK has excessive inertia in its planning laws and permits to operate. For example, securing permission to establish wet chemistry facilities near residential areas, or when a company wants to build a bespoke manufacturing facility, securing legal permissions in the UK may cause slippage in the opportunity to meet the preferred market window. This must be addressed by improving the Local Planning system to facilitate more "high-tech business friendly" support mechanisms.

5. *Further Recommendations*

5.1. To ensure that the UK remains at the leading edge of the Plastic Electronics revolution it is vital that there is full engagement and continuity of support from Government through the Technology Strategy Board, the Research Councils and SBRI.

5.2. The Members of UKDL particularly request the implementation of the 2006 DTI report into Plastic Electronics that recommended a Managed Programme to invest £50 million ring-fenced CRD finance over a three to five year period into the Plastic Electronics community. This Managed Programme should be jointly run by TSB and the Plastic Electronics community, and should be empowered to run competitions to address technology hurdles that the Community itself identifies. It should also be empowered to support "single company" developments where such activities are too early for general collaborative activities within the community, but which, if successful, would result in materials, equipments or device architectures that would be of broad interest and potential usage within the UK's Plastic Electronics community.

5.3. The Members of UKDL recommend that the Government should sponsor programmes to produce a variety of flagship demonstrators. Since these specific products may themselves be of limited commercial appeal, but would be used to address the "top ten" problems identified by the community, or would be demonstrations of a technological capability rather than an exact market need, the projects should be supported with 50% funding or more.

5.4. Examples of flagship projects might include:

- Wireless flexible Electronic Paper devices for every Cabinet Minister (or every MP)
- Electronic Paper devices for use at the 2012 Olympics.
- Battery-free energy-neutral consumer electronic devices to control domestic AV units.
- Intelligent, disposable, printed medical sensors for general use within the healthcare environment.
- Electronic books for use within schools to reduce/eliminate the need for individual issue of textbooks.
- Electronic wallpaper to demonstrate the use of alternative lighting concepts.

Authors of this Report

This report was prepared by Dr Ric Allott, Deputy Director of the UK Displays & Lighting KTN, based on written and oral inputs from the FLEXYNET sub-group committee of the UKDL KTN, and individual members of the Plastic Electronics community around the UK. The report was approved by Chris Williams, Director of the UK Displays & Lighting KTN.

The report is submitted on behalf of the Members of UKDL.

March 2008

Memorandum 129

Submission from the Engineering and Physical Sciences Research Council (EPSRC)

Executive Summary

The Engineering and Physical Sciences Research Council (EPSRC) currently invests £68.2 million in research, training and knowledge transfer of direct relevance to the area of plastic electronics:

- 42% of this investment is provided to universities through investigator-led research.
- £2.6 million of this investment goes towards training of PhD students.
- 38% of all research and training grants are collaborative with industrial partners and other stakeholders; this represents a total of over £12 million of in cash and in kind contribution from industry and other collaborators.

EPSRC, and previously the Science and Engineering Research Council (SERC), has a long history of supporting this area of growing value to the UK economy; continuous support for fundamental conducting polymer research in the 1980s and 1990s has led not only to outstanding scientific development in the field but also to successful exploitation of the research with direct benefits to the UK economy.

EPSRC, via the implementation of its recently published delivery plan, aims to further strengthen the UK research base and to demonstrate effectively the economic impact of the research it funds. Plastic Electronics, an area predicted to reap huge benefits for the UK economy in the next 10–15 years, benefits from a solid and internationally competitive science and industrial base. UK universities working in the field, in collaboration with industry, stand to benefit further from future EPSRC funding opportunities.

Introduction

2. EPSRC is the main UK government agency for funding research and training in engineering and the physical sciences, investing around £740 million a year in a broad range of subjects—from mathematics to materials science, and from information technology to structural engineering. We operate to meet the needs of industry and society by working in partnership with universities to invest in people and scientific discovery and innovation. The knowledge and expertise gained maintains a technological leading edge, builds a strong economy and improves people's quality of life.

3. Our work is complementary to other research investors including other research councils, government agencies, industry and the European Union. We actively engage in and encourage partnerships and collaborations across disciplines, boundaries and the world. We also actively promote public engagement in science, engineering and technology.

4. Plastic electronics covers any aspect of the fabrication of electronic devices (eg thin film transistors) using semiconductor polymer materials, which can be deposited from solutions thus allowing the device to be printed. The primary reason for using polymer materials is the inherent flexibility that it can provide to the resulting devices; this has already led to a broad range of applications such as flexible panel displays and electronic paper. The field of "plastic electronics" is also often referred to as "organic electronics" or "printed electronics".

Background

5. Plastic electronics evolved from fundamental work carried out in the field of molecular electronics, principally in the US, in the 1960s and '70s. In 2000, American researchers Alan Heeger and Alan MacDiarmid, along with Hideki Shirakawa, were awarded the Nobel Prize in chemistry for their contribution to the field.

6. EPSRC's investment in plastic electronics can be traced back to the late 1980s when SERC/EPSRC-funded researchers at the University of Cambridge's Cavendish laboratory began to harness the potential of different types of light-emitting polymeric materials for flexible display applications. Earlier industry R&D funding, such as that of BP (electronic materials) and BT (electronic devices), had allowed for the UK to become internationally competitive in the field, especially through successful collaborations with the science base eg with the Universities of Cambridge, Durham and Sussex. Industry funding dried up in the late 1980s as more fundamental problems needed to be resolved before real exploitation could be envisaged. SERC/EPSRC continuous support for fundamental work in the field helped taking plastic electronics to the next stage of its development: the key to success was in the natural evolution of apparently unrelated ideas developed through EPSRC funding.

7. Since then, EPSRC's support for plastic electronics has been significant and has largely contributed in placing the UK at the forefront of not only discovery but also knowledge transfer and exploitation for the area (more information on this is available in a recent RCUK study of the economic impact of basic research in polymer science[18]). Plastic electronics is a field inherently trans-disciplinary; it has developed as a result of successful collaborations between university researchers in materials science, chemistry, physics as well as engineering. EPSRC funding for the area over the past 20 years, jointly with other stakeholders such as the Department of Trade and Industry and more recently the Technology Strategy Board (TSB), has enabled successful UK universities and businesses to work closely together to ensure that the UK is highly competitive on the world stage and that it can bring potentially significant returns for the UK economy.

8. EPSRC has a key role in supporting the fundamental science, technology and engineering that underpins research into plastic electronics, and pre-competitive research that will position the UK to most effectively develop and exploit technology advances in the area. Applied business-driven research, development and demonstration are supported by the TSB, the Department of Business, Enterprise and Regulatory Reform (BERR) and by Regional Development Agencies (RDAs). EPSRC works closely with the TSB and BERR to develop joint programmes in areas of common strategic importance. For example, EPSRC has partnered with TSB for their recent call for applications in the areas of advanced displays, lighting and lasers, for which plastic electronics is likely to feature strongly.

9. Current EPSRC funding with direct relevance to the field of plastic electronics is £68.2 million. EPSRC funding is provided, for the major part, directly to universities as research or training grants, a significant proportion of which are collaborative with industrial partners and other relevant stakeholders. This case study outlines the areas of EPSRC support for plastic electronics; those are described below either as research, training or knowledge transfer activities.

[18] http://www.rcuk.ac.uk/cmsweb/downloads/rcuk/economicimpact/ei2.pdf

Research (Fundamental, Strategic and Applied)

10. EPSRC currently supports research projects in two ways: via responsive and via targeted mode:

— In responsive mode—also referred to as investigator-led—university researchers can submit applications for projects at any time; these are assessed via a high quality competitive peer-review process (ISO 9000 standard). This mode of funding allows researchers to pursue their own research interests whilst ensuring that only the best projects are supported; research quality is the primary criteria in the assessment process and all projects get reviewed by elected members of the EPSRC College, which is made up of over 4,000 UK and international and academic experts in their respective fields.

— Current responsive mode funding for plastic electronics related research projects is £28.4 million, which represents 42% of the current EPSRC investment in the field. Investigator-led research funded addresses a broad range of sub-areas of plastic electronics, from research into understanding the physics of materials and devices, via synthesis, processing and characterisation of novel materials and devices, all the way through to direct applications into, for example, flat panel displays for mobile phones and other consumer electronics, solar cells, RFID and sensor technologies.

— In targeted mode, EPSRC will actively seek to promote either specific types of support for research (eg platform, fellowship) or whole areas of research by releasing specific calls for research or training grants (eg EPSRC carbon-based electronics initiative, TSB-EPSRC plastic electronics initiatives). EPSRC has, in the past five years, increased its support to the most successful academic researchers (individuals or groups) via its platform grant and fellowships schemes; these aim not only to provide baseline funding for the best groups (platform) to prevent the loss of key staff but also to support the best individuals at up to 100% of their time to concentrate on challenging research problems (fellowship).

— EPSRC funding for plastic electronics under responsive and targeted mode is displayed in Table 1.

Table 1

EPSRC FUNDING FOR RESEARCH IN PLASTIC ELECTRONICS

	Responsive mode	*Targeted Mode*			
	Standard grants	*Platform grants*	*IKC/IMRC*	*Fellowships*	*All other grants*
Value of grants (£M)	28.4	1.8	12.5	3.3	26.7
Total (£M)	28.4	38.3			

11. One of the large investments that EPSRC has made in targeted mode is for the electronics innovative manufacturing research centre (e-IMRC). With a total budget of £5.4 million for five years, this new centre of expertise has been established to enable UK industry to access and influence research into electronics manufacturing. The centre invites bids from researchers across the UK under its remit; it already counts over 50 industry collaborators, contributing over £1.6 million towards the projects funded by the IMRC. One project funded by the consortium is led by researchers at the University of Surrey, in collaboration with Qinetiq, BAE systems and Hydrogen Solar; the research focuses on developing and optimising new materials and manufacturing techniques for making 3D-compliant transparent electrically conductive plastics for solar cell applications. EPSRC will be carrying out a review of the e-IMRC in spring 2008.

12. A good example of successful investigator-led research is a large grant awarded by EPSRC to Professors Sir Richard Friend and Henning Sirringhaus at the University of Cambridge. With a total funding of £3 million, the two investigators and their research groups have been working towards building a greater understanding of conducting polymer nanostructures so as to develop better printing techniques that can in turn be used to produce nano-scale devices with suitable characteristics for plastic electronics applications.

13. Another illustration of effective investigator-led research is that of Professors Martin Bryce and Andy Monkman at the University of Durham. With £500,000 of EPSRC funding, they are developing new types of polymeric materials that can emit white light, thus bringing forth new potential applications such as in solid-state lighting and in many types of display applications.

14. It is worth noting that in the area of plastic electronics 38% of all EPSRC-supported research projects have received tangible support from relevant industry partners; this represents over £12 million worth of in cash or kind across the totality of the relevant EPSRC grant portfolio.

Skills and Training

15. Skills and training are mainly addressed in three ways: project studentships on grants, Doctoral Training Accounts (DTAs) and Collaborative Training Accounts (CTAs). There are also other training activities such as industrial CASE awards that support a small number of industrially-relevant studentships.

— DTAs are four-year grants, awarded annually, which are directly allocated to universities to fund PhD studentships; DTAs offer recipient universities the freedom to deploy the funds according to their strategic needs.

— CTAs allow a single flexible mechanism for universities to fund all EPSRC schemes that link postgraduate training with the workplace, such as Masters Training Packages, Engineering Doctorate, Knowledge Transfer Partnerships, secondments for Research Assistants into Industry, Industrial CASE and CASE for New Academics. They provide a responsive approach to training allowing universities the flexibility to deploy funds in response to emerging themes and industry needs.

16. Current EPSRC support for training and skills for plastic electronics is £2.6 million, and is concentrated either in funding of PhD students on grants (30 in total) or in the funding of PhD students via DTAs and CTAs (39 in total), including industrial CASE studentships (6) and CASE for new academics (2). There are currently no directly relevant masters courses, funded via CTAs, run by Universities in plastic electronics. However, there are a number of MSc and MRes courses, covering areas such as polymer materials and opto-electronics that do incorporate significant elements of teaching for the area.

17. There are no directly relevant knowledge transfer partnerships in this area, which is surprising considering the level of engagement between the science base and industry; the same is also true for Engineering Doctorate Centres.

18. Considering the nature of PhD courses and the grounding of plastic electronics in traditional subject areas such as physics, chemistry, materials and engineering, it is therefore not surprising that the majority of the research and development carried out in this area is pursued for the main part by more experienced research assistants. There are currently a total of 139 research associates employed on EPSRC-funded plastic electronic grants. However, as the field of plastic electronics develops further and leads to significant job creation in the UK, the skills gap is likely to increase accordingly; more industry-relevant training is therefore likely to be needed in the next 5–10 years. Both the Council for Science and Technology (CST) and the TSB have recently identified plastic electronics as a key priority area with significant potential for returns on the UK economy.

Knowledge Transfer and Exploitation

19. As EPSRC funds both fundamental and applied science, technology and engineering it is important that strong partnerships and increased engagement with users of the research is made in order to improve, and increase, knowledge transfer and economic impact. Knowledge transfer and exploitation are embedded into all of EPSRC strategies and processes. Currently, 38% of plastic electronics relevant research and training grants are collaborative with industry. Examples of industrial collaborators on grants relevant to plastic electronics include some of the most successful businesses in the field eg Cambridge Display Technology, Plastic Logic, Kodak, Merck, Dupont Teijin and Alps Electric.

20. Although EPSRC does not fund industry directly, it partners regularly with TSB to co-develop and co-fund R&D programmes and projects. The current target for EPSRC collaborating with TSB is £45 million over the next three years, including funding for the Energy Technologies Institute (ETI). EPSRC currently partners with TSB in two initiatives of immediate relevance to plastic electronics; £2 million has been earmarked by EPSRC to complement a TSB £10 million investment in the new "Materials for Energy" initiative, where new technologies for advances in photovoltaics will feature strongly. EPSRC also aims to support successful applications for the TSB "Advanced displays, lasers and lighting technologies" R&D call, on a case by case basis. EPSRC has a long history of successful collaboration with the DTI Technology programme across its remit, having joint-funded over £27 million of support for academic groups involved in a number of business-science base grants since 2004. EPSRC currently has £1 million worth of investment in projects joint-funded with TSB in plastic electronics.

21. One successful example of science to business collaboration, funded jointly by TSB and EPSRC in 2006, is a project led by Professor Bill Eccleston at the University of Liverpool. With £200,000 support, Prof Eccleston and his group, in collaboration with Mentor Graphics and a number of SMEs, are developing a rudimentary RFID tag which can be implemented in prototype organic electronics on low cost flexible substrates. If successful, such research could have an immediate impact on RFID applications for retail outlets.

22. To further facilitate the exploitation of the research it funds, EPSRC has recently invested in the Cambridge Integrated Knowledge Centre (C-IKC). The £7 million centre, funded in 2006 for 5 years, aims to create innovative knowledge exchange spanning basic research, training and specific exploitation. The work of C-IKC centres around developing advanced manufacturing technologies using new material systems, such as polymers and liquid crystals, for applications in computing and sensing technologies, displays and communication systems, and to create valid routes of exploitation for these innovation.

Building on the success of the centre, EPSRC, in partnership with TSB and the Biotechnology and Biological Sciences Research Council (BBSRC), has just launched a new call for IKC bids, with a specific focus on emerging technologies.

23. Past SERC/EPSRC funding for research carried out in the 1980s and 1990s at the Cavendish Laboratory has also led to the creation of two very successful spin-out companies, Cambridge Display Technology and Plastic Logic. Plastic Logic was recently the focus of wide media coverage when they secured over £50 million of venture capital funding in Germany for setting up a manufacturing plant. Plastic Logic was also recently backed to become the first University spin-out to reach the £100 million profit margin, which would make it one of the world's most successful spin-out companies.

24. EPSRC, via its electronics sector team, has recently partnered with the TSB-funded UK Displays and Lighting Knowledge Transfer Network (UK D&L KTN), a network whose mission is to serve the needs of the business and academic communities working in the areas of plastic electronics, flat panel displays and solid state lighting. EPSRC supports the network both by information provision and by releasing small amounts of funding for academic researchers to participate in UK D&L KTN events to develop suitable collaborations with business partners.

Conclusion and Forward Outlook

25. EPSRC currently invests £68.2 million in research, training and knowledge transfer of direct relevance to the area of plastic electronics. 42% of this investment is provided to universities through investigator-led research and 38% of this is in collaboration with industrial partners and other stakeholders. £2.6 million of this investment goes towards training of PhD students; this apparent low figure—EPSRC spends 25% of its total budget for training across its remit—can be explained by the highly trans-disciplinary nature of the field, which results in the most relevant research being carried out by highly trained research associates and fellows.

26. EPSRC, through a variety of funding models, enables not only the fundamental research in science, technology and engineering necessary for the health of "plastic electronics" as a new and emerging discipline but also the training of the next generation of researchers, grounded in the traditional disciplines of physics, materials science, chemistry and engineering. EPSRC has also developed new funding models, such as the IMRC and the IKC, to ensure that the research it funds serves the needs of users but that it is also exploited appropriately to maximise economic and societal impact.

27. In its recently published delivery plan[19], EPSRC outlines its action plan for the next three years. Several of the delivery plan themes will impact on future funding for plastic electronics.

— Under the "Essential Platform to the Knowledge Economy" theme, EPSRC aims to focus funding towards the most successful academic research groups, eg by providing baseline funding to retain key staff, by ensuring early career support, by encouraging ambitious longer and larger programmes of research and by signposting key areas of need for targeted funding. EPSRC plans to achieve this in a variety of ways, including via the use of bottom-up and top-down grand challenges. Plastic electronics should feature strongly here as the field relies on an already successful science base.

— Under the "Securing the Future" theme, EPSRC will support the best individuals for both research and training via its DTA, Knowledge Transfer Accounts (KTA)—to replace the current CTA—and fellowship schemes, focussing particularly in areas of shortage for the UK. The area of plastic electronics would certainly benefit from further support for training for new cohorts of students, either via engineering doctorate centres or CASE funding. EPSRC expects the relevant academic and business communities to take full advantage of the current call for Engineering Doctorate Centres and Doctoral Training Centres, the outcome of which will be known in 2008–9.

— Under its "Better Exploitation" theme, EPSRC will increase its partnership with TSB, RDAs and appropriate industrial stakeholders, particularly for the development of new IKCs. EPSRC also aims to build on its current portfolio of strategic partnerships with industry and other users, hence maximising the potential economic impact of the research it funds. Plastic electronics will most certainly benefit as funding opportunities develop, especially as a result of the ongoing partnership TSB-EPSRC.

— Out of the four remaining thematic areas—"Digital Economy", "Towards Next Generation Healthcare", "Energy" and "Nanoscience through Engineering to Application"—the latter is likely to incorporate R&D of relevance to plastic electronics. One of the grand challenges, selected post-consultation with the science base and industry, will focus on new technologies for enhanced solar energy conversion; research underpinning the plastic electronics area also stands to benefit from future investment in this area.

March 2008

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[19] http://www.epsrc.ac.uk/Publications/Corporate/DeliveryPlan2008-11.htm

Memorandum 130

Submission from DuPont Teijin Films

EXECUTIVE SUMMARY

The UK enjoys a position as world leading in the emerging Plastic Electronics industry with strengths extending across academe, industry and national centres. Government support through EPSRC and DTI/Technology Strategy Board has been important in developing this position. The global market for Plastic Electronics is forecast to grow to be multi-billion dollar in scale in the next decade and with its existing strengths in place, the UK Plastic Electronics community has an opportunity to become a key player in this industry. It is almost certain that the UK will continue to contribute as a key source of leading technologies and supporting IPR—this author's view is that it is also reasonable to expect that UK-based companies can be a significant source of manufacturing capability also. This capability could impact across the full range of value chain options from materials supply through to device manufacture. UK Government can play an important role in the specification of high profile demonstration projects that could assist in the adoption of these new technologies.

1. *Overview of Plastic Electronics in the UK*

UK industry and academe have developed a world-leading science and technology position in the emerging industry of Plastic Electronics (aka Organic Electronics, Printed Electronics). This new market is forecast to undergo dramatic growth to levels of $15 billion by 2015 and as much as $125 billion by 2025 (IdTechEx forecast 2007). In addition the Council for Science and Technology has identified Plastic Electronics as a "high risk/high reward" priority technology area ("Strategic decision making for technology policy, CST, November 2007). In summary, the UK has developed key strengths in the following areas in recent years:

- — Strength of academe—well exemplified by UK academic activities in light emitting polymers and organic semi-conductors (groups in Cambridge, Manchester, Imperial, St Andrews and others). EPSRC funding at the £20 million/annum rate key here
- — Strength of UK industrial base—a combination of multi-nationals (eg DuPont Teijin Films, Kodak, HP) and SMEs (eg Plastic Logic, CDT, Elumin8) demonstrate the UK's ability to convert leading technology into credible product offerings. Key questions are how many of these companies can compete in this, inevitably, international market?
- — Network of publicly-funded centres of excellence which contribute to this area. Key centres here are the PETeC centre (Sedgefield), CPI (Wilton), IKC (Cambridge), NPL (Teddington), OMEC (Manchester), Welsh Centre for Printing and Coating (Swansea)
- — Government allocated funding to support this area, initially through DTI Technology Programme, now Technology Strategy Board. Over the period 2004–2007 this amounted to £48 million which has fostered innovation across the academe/industry interface
- — The role of the UK Displays and Lighting KTN—formed initially from the Flexynet group which was created in 2003 to provide a key networking platform for Plastic Electronics. Flexynet membership today stands at a level of 640 members drawn from 392 companies and 65 universities. The UKDL KTN plays a key role in the facilitation and administration of TSB funded programmes, education, networking and management of both inward trade missions (eg China/Korea/Taiwan 2005, Switzerland 2008) and outward trade missions (eg China/Hong Kong/Korea/Taiwan 2006). The level of interest from overseas organisations in the UK's strengths in Plastic Electronics remains at a very high level

2. *Responses to Plastic Electronics Engineering Case Study Terms of Reference questions*

- — The potential for Plastic Electronics in the UK/Global economy

As already described above, this industry is on the brink of explosive growth which will result in the creation of a market valued at the tens of billions of $ level. This growth will develop in a range of end use applications exemplified by flexible displays, photovoltaic devices, sensors, RFID, printed memory and batteries. This author considers it as a "given" that the UK will always participate in these new technology areas in the creation of new science and supporting IPR.

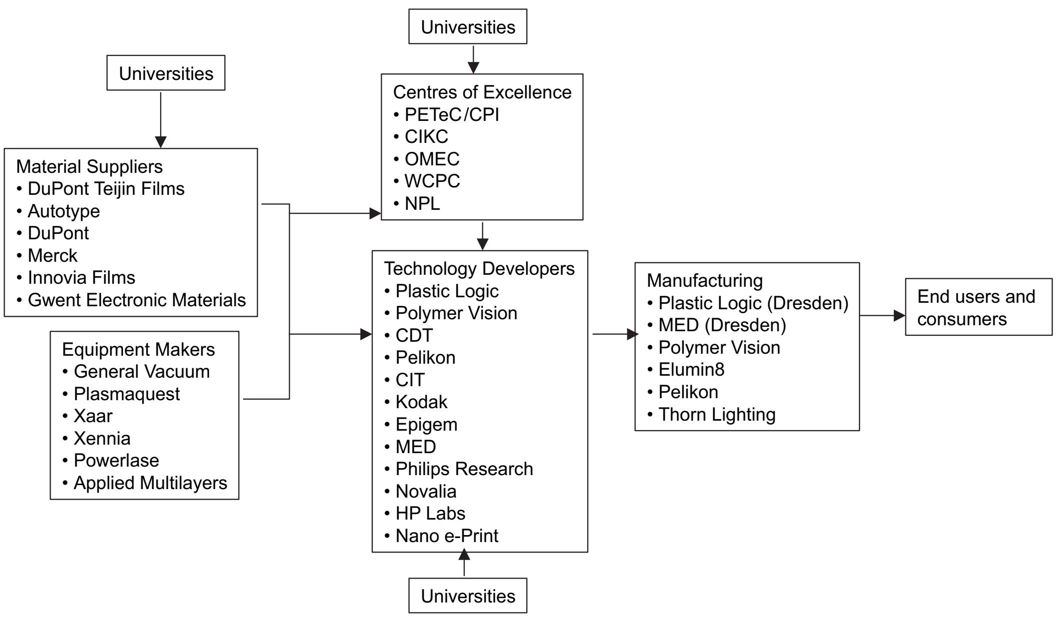
This opportunity is well recognised across the globe with a recent IdTechEx study indicating that in the US there are 200 organisations active in this area, in Asia 140 and in Europe 250. The success of Korean and Taiwanese companies in the LCD industry can lead to a mindset of "develop technology in UK/Europe but manufacture in Asia" and while it's certainly the case that Asia will make a play in the manufacture of Plastic Electronics there is no reason at all why UK/rest of Europe should not participate via a manufacturing business model also. Indeed the decisions by Plastic Logic and MicroEmissive Displays to establish their first manufacturing base in the Saxony region (Dresden) of Germany are the first examples of this type of investment behaviour.

A further factor to consider when considering UK potential in this area is again the example provided by the LCD industry. While it is true that the final manufacture of LCD panels is dominated by Asian companies such as Samsung, LG Philips, AUO and others there are excellent businesses that have been developed by non-Asian companies for the LCD industry. The successes demonstrated by 3M (optical films), Merck (liquid crystal materials) and Corning (glass) have shown clearly that it is possible for non-Asian companies to develop sustainable, profitable businesses for industries where heartland manufacturing takes place in Asia. It is well understood in the LCD industry that the most profitable parts of the supply chain are at the "front end" (eg materials, glass, equipment) or at end of the chain selling product to consumers. This experience suggests that there can be good opportunities for UK-based organisations to participate in the emerging Plastic Electronics industry(in addition to the science generation and IP/licensing opportunities).

— The current and future roles of engineers in the field of plastic electronics

Plastic Electronics is a very young industry and much of the engineer staffing need in the last 10 years has been satisfied by the output from universities in disciplines covering electronics, engineering, physics, materials science and chemistry. As the development platforms of the last 10 years migrate to commercialisation then new technical and management skillsets need to be brought into play. This is further complicated by the loss of critical UK skillsets in areas such as supply chain management, prototype manufacturing, experienced operational managers over the same period. A contributory factor here is the exit from the UK of major multi-nationals such as ICI, GEC and others who in times past would have acted as a training house for these type of skillsets resulting in the creation of a fragmented, largely SME electronics industry. A potential, today, untapped source of these resources are the remaining larger companies in the UK operating in industries such as the Pharmaceutical and Oil industries.

— How universities, industry, venture capital and Government are involved in the development of the UK Plastic Electronics sector



The activities of industry, academe and centres of excellence in the UK Plastic Electronics industry can be summarised as:

Government has played an important role in supporting the Plastic Electronics industry in the UK with the allocation of £48 million in the TSB-supported Technology programme over the 2004–07 period. These monies are generally speaking applied to support innovations at the interfaces between universities, materials suppliers, equipment makers and technology developers. In addition to this EPSRC has also provided direct university funding of the order of £20 million/annum. These monies have been of critical importance in the generation of the portfolio of technology development activities reflected above.

Venture capital money has typically been applied to both early and later stage technology development work as well as to the funding of manufacturing facilities. The highest profile examples of this have been the VC -supported Plastic Logic and Polymer Vision facilities in Dresden and Southampton respectively.

In addition to these investments, there are the, often not publicly quoted, industry R&D investments in this space which have been estimated to amount to £65 million in the November 2007 CST report.

Finally it is important to recognise the work of the UK Displays and Lighting Knowledge Transfer Network which has provided over the last five years important network, education and programme co-ordination support to those organisations involved in Plastic Electronics in the UK.

— Whether the UK engineering and manufacturing sector are set up to handle growth in this area or other areas like it

Worthwhile to consider this challenge in terms of the UK community's strengths and weaknesses:

Strengths

— UK has developed a globally recognised leadership position in Plastic Electronics technology—reflected in the technology development, materials and academic portfolios.

— A strong UK sense of community around this market space with the KTN playing an important role.

— Some well established strengths which are commercially viable in this new area—amongst these one would count substrates, materials and some aspects of equipment.

— Significant investments in centres of excellence which if utilised effectively have an important role to play.

— Early stage R&D/prototyping well supported through EPSRC/TSB/RDAs but weak at pilot/full manufacture stage.

— Much lower capital intensity for manufacture of plastic electronics breaks the "only manufacture in Asia" paradigm.

Weaknesses

— The UK no longer has access to a world-leading multi-national electronics company (similar in standing to companies such as a Samsung, Sony type) which would drive the creation of supply chains and commercialisation critical mass.

— Perceived attitude that manufacturing is no longer part of UK plc USP.

— Taxation schemes when compared to competing regions of manufacture (Asia, Ireland?)

— Early stage R&D/prototyping well supported through EPSRC/TSB/RDAs but weak at pilot/full manufacture stage.

— Loss of manufacturing competencies to support high volume manufacturing.

Taking a purely industrial view of how ready the UK is to handle this growth, I'd summarise the position as:

1. For those companies (my own company would be an example) where Plastic Electronics is seen as a significant opportunity then resources will continue to be allocated to develop a new business in this space.
2. For aggressive SMEs receiving healthy levels of VC and other funding then these companies will take decisions regarding manufacturing which maximise their spend return. Recent investment decisions by Plastic Logic and Polymer Vision illustrate this position.
3. For SMEs who are perhaps at an earlier stage of development compared to class 2, then these companies will continue to operate within TSB, EU, RDA led funding regimes. Once their technology then reaches a level of commercial maturity then they have the opportunity to become class 2 companies as above.

Issues for the Select Committee to Consider

1. The Technology Programme founded by DTI and now managed by TSB has been a success in helping the UK to develop what is today a very strong position. We should encourage Government and TSB to continue funding support in this way

2. EPSRC funding at its present level is important in order that:

— The UK's technology pipeline and IPR remains strong; these are the foundations of the next generation of companies.

— The ongoing flow of trained engineers and scientists continues as the Plastic Electronics industry delivers its promised growth in 2015 and beyond.

3. As stated above, the UK no longer has a domestic large multi-national electronics corporation which could drive growth in this sector. However, UK Government could play a vital role in creating demand, at least at the product demonstrator stage, for Plastic Electronics products in the UK. Target pilot projects could be in one or all of the following areas:

— London 2012, "paper-less" Olympics…pilot adoption of e-readers.

— Education—significant trial of e-readers in school/university environment.

— Energy—trial of photovoltaic/fuel call devices in government construction or other projects.

There is a lot of enthusiasm in the UK Plastic Electronics community to engage with Government on all of the above.

March 2008

Memorandum 131

Submission from OLED-T

EXECUTIVE SUMMARY

In order to provide access to world class equipment to innovative companies in the plastic electronics supply chain, it is proposed that critical items of capital equipment are fully funded for key companies. These companies would be obliged to provide access to the equipment to innovative small and medium companies and start-ups so that a number of parties have access to world class equipment to rapidly develop the industry.

1. The plastic electronics industry has a potentially valuable supply chain stretching from fundamental R&D to the production of final products including:

— Research activities at Universities and applied Research and Development at start-up companies.

— Materials and chemicals.

— Equipment for prototyping and manufacturing.

— Product development.

— Product manufacture.

The manufacture of the final product is just one part of the supply chain. Indeed, the greatest value may be gained from the development and supply of materials, equipment, and intellectual property to a global manufacturing industry. The establishment of such a broad supply chain may be the key to the success of an emerging plastic electronics industry.

2. For start-up companies, the costs to acquire or gain access to equipment to evaluate new materials, processes, and concepts is often prohibitive. Early stage investors in start-ups are rarely able to provide the capital to purchase the specialised equipment that is necessary to accelerate development. As a result, development is too frequently done on small scale equipment that does not provide the quality or the scale necessary.

3. It is proposed that significant and critical items of capital equipment necessary for the development of the plastic electronics industry should be fully funded for key companies in the supply chain. A mechanism will be required for determining which companies should qualify, perhaps along the lines established under Technology Programmes. These key companies would have responsibility for managing and maintaining the equipment for their own developments and would be contracted to provide access to the equipment to small and medium and start-up companies in the field. In this way, innovative companies with limited resources will have access to world class equipment to accelerate the development of the industry.

March 2008

Memorandum 132

Submission from "CEESI-Training"

EXECUTIVE SUMMARY

1. We recommend developing one or more modules at postgraduate level for study over the internet as the fastest and most cost-effective way of developing a broader base of expertise in the new area of plastic electronics.
Distance learning over the Internet has already proven successful in reaching design engineers employed by small companies (SMEs). Since it is widely acknowledged that growth and innovation in the UK now arises mainly through SMEs, this route is commended in favour of alternatives such as commissioning a new classroom-based MSc programme for full time study. Concerns are raised that existing funding channels are unlikely to lead to either route proceeding because of the perceived risk in an uncertain market.

Brief Introduction

2. This submission has been prepared by the following people:

Professor Ted Pritchard	Co-ordinator of CEESI-Training. Previously Head of Dept. at University of Huddersfield and advisor to DTI
Mr David Rees	Chairman of CEESI Management Board, Seer Consultants
Roy Attwood	Co-ordinator of postgraduate distance learning courses in electronics from the University of Bolton. Previously a design engineer with Philips Electronics.

All the above are Chartered Electrical Engineers with many years experience of academe and industry.

Factual Information

3. A search using Google suggests there are currently no commercial or university training courses available in plastic electronics.

4. The preferred vehicle for universities to develop and deliver postgraduate training in new technical areas is through modules that can lead to a Master of Science (MSc) qualification. There are five solid reasons for this:

- university quality procedures are geared to courses that can lead to a qualification;
- students enrolled on courses that can lead to a qualification can potentially bring in additional funds to the university from the *Higher Education Funding Council for England* (HEFCE);
- a new module can be added to an existing MSc course quickly, with very little administrative burden and at low risk. Subsequently, once sufficient new modules have been developed this way, a new MSc degree title can be validated if it is then thought appropriate;
- students appreciate they are gaining credits towards a validated qualification, and the flexibility of the modular masters approach; and
- European harmonisation of qualifications (the Bologna process) has made the modular masters framework the standard throughout Europe. Most countries outside Europe also recognise this framework.

5. It is expensive, time consuming and risky for any one university to develop a full-time taught masters course in a new area. In the past such developments have generally only happened with a *Masters Training Package* (MTP) allocation of upwards of £300,000 from the *Engineering and Physical Sciences Research Council* (EPSRC). Specific awards like that are no longer made; instead EPSRC has rolled together all the funding allocations made to any one university into a single *Collaborative Training Account* (CTA) and the university decides its own priorities internally. This system has many advantages, but one disadvantage is that developments seen as relatively risky or having a relatively long payback time are less likely to be supported. An MSc in *Plastics Electronics Engineering* would probably fall into that category, making it unlikely to be developed.

6. Bearing in mind the time delays inherent in the next CTA bidding and award process, it is unlikely work could start on designing a new MSc in *Plastic Electronics Engineering* for at least 18 months, and a realistic timescale for the MSc to be ready to recruit is three years. So the first MSc graduates would become available to industry in four years time. This is a long time for industry to wait. Worse still, such graduates would probably have little work experience and it would be another six months or more before they became fully productive.

7. A mechanism that allows organic growth of MSc modules available nationally by distance learning over the Internet already exists through a scheme known as CEESI-Training. The CEESI scheme has been supported by EPSRC since 2001. Taking this route would allow new modules in plastic electronics to be developed without delay and added to existing frameworks. Design engineers choosing to study the modules would be doing so on a part time basis for CPD. They would already be in productive employment and in a position to inform and influence management decisions. Proceeding on the path of organic growth can be expected to start being effective two to three years ahead of the equivalent full time MSc route. Risks are reduced because the market can be tested and adjustments made along the way.

8. The cost of developing a 15 credit module in a new topic area, in a format suitable for distance learning is of the order £30,000. It would typically be studied over a 14 week period and is roughly equivalent to the amount of material that would be covered in an intensive 5-day residential course, when backed up with reading lists beforehand and practical work afterwards. A 15 credit module is expected to involve a total of 150 learning hours.

9. Perhaps two such 15-credit modules would be appropriate at this stage of development, with more to follow as the technology matures. A budget of £60,000 would be realistic to bring the first two modules to fruition. Additional funds would be needed to market the new modules.

10. Internet-based courses have become the preferred mode of study for engineers engaging in continuing professional development. Such courses are accessible to employees of the smallest companies, regardless of location, as well as to those working for multinationals, research establishments or universities.

11. Internet-based courses are also more inclusive and offer wider access than classroom-based courses, being non-confrontational and blind to disability, age and gender.

12. The authors are of the opinion that a modest outlay in preparing internet-based modules at MSc level is the surest way of raising awareness and disseminating the technology to the people who are most likely to innovate and create new products, and influence management. At the national level, returns on such an investment could be very high.

Recommendations

13. The committee should consider the two routes outlined for developing awareness and expertise in the area of *Plastic Electronics Engineering*.

14. If the committee feels that an MSc course in *Plastic Electronics Engineering* is the appropriate way forward, given the timescale of new developments, they need to satisfy themselves that a university will be willing to commit the necessary investment. If they are unable to satisfy themselves on this matter, they might consider whether some other mechanism or inducement needs to be brought into play.

15. If the committee considers that the faster route of organic growth to existing courses is more appropriate, then again, the committee should consider how this might be funded.

March 2008

Memorandum 133

Submission from the Centre of Excellence for Nano, Micro and Photonic Systems (Cenamps) and the Centre for Process Innovation (CPI)

Both Cenamps and CPI were established in 2003 as part of the North East Regional Development Agency's (ONE North East) strategy to transform the regional economy through support for innovation and technology. CPI's focus has been on the process industries, including bio-processing, low carbon technologies and coating technologies for advanced polymer electronics. Cenamps has focused on new enabling technologies including bio-nanotechnology, plastic electronics, atomic layer deposition and nanomaterials.

Both companies role is the development and promotion of these technologies in the North East, bringing together skills, capabilities and facilities from academe and industry to encourage greater collaboration of science with business, promoting sustainable innovation and technological development to open up new markets for the technology and capabilities, with the long term aim of generating sustainable economic benefit to the region and the UK as a whole. As part of this strategy a number of national centres have been established and are run the both organisations including the National Bio-processing Facility, the Nanotechnology Knowledge Transfer Network and importantly for this Committee the Plastic Electronics Technology Centre (PETeC).

PETeC is a nationally recognised centre based at NETPark near Sedgefield, that will provide world-class facilities, services and expertise at the hub of a UK-wide network in Plastic Electronics. The need for such a Centre was recognised by the DTI, who said

> "The most promising plastic electronics technologies are now reaching a critical stage in their development. They have been proven at the laboratory scale; manufacturing processes now need to be engineered so that devices can be manufactured efficiently and economically. This calls for an open access facility, and associated skills, that is between the research stage and full production and represents an interim development phase prior to full manufacturing. Without such a facility, these technologies cannot be brought to the market"

The UK already has an early internationally pre-eminent position based on university research and the activities of both SMEs and larger firms. The UK plastic electronics community is already well established and has a strong collaborative tradition. PETeC will provide a national focus for the UK's activities in plastic electronics. The Centre will house clean rooms, production and testing equipment and design and engineering skills, made available on an assisted access basis. These will fill the gap identified above, enabling a range of developers to take technologies to a stage whereby they can make the full-scale market introduction and where appropriate manufacturing of new products and related processes and services.

PETeC will therefore enable the development of internationally competitive, knowledge intensive activities for the benefit of the UK. It will enable the commercialisation of a scientific development made in the UK, which will transform one of the world's most significant technology industries. It will enable new applications and opportunities across a range of sectors, including in healthcare and energy. This national facility will enable the retention and attraction of regional, national and international investment.

This response addresses the four aspects requested by the IUS Committee, namely:

— the current and future roles of engineers in the field of plastic electronics;

— the potential for plastic electronics in the UK/global economy;

— how universities, industry, venture capital and Government are involved in the development of the UK plastic electronics sector; and

— whether the UK engineering and manufacturing sector are set up to handle growth in this area or other areas like it.

The current and future roles of engineers in the field of plastic electronics

Plastic electronics involves a wide range of disciplines including chemistry, materials science physics, engineering (mechanical, electrical, process) and design. Plastic electronics is pushing the boundaries of existing knowledge and capabilities and there needs to be training and skills improvements to produce a workforce capable of implementing these new technologies. It is not that long ago that the idea of plastics being conductive was considered radical and had not been observed, now it is possible to build transistors and electronic circuits entirely from polymers. The technologies that have formed the basis for plastic electronics have originated in the disciplines of chemistry, physics and materials science, this has created the breakthroughs and the understanding of how these materials and devices work. There is still work to be done to improve the performance and efficiency, but the next stage to bring plastic electronics to market is dependent on having strong engineering skills applied to the conversion of lab devices into scalable, reliable and repeatable processes that can be use to fabricate hundreds of thousands and then millions of devices that can be incorporated into products. Existing expertise in silicon wafer based device manufacture can be adapted for some plastic electronics production process but not all. However, the basic understanding of how to operate processes in high clean room environments can be transferred to plastic electronics. This is fine for batch processes but the real benefits of plastic electronics will only be realised once high volume rapid processing is introduced. This will take an new breed of engineers who will be able to bring together the high precision and clean room level cleanliness of advanced electronics with the high volume of roll-to-roll printing. There are still some major hurdles to be overcome due to the nature of the materials used in plastic electronics that need robust engineering solutions to be developed. This will require a multi-disciplinary approach to be adopted by current engineers and the training institutions that will engineers of the future.

The potential for plastic electronics in the UK/global economy.

Firstly we have to be clear what we mean by plastic electronics. The printing of conductive tracks onto a flexible polymer substrate, for example in inkjet printer head connections and antennas for simple RFID tags, is not considered to be plastic electronics. For a product to be considered made from plastic electronics it must have a combination of material or components that are active, ie change in response to a stimulus, and preferable polymeric in composition. Examples of products that are being developed using plastic electronics include flexible displays, solid state lighting, photovoltaics, and sensors. Plastic electronics should therefore be considered as a platform technology that has a myriad of potential applications. This means that plastic electronics has an enormous potential to generate considerable economic activity worldwide.

Numerous market studies have been undertaken that give estimates for the size of the global plastic electronics markets. These vary from $1.18 billion in 2007 to over $48 billion by 2017 [Error! Reference source not found.], to $71 million in 2006 through to $31illionn in 2013, and technology analysts speculate that these new markets could be valued in the hundreds of billions of dollars within 20 years, with one study estimating the market in 2027 to be worth $330 billion. Whatever the actual estimates what is clear is that plastics electronics will be a major industry. The principle applications that are being pursued are displays for electronics, billboard/poster signage, lighting, portable power, sensors and other components, logic/memory and smart RFID tags.

The UK has a world leading capability in the understanding of plastic electronics through the pioneering work undertaken at Cambridge, Durham, Imperial, St Andrews and Swansea Universities. The number of other university groups building their expertise in this field is growing and there is a increasing degree of multi-disciplinary activities being undertaken both within and between universities.

The commercial sector is less well developed in general but commercial activity divides into companies into that can provide essential enabling technologies and those that are focused on developing applications. The former category the UK has considerable capability through companies such as DuPont Teijin Films, Merck, Xaar, Xennia, McDermid, Akzo Nobel etc. There are numerous major international companies here but also smaller companies with world recognised capabilities. In the latter arena the UK has leading companies in CDT, Micro Emissive Displays, Polymer Vision, Thorn Lighting and Plastic Logic and has recently attracted G24i to the UK on OPVs. However, these application orientated companies tend to be small emergent companies and not the major multi-national giants, which is a disadvantage for the UK. The principal value to the UK will therefore lie in materials, device designs/structures, and process knowledge.

Having said this we firmly believe that the UK has the potential to be a world leader in this technology area in the next five years. The technology is still in the emergent stage with no one country in a dominant position. The scale of interest around the world is increasing rapidly as researchers and companies identify new applications and are able to quantify the levels of investment and reward. Investment will go to where the best technology and capability is being developed and apart from displays is not necessarily tied into existing capital investments

The key aspect will be the transition of the academic lab based science and technology, in conjunction with the enabling technologies mentioned above, into demonstrable processes that will provide reduced risk production capability and the proven ability to manufacture low volumes of usable products. Improvements in materials and processes will be key to achieving this including increased mobility materials, encapsulation and extending lifetimes.

How universities, industry, venture capital and Government are involved in the development of the UK plastic electronics sector

Much of the underpinning research into plastic electronics at universities has been funded by the Research Councils and this continues to be a valuable source of investment into the fundamentals and basic research. Key academic bases include Cambridge, Durham, Imperial, St Andrews, Manchester and Swansea Universities. This is important as there is still much to discover and understand about how these materials and devices behave which will not only inform current developments but also create new opportunities. In addition the DTI and now the TSB have consistently supported the plastic electronics arena with regular programme of calls covering different aspects of plastic electronics. This investment has leverage matching contributions from industry. This investment has been a major factor in maintaining the UK's capability and ensuring that we can compete on the world stage. The approval for the building of the Plastics Electronics Centre (PETeC) at NETPark in Sedgefield will provide a national focus for the activity. The IKC at Cambridge will provide early stage support to PETeC and a link with the academic activities. The Regional development Agencies have also been significant supporters of building plastic electronics capabilities, in particular the Northern Way RDAs, ONE North East, North West and Yorkshire Forward, and the Welsh and Scottish Devolved Administrations. In addition other Government supported bodies have recently become involved in this arena, for example the Carbon Trust recently ran a competition aimed at accelerating the exploitation of Organic Photovoltaics.

UK industry is also investing heavily in the development of the tools, materials and manufacturing technologies for plastic electronics. The companies identified above have, recognised that plastic electronics will provide a major opportunity for them and are developing materials and processes that will play a major part of future applications. However, the UK is not strong in having capability from the major multinationals in the UK. The principle display manufacturers are in the Far East, the major players in lighting are in the US and Europe, the large chemicals companies are in Europe and the US. So the UK will probably have to both attract inward investment and partner with overseas companies to bring their innovations to market. The recent investment by G24i in Wales indicates that in can be done, but the decision of Plastic Logic to locate it's first production facility in Dresden shows that the competition, and provision of related incentives, from other countries is fierce. It is important that the UK offers the most attractive package to investors. There is a tendency in central government to let regions compete and focus in ensuring a fair internal competition rather than offering the best UK offering.

The venture capital community is active with most of the UK applications companies mentioned above being funded through VC funds. However, the levels of investment are still modest compared to the US, although this is a general trend and not specific to plastic electronics. As the technologies mature then VC investments should increase but many innovations are still some way from attracting the levels of investment that will take the companies to the next level and bring products to market.

Whether the UK engineering and manufacturing sector are set up to handle growth in this area or other areas like it

The devices and components made using the current generation of plastic electronics are small in size, such as readout displays for consumer goods, and utilise batch processing methods. The majority of these are fabricated either in Europe but predominantly in the Far East and not in the UK. The next generation of devices, larger, better quality and more flexible, are beginning to be scaled up with plants being built in Germany (Plastic Logic) and Wales (G24i). Most companies in the UK are specialising in one activity at one stage in the supply chain and not looking to vertically integrate their activities. While vertically integrated companies are not essential we believe the lack of supply chain integration will add complexity to the commercialisation process. Company collaboration will be required where there will inevitably be information sharing sensitivities. However, having said this, the UK has many of building blocks and skills that be brought to bear to support the growth in this area. Many if the materials technologies and emerging companies are UK based and it has expertise in related industries such as the Si devices, printing and test equipment. What the UK lacks is the infrastructure and knowledge of high volume manufacturing such as flat panel displays, solar cells and LED lighting. Facilities such as PETeC and the IKC at Cambridge will go someway to providing the UK companies with a location to acquire these skills and to develop and try out production process without the high risk investment in unproven combinations of production equipment that will be required.

March 2008

Memorandum 134

Submission from the Institute of Physics (IoP)

The current and future roles of engineers in the field of plastic electronics

1.1 The field of plastic electronics has its roots in physics and chemistry research into the fundamental properties of polymers, but in the development of future applications and devices, engineers and engineering are essential. Currently engineers are predominantly engaged in translating scientific innovations and R&D into potential device technology. Further development of plastic electronics technologies and applications will require engineers working in a range of fields:

> Electrical and Electronic Engineering: Plastic electronic devices behave in a different manner to traditional electronic circuits based on silicon; as such they require the design and implementation of new structures. For example, organic light emitting diode (OLED) based displays require different driving electronics than those used in conventional liquid crystal displays (LCDs). Organic photovoltaic (OPV) solar cells will require new power electronics to link them into the national grid.
>
> Optical Engineering: The coupling of light out of OLED based displays, and coupling light into OPVs, requires new optical designs and modeling to maximise efficiency.
>
> Chemical Engineering: Solution "processable" plastic electronics require detailed control and understanding of many factors (eg viscosity, evaporation rate) in the polymer semiconductor formulations. All of these factors need to be adjusted depending on the production method used for fabrication. Furthermore there is the need to scale-up the production of plastic electronic materials from milligrams in the laboratory to kilograms in factories, bringing together reactor and reaction engineering with process modeling and control. This requires chemical engineering design of the large scale production facilities needed to mass produce conjugated polymers, small molecules and fullerene based materials.
>
> Production Engineering: Production of solution processed plastic electronics requires a novel range of fabrication facilities. The most fully developed is of these in the UK is ink-jet printing, but other potential techniques include: gravure printing, "flexo printing", screen printing, micro-stamping and hot-stamping. Challenges in this area are both registration between different printed layers, as well as resolution (minimum feature size) to maximize device performance.
>
> Environmental Engineering: Plastic electronics is a developing technology and it should be possible to minimize the environmental impact of production from the bottom up, both in use and disposal. This includes energy efficiency, biological toxicity and the use of biodegradable and compostable materials. The latter aspect covers not only the electronic materials themselves, but also their production solvents (eg use of water and alcohols as opposed to chlorinated solvents) and device encapsulation materials.

The potential for plastic electronics in the UK/global economy

2.1 The economic impact of the plastic electronics sector could be very significant, both in terms of businesses and jobs created and in terms of revenue. The global market is currently worth around $1bn with predictions that this will rise dramatically over the next two decades reaching $30 bn by 2015[20] and $330 billion by 2027[21]. Conventional fabrication plants for electronics and displays require substantial

[20] http://www.nanomarkets.net/news/pr—detail.cfm?PRID = 195
[21] http://www.idtechex.com/products/en/articles/00000640.asp

capital resources (of the order of $100 millions). Plastic electronic devices in contrast can be produced through ink-jet printing at room temperature and pressure. As such fabrication plant cost is greatly reduced moving within the reach of small and medium-sized companies.

2.2 Plastic electronics have the potential to address some of the key challenges of this century: environmental protection, and energy generation and usage, through the low energy consumption in production, use and recycling, as compared with traditional electronic technologies. There is also the potential for devices to be engineered to have a much lower biological impact in terms of toxic waste in production and disposal.

2.3 Some key potential usages of plastic electronics are:

Solar cells: OPV solar cells are lightweight, flexible, can cover large areas and can be mass-produced through solution processing. Although current efficiencies are relatively low (5%) compared to their inorganic semiconductor counterparts (28%), their comparatively low production costs compensate for this in the short term, and in the longer term there is scope for improvement. Such technology could have a major impact on the field of renewable energy generation.

Displays & lighting: OLED-based information displays (both single-colour and full-colour) and large-area lighting are lightweight, flexible and can be mass-produced by solution processing. OLED-based devices have the same richness of colour of a conventional cathode ray tube (CRT) or plasma screens but have advantages in energy efficiency, size and weight. Large-area OLED lighting is also energy efficient and can be designed in any type of curved shape or flexible structure, producing a range of exciting new design and products.

Display electronics, radio frequency identity tags (RFID), data storage & processing: Organic field-effect transistors (OFETs) have similar advantages to OPVs and OLEDs. They can be used as thin film transistors in liquid crystal displays (LCD) and electronic paper displays, allowing the production of flexible, lightweight devices. They can also be used to produce cheap, printed RFID tags for commercial and security measures. Novel lightweight electronic devices are also possible, with the potential for moving into new three-dimensional architectures not possible with conventional silicon based electronics.

Sensors: Organic photodiodes (OPDs) can be used to produce new imaging and sensing devices. These include biological sensors (eg the replacement human eye project at Imperial College) and X-ray imaging devices for medical use.

Telecom & optical signal processing: Polymer and small molecule semiconductors can be used in optical amplifiers and optically pumped lasers for use in fibre optic networks. Their ease of processing could be used to fabricate using simple methods a range of different optical device architectures for telecommunications, local area networks and all-optical processing.

2.4 There are also hybrid technologies that could combine conventional silicon electronics and organic electronics on both glass and plastic substrates. These could provide a quicker route to market than novel technologies.

2.5 Current production techniques are principally molecular deposition by thermal evaporation and ink-jet printing from solution. Strong opportunities exist in developing these and other production methods. Highly specialized, precision engineering firms will be needed to develop these new techniques; however, there is a very weak UK presence within these fields compared with other European nations (eg Switzerland, Germany and Finland).

How universities, industry, venture capital and Government are involved in the development of the UK plastic electronics sector

Universities

3.1 There are several examples of a very high level of involvement in the basic research that underpins plastic electronics within the UK. Universities currently undertaking this research area include: Imperial College, Cambridge, Oxford, UCL, QMUL, Sheffield, Manchester, St Andrews and Durham, principally in the departments of physics, chemistry and materials science. The main research interests are in displays and solar cells, but there are other possible applications in sensors.

Industry

3.2 There is a broad range of companies currently involved in plastic electronics R&D in the UK including Cambridge Display Technology (CDT), Merck, Plastic Logic, Microemissive Displays (MED) BP Solar, Sharp Laboratories of Europe, Kodak UK and QinetiQ. There is also some investment in production facilities within the UK: a plastic hybrid solar cell manufacturer (G24i) is showing an intention to build a major facility in Cardiff. However, CDT was recently sold to the Japanese Sumitomo Corporation and Plastic Logic has moved it production base overseas.

Venture Capital

3.3 Start up companies such as CDT, MED, Plastic Logic and Molecular Vision benefited from both a supply of venture capital together with government support; these companies are now successful multi-million pound enterprises. Those wishing to attempt to repeat these successes still experience difficulty in obtaining private funding. Venture capital organisations need to understand the particular risks and benefits of high-technology start-ups; an issue highlighted in the Engineering and Technology Board report *Set and the City*[22].

Government

3.4 Government has a role to play in providing funding at a proof-of-concept stage of innovations and also providing assistance at the technology readiness stages of what is currently a relatively healthy embryonic industry. This approach has previously yielded successes such as Plastic Logic and MED. An implementation of "mission-led" funding and the application of an intelligent procurement strategy in this area have the potential to encourage growth.

Whether the UK engineering and manufacturing sector are set up to handle growth in this area or other areas like it

4.1 The UK is currently not well placed to fully exploit the domestic strength of scientific research in the field of plastic electronics. In common with related industries such as nanotechnology and biooptics, there is an insufficient number of trained engineering being produced in the UK to meet current demand within the plastic electronics industry. (In particular the levels of qualifications and experience required by start-up companies working in this field often results in them recruiting staff almost exclusively from overseas.)

4.2 In the case of plastic electronics there are possible avenues for re-training workers from other electronics and printing industries to meet demand. However, to date we do not believe that this has been pursued with sufficient vigour by government and skills agencies and there is very little awareness of the issues in universities. The UK must substantially increase its work force from the present level in order to be competitive with overseas centres. World-leading companies *outside* UK including Sony, Samsung, BASF, Philips, Epson, DuPont, Sumitomo and Kodak are already producing commercial devices such as full-colour and single-colour displays for mobile phones, electric razors and MP3 players and flat screen OLED televisions.

4.3 There are strong growth opportunities in direct manufacturing in the UK. Given the current predicted global market revenues, a large number of major international companies (eg Sony, Philips, Samsung, LG and Epson) are putting considerable resources into this area to produce the equipment needed to produce plastic electronics devices. In contrast in UK there are very few companies working in the area so much of the equipment may have to be purchased from overseas (although there are some aspects of high technology printing techniques in which the UK is very strong). The two UK companies who are leading this field, MED and Plastic Logic, are currently building fabrication plants in Dresden, Germany (likewise US firm Nanosolar Inc. is building OPV fabrication plants in California and also in Germany). One of the reasons for the attractiveness of Germany to such high-technology manufacturing companies is the ready supply of skilled workers.

4.4 Underlying the exploitation of plastic electronics research and device manufacture is the question of the market. High quality research work from universities in the past has been "forced" into markets that may not be in need or have rather different requirements. To fully realise the potential of plastic electronics, more thought should be given to whether the plastic electronics technology really offers the ideal solutions to product needs. Despite the research strength in the UK, there are currently not enough proof-of-concept demonstrators in the field and as such there are serious concerns about the stability and longevity of the end product. We recommend the Technology Strategy Board's approach of establishing first the market needs and then assessing much of this technology sector will meet that need be more closely adhered to.

March 2008

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[22] *Set and the City*, etb. 2006

Memorandum 135

Submission from M-solv Limited

Executive Summary

Many believe the market for plastic device electronics will be worth $16 billion by 2015 (PETeC). However, most market reports do not include the value of advanced manufacturing equipment and/or supply chain economy needed to support the high rates of production that enable commercial plastic electronics. UK Original Equipment Manufacturing (OEM) needs the support of government to be globally competitive through sponsored R + D and international business development. OEM's must create national and international alliances in development and collaboration of advanced tools, forming supply chain networks with focus on partnering expertise. The government should be supporting tool suppliers and manufacturers to drive globalisation of UK industry.

1. UK manufacturing has lost the ability to be as competitive as Asia mainly because of the high costs associated with the value of the pound (£). In development and fabrication of high-tech products such as microelectronics and displays it is increasingly expensive and difficult to be commercially competitive in a global market. Asia governments have invested in extremely high volume production methods and promptly responded to the popularity of computers and displays to secure their export future. The cost of commodity products using micro-electronics and display technology is constantly driven down through automation and volume manufacturing whilst not compromising on high quality.

2. Plastic electronics has given rise to an up and coming market and enterprise framework for manufacturing microelectronics with low material costs and full automation in plants. This technology has generated a significant amount of hype in the market place as a disruptive technology which could displace flat panel display technologies such as LCD and PDP display to become the market leader. As this remarkable story has begun to unfold it is clear that it is simply not the case where OLED and plastic transistors will be the dominant electronic system to supplant inorganic (silicon) technology for the foreseeable future. Nonetheless, organic electronics has given rise to applications which silicon based logic could not establish. Food packaging electronics and disposable displays ensures the FPD market continues to show growth with emerging technologies and fresh impetus on "product life cycle" and the environment.

3. It was expected that manufacturing giants such as LG or Samsung would have adopted the plastic technologies over LCD because of low costs, simplified manufacture and materials advantages in flexibility. However, and understandably with the huge investments made in Asia to ramp up LCD production why would they make this dramatic change? In other words every Polymer display that sells equates to one LCD that did not, thus devaluing the initial investment. Encouragingly, organic electronics has proved too big to ignore and many of the large Asia manufacturers are separately qualifying the technology and have put small/medium size displays in short lifetime products such as mobile phones.

4. The reality which is unfolding through the bravado shows that developers of the technology in the UK have to exploit the system using licences and in niche applications. Gaining acceptance into Asia & Japan export markets that utilise many more displays than the West will be a key strategy. It was reported the early adoption of OLED and Plastic electronics was through technology integrators such as Sony (engadget.com) and, only in prototype volumes and in certain applications where fashion rather than functionality in ruggedized applications gave the public visibility of the products. Where product lifetimes and environmental stability are major considerations for military or aerospace significantly more work is needed on organic semiconductors to enter this market. The commercial exploitation is growing rapidly although not at the pace many experts predicted because the technology is expensive to manufacture particularly in large formats and outdoors.

5. The complexity of equipment and degree of sales and services needed to support plastic electronics in manufacturing on a global scale requires an infrastructure to be put in place which can only be achieved through partnerships and alliances with other companies that form a strategic supply chain. These relationships would be easier to access through government sponsored trade missions on a company to company basis which is specific to individual UK OEM's and products they make. Using Knowledge Transfer Networks, subsidies to assess the international market for the supply of equipment would ensure the UK is part of the global supply chain.

6. The UK has been a market leader for manufacturing tooling such as plant equipment, plastic moulding, laser processing, inkjet, mechanical drilling and so on for Europe and Asia markets and this needs to continue. After academic ideas become commercially viable a significant amount of work thereafter relies on development processes and process equipment to meet market expectation and supply demands for commercially successful products. Industrial engineering solutions are generally in response to market needs and then commercially driven at risk where equipment development is involved often using private venture (PV) money unless the activity can qualify for grant support.

7. Although the UK no longer manufactures microelectronics we still design electronics and make manufacturing equipment of the highest standards for sale into Asia and low labour cost markets. UK businesses and entrepreneurs working in this field need the support of government to sponsor work between

company to company collaboration, and provided eligibility criteria are met good design projects should qualify for a sponsored grant. Support should be made available to industry where there exists a mutual collaborative commercial drive for advanced tools and equipment. Financial support from government would reduce PV risk capital and enable a greater facility for engineering companies to transition the risk on new ideas and Intellectual Property IP with practical applications.

8. Historically, OLED and plastic electronics developers have had little choice and looked toward importing or licensing with overseas companies such as Litrex, Microfab, Fuji or Epsom as preferred suppliers to the process. Looking forward this could be retained within the UK where large organisations such as PETeC who are also gearing up for pilot production lines should consider retaining more UK businesses as part of the supply chain knowing it is secured by public investment.

March 2008

Memorandum 136

Submission from Polymer Vision

Specific relevant information

To ensure that Polymer Vision (PVL) will maintain control and focus over the manufacture of the company's unique plastic electronics display, and prevent loss of the technology leadership to others in for example Asia, PVL decided that the first generation displays must be produced locally in Europe.

So in 2007 PVL acquired Innos Ltd in Southampton, UK and since then has invested in the facility to prepare for display production in 2008.

Headcount has increased from 25 to 40, will further double to 80 before the end of 2008 and double again in 2009.

Concerns & Risks

With the current manufacturing technology used there, the Southampton facility will not be a cost competitive operation within just two to three years. To become cost competitive at larger volumes, PVL must establish greater production capacity based on a newly developed cost-effective manufacturing flow. The preference is to do this in the UK by expanding in Southampton. If investment to do so cannot be secured then PVL will be forced to look abroad to investment in the required cost-effective manufacturing. The future of the Southampton facility will then be in danger.

Recommendation

Investment by UK government in PVL to finance the development of a "plate based" manufacturing flow (as opposed to current "wafer based") and the expansion of the Southampton facility with plate based production capacity. This would allow PVL to keep the current and future display generations in production in the UK.

June 2008

Memorandum 137

Submission from High Force Research Limited

PLASTIC AND PRINTABLE ELECTRONICS
BUSINESS OPPORTUNITIES FOR THE CHEMICAL AND PHARMACEUTICAL SECTOR

Introduction

High Force Research Ltd is a chemical research and development company that was established 20 years ago in Durham. The business has developed primarily as an R & D service company specialising in the synthesis, manufacture and process development of novel organic chemical compounds.

The major market for this type of service has been with the Pharmaceutical and Biotech companies and they have had a growing requirement for the synthesis of small quantities (grams to multi kilograms) of novel intermediate chemical compounds for use as potential new pharmaceutical products.

The traditional medium sized UK chemical manufacturers have been unable to compete in the bulk commodity chemical market due to intense price competition from the Asian bulk chemical manufacturers. However, the smaller, more research focused companies such as HFR, have grown while the traditional UK bulk chemical companies have contracted over the last decade.

Plastic Electronics

Plastic or Printed electronics is a rapidly growing global industry having an estimated current value of \$1b and it is estimated to grow to \$30b by 2015 (1). It encompasses an emerging set of technologies that enable electronic components, eg circuits, transistors and displays to be made using conventional printing techniques with electronic "inks" being coated onto flexible substrates such as paper and plastic. These electronic "inks" will contain novel semiconducting organic molecules. Printed electronics should be seen as complementary to conventional silicon electronics.

An example of a large scale use of organic chemical compounds in display devices are the Liquid Crystal formulations used in LCD TVs. The UK has a long history in developing these materials although the manufacture is now largely done elsewhere in Europe.

The materials used for plastic electronics are in the main organic molecules of varying complexity and structure. The technology skills, expertise and equipment that are needed to produce and analyse pharmaceutical compounds are exactly those required for the manufacture of materials that will be used in plastic electronic devices. Therefore, companies having similar skills to HFR should be well placed to participate in the development and manufacture of such materials.

A key requirement for organic materials that will be used in electronic applications is that they should be able to be made to very high purity and with high batch to batch reproducibility, thereby enabling the highest chance for OEMs to produce stable electronic devices.

A great deal of research and development is still needed to identify the best materials for these new electronic applications. Once novel materials have been identified as potentially useful components in this new technology area then their manufacture will be required. In general terms, these organic molecules are likely to be very high value materials where production volumes are likely to be significantly lower than conventional bulk chemical compounds and so offer potentially high revenue for companies that develop and manufacture such materials.

However the synthesis of the organic materials is only the first step in producing useful electronic devices. The organic materials will then need to be formulated into printable inks and made into prototype devices. This requires a completely different skills set, expertise and equipment from those used in the manufacture of the molecules themselves. A multi-disciplinary approach is needed to enable new electronic devices to be developed.

Collaboration with organisations such as PETEC will be required in this respect as they have an excellent overview of the plastic electronics technology area, coupled with a good network into key organisations and a good route to market. They are a valuable resource for all companies and academic institutions that wish to enter this new market area. Further, they can advise and collaborate with partner companies having complementary skills which may lead to new and innovative products being developed.

Challenges for Chemical and Pharmaceutical Companies in the Area of Plastic Electronics

Apart from the technical challenges that arise with synthesising new organic compounds, the initial challenge is in identifying the types of molecules that may be useful in these new applications.

This is not dissimilar to the challenge of developing new pharmaceutical compounds and new targets are identified by a multi disciplinary collaboration between clinicians, biochemists and medicinal chemists.

In this respect a multi disciplinary approach is needed for developing new materials and devices for the electronics industry, combining the competencies of synthetic chemists, formulators, physicists and manufacturing engineers.

Again, an organisation such as PETEC can align companies and academics with complimentary expertise in the areas needed to develop novel new materials and technologies and help guide such groups towards a common goal.

In conclusion, the area of Plastic and Printable electronics offers the opportunity of a new, high value growth area for UK companies to exploit. The skills and expertise exist within the UK to make major advances in this sector as has already been demonstrated with liquid crystal technology. Encouragement of UK companies to participate in this area of research and development could help to generate a new, vibrant manufacturing sector in the UK.

October 2008

Memorandum 138

Submission from Merck

Merck

Merck is a global pharmaceutical and chemical enterprise with approximately 32,000 employees in around 60 countries (as of June 30 2008).

Since going public in 1995, Merck's operating activities are under the umbrella of Merck KGaA. Today, around 30% of the company's total capital is publicly traded, while the Merck family owns an interest of about 70% via the general partner E. Merck OHG.

With the acquisition of Serono, Merck became one of the world's leading biotech companies.

Total revenues in 2007 amounted to €7.1 billion, adjusted for the disposal of Generics. Profit after tax reached a record €3.5 billion as a result of the disposal.

Merck is the world's oldest pharmaceutical and chemical company, with roots dating back to 1668. From the start of industrial production in 1827 to first research on liquid crystals more than 100 years ago up to our entry into targeted cancer therapy with the launch of Erbitux® in 2003, many milestones provide strong evidence of the pioneering spirit of the people at Merck.

Pharmaceuticals Business Sector

Merck discovers, develops, manufactures and markets innovative prescription drugs as well as over-the-counter products.

Merck develop therapies for high unmet medical needs. Through their targeted effect, these help patients to live a longer and better life. Our over-the-counter products can prevent disease and relieve minor complaints.

Chemicals Business Sector

Merck offers a very wide range of specialty chemicals for technologically sophisticated applications. Many of these are contained in products that people encounter in everyday life, such as mobile phones, televisions, automotive coatings and cosmetics. Top quality, diversity and a customer-centric approach to research and product development characterize the Chemicals business.

Liquid Crystals

Close cooperation in development and production of liquid crystals (LC) with the world's leading display manufacturers has made Merck the number one company worldwide. All over the world, liquid crystals from Merck are found inside most LCD televisions, computer monitors, notebooks, digital cameras, mobile phones, PDAs and MP3 players. In order to meet the growing demand, Merck is investing in research for customized LC mixtures and OLEDs (organic light-emitting diodes).

Organic Electronics

Following the success model of liquid crystals, Merck is developing future businesses for the liquid crystal division. Among others, Merck's research and development centre in Southampton, which is a part of Merck Chemicals Limited, is dedicated to future materials business in the field of optics and electronics. One key area is the emerging technology of organic electronics, where the operations in Southampton focus on the development of materials for organic photovoltaics and organic transistors for flexible displays.

Merck's Southampton site is profiting from a vivid UK university network, which can be considered as one of the leading countries academic framework in Europe in organic electronics.

A number of key players in the field did emerge from UK, like the company Plastic Logic, being spun off from Cambridge University and now in preparation to manufacture flexible displays in Dresden, Germany.

The overall potential of organic electronics is still to be explored and developed. One of the challenges will be to merge existing competencies of microelectronics, the classical printing industry, organic chemistry and other fields, which in established industries do not interact on a regular basis.

This might require flexible and open-minded engineers, which could be fostered in highly interdisciplinary education and training programs already. This could be driven both by university but also by on-the-job programs.

From a value generation point of view, UK currently appears to play a more active role in generating intellectual property and services, than in seriously preparing for manufacturing or assembly of final products.

With major display companies already established in Asia for decades, it might require massive political efforts to create a favourable manufacturing environment for organic electronics products in UK. Major interest of established manufacturing companies in UK is currently not visible in UK but also not too pronounced in the EU in general. The main driving forces in first manufacturing moves appear rather to be small companies from a start-up environment. Bigger companies involved in the field are chemicals companies like Merck and other big chemicals players in Europe and Asia.

It might be worth considering how established engineering and manufacturing enterprises could be attracted further to the exciting area of organic electronics, for example by shared risk programs supported by public programs.

From a general society point of view, the overall industry could be supported from the Government to prepare general acceptance of the field but also to avoid adverse reactions and to create awareness and understanding, which is key for new technologies. The ecological aspect of the technology, especially of organic photovoltaics is to our knowledge currently almost not present at all in public discussions in the UK.

October 2003

Memorandum 139

Supplementary evidence from the Department for Innovation, Universities and Skills following the evidence session with Lord Drayson and Lord Carter on 3 November 2008

ENGINEERING INQUIRY—PLASTIC ELECTRONICS CASE STUDY

Value Chain Analysis for the Plastic Electronics Sector

A mapping of UK capability and the supply chain for Plastic Electronics has already been conducted, highlights of which have been published in the BERR/UKTI publication "Plastic Electronics in the UK—A guide to UK capability" (URN 08/668—http://www.berr.gov.uk/files/file45988.pdf). Also Dr Zella King of Reading University, with funding from the Economic and Social Research Council, has conducted a detailed independent analysis of plastic electronics in the UK (see http://www.printedelectronics.net/ for details).

The technology and markets for products incorporating plastic electronic technologies are however at an early, but critical stage of their development, and the value chain and margin balance across the supply chain will continue to evolve, including as a function of the final product under consideration (eg Displays vs. RFID). In its current state with no major products on the market, no robust assessments can therefore be made of the emerging value chain for plastic electronics. As such, the Technology Strategy Board will continue to work closely with other funding partners and Government Departments, including BERR and DIUS, to help develop the UK's embryonic plastic electronics community and review the need to conduct further detailed value chain analysis as products and markets mature.

The Committee may also wish to note that the Technology Strategy Board has allocated £3 million to work in the Value Systems area under its recently announced High Value Manufacturing research competition. This recognises that most manufacturing companies operate in an international environment and the research funding will support work into how UK companies can best configure their activities to extract the most value both for themselves and for the UK more generally.

Examples of UK SME Growth through Government Procurement

Promethean, headquartered in Blackburn and now a global leader in interactive learning technology, has benefited from UK Government procurement.

The Committee may also wish to note that current work underway to ensure that UK based businesses are better able to benefit from the demand for new innovative products and services driven by UK Government procurement includes: a reformed SBRI, pilots of which are currently underway involving MoD and DoH; and DIUS inviting expressions of interest from procurement and policy professionals in the public sector who would like to develop flagship Forward Commitment Procurement (FCP) projects and make a real contribution to sustainability. The winners of the competition will receive the resources and know-how to implement an "Innovation for Sustainability" FCP project and develop in-house FCP capability.

November 2008

Oral evidence

Taken before the Innovation, Universities, Science and Skills Committee

on Monday 10 November 2008

Members present

Mr Phil Willis, in the Chair

Dr Ian Gibson
Dr Evan Harris
Dr Brian Iddon
Mr Gordon Marsden
Ian Stewart

Witnesses: **Professor Brian Launder**, University of Manchester, **Dr Dan Lunt**, University of Bristol, and **Dr David Santillo**, Greenpeace, gave evidence.

Q1 Chairman: Good afternoon. It is very nice to see you. Could I welcome our first panel of witnesses to this, the geo-engineering case study within the Innovation, Universities, Science and Skills Select Committee's investigation into geo-engineering, and to thank very much indeed, Dr Dan Lunt of the University of Bristol for joining us. Welcome to the Committee. And Professor Brian Launder from the University of Manchester, welcome to you, Brian, I hope you enjoy your experience with us. We have an empty chair for Dr David Santillo who is geo-engineering the Tube at the moment to try and make sure that it arrives on time! When he arrives he will join us on the platform. I wonder if I could start with you, Professor Launder. Could you tell the Committee, as briefly as you can, what is your understanding of geo-engineering? What is it?
Professor Launder: Geo-engineering is the beneficial intervention in order on a global scale to change the climate in directions that we wish in the context of severe global heating with which we are threatened. It amounts to looking at schemes that will either provide a shade against incoming solar radiation or ways of withdrawing carbon dioxide from the atmosphere.

Q2 Chairman: It is not sensible, is it, Dr Lunt? It is not a serious suggestion, is it?
Dr Lunt: It has certainly been suggested seriously within the scientific literature and also it is out there in the public conscience. There have been some articles in the popular press and the scientific press as well. It is certainly out there and is certainly being considered seriously within the scientific community.

Q3 Chairman: In terms of the scientific community, and we on this Committee take the science community very seriously most of the time, where is the consensus within the scientific community on geo-engineering?
Professor Launder: I would say that of those who have looked at the issue 90% believe that we are in dire straits and the only way of escaping is to give time to move towards a genuinely almost carbon-free lifestyle globally, we must have a period two or three decades at least, but perhaps indefinitely, where we rely on the types of intervention that I have hinted at in order to give time.

Q4 Chairman: Are you actually saying that this is a technology, or a group of technologies, which will seriously buy us sufficient time in order for us to have the long-term solutions to the amount of carbon we are putting into our planet?
Professor Launder: They have the potential. Sceptics could say, "Well, this hasn't been tested" or "That hasn't been tested". What is very urgently needed now is to properly evaluate, to spend enough time developing schemes from the drawing board to at least an operational scale where their effectiveness can be evaluated so that one may discern barely workable schemes from those that really do work.

Q5 Chairman: Dr Lunt, do you buy into this, that this is a holding technology with the potential to be a long-term solution?
Dr Lunt: I guess this has to be a personal viewpoint really. For me, I would be very worried about seeing this as a long-term indefinite solution. Any sort of geo-engineering that is carried out should also be carried out at the same time as a concerted effort to reduce emissions, a move to more energy efficient lifestyles, new technologies, so that we do not have to rely on it indefinitely because there are certainly worries about some technology that you have to rely on indefinitely because of the problems of it failing or becoming too expensive. If we do aim for it, we should certainly aim for something that is temporary.

Q6 Dr Gibson: This is not scientists just making up the terminology to be unique and set up their own little enclave of conferences and so on? There have been examples of this in the past. Is it a serious concept that came out of conferences at the beginning or is it just a dream in somebody's head?
Dr Lunt: I do not know of any conferences that have been solely about geo-engineering, but certainly within the very major conferences in the geo-sciences, for example the AGU, which is the big American geo-science conference, and the EGU, which is the European one, for the last few years

there have been dedicated sessions to geo-engineering and there has been a relatively large number of submissions. It is not just a thing that people discuss on internet news groups, it is actually out there in conferences, yes.
Professor Launder: The first scientific papers on what we have started to call geo-engineering emerged in the 1970s. By the beginning of this century there was a very well-developed feeling amongst a group of scientists that we would need to move towards that. In 2004 the Isaac Newton Institute in Cambridge held a two-day event on the topic and more recently there have been expert group meetings in Harvard. It is by no means a fanciful group of scientists looking for some easy way to get money.

Q7 Dr Gibson: Some of the effects of geo-engineering ideas may be irreversible, is that so?
Professor Launder: In the short-term if, for example, we simply cut down the incident sunlight by 2 or 3% in order to cool the planet but do nothing about the level of CO_2 in the atmosphere that will increase the acidification of the oceans and those effects will be irreversible, yes.

Q8 Dr Gibson: Who are your big competitors in this field in terms of the way forward? Are you in the Coca-Cola Championship or are you in the Premier Division as against the other technologies? Give us a picture of it because we do not know where you sit as against other mitigating technologies.
Professor Launder: Personally, I would be delighted, and I think this probably goes for the majority of the experts you will be talking to, if somehow someone had a magic bullet that would discover how to make fusion work and we could use that for all of our power. I just do not see it happening fast enough.

Q9 Dr Gibson: The man on the Tube will speak for himself when he arrives, but how do you see the criticisms that Greenpeace have levelled at the issue in terms of morality, ethics and so on? You must have had this levelled at you many times, I am sure.
Professor Launder: I do not think I can answer that simply because I have not acquainted myself sufficiently. I just keep my head down like any eager-beaver scientist.

Q10 Dr Gibson: Does that mean that you do not care about the morality?
Professor Launder: Not at all.

Q11 Dr Gibson: You are opening up that point.
Professor Launder: Let me say more than anything else what alerts me is when I look across the Sunday lunch table and see my two granddaughters who are five years-old and think what will they inherit in 25/30 years' time.

Q12 Dr Gibson: Dan, what do you think about this area of morality and ethics?
Dr Lunt: I am not completely aware about the Greenpeace arguments, but my understanding from what I think David would say if he was here is if we go down this route of geo-engineering then there is the danger that in the public mind if there is a solution out there then they do not need to be energy efficient, reduce their energy use or whatever. Personally, I do have some sympathy with that, it is a fair argument, but it is very difficult to test whether that would be the case or not. These geo-engineering ideas are out there already and certainly a proportion of the public are aware of them. My impression from talking to friends is it is not affecting their decisions about energy use at the moment. In terms of the ethics and morality, it is a case of is it the lesser of two evils? The idea of geo-engineering per se to me is pretty grotesque really in some ways, but if it is the lesser of two evils then maybe that is the route we have to go down.

Q13 Dr Gibson: Where do you chaps get your funding from?
Dr Lunt: I have not been in the field of geo-engineering very long at all so I would not call myself a complete expert. The one study that we have done and carried out at Bristol that I led just arose out of a chat over coffee. I think it was an article in the *New Scientist* or something talking about geo-engineering and we thought that was something we could try and we did it in our spare time using free computer time on the university machines. No funding.

Q14 Dr Gibson: What did you work on before?
Dr Lunt: The geo-engineering stuff was and still is completely in my own time, if you like. My actual speciality is I am a paleoclimate modeller, a past climate modeller and future climate modeller.

Q15 Dr Gibson: You must get funded, Professor Launder?
Professor Launder: My field of research, I hasten to say, is not in geo-engineering. I will not bore you with how I got involved.

Q16 Dr Gibson: How did you get your chair?
Professor Launder: I am a mechanical engineer. Gosh, I have forgotten what I was going to say.

Q17 Dr Gibson: So what got you into this geo-engineering stuff? What was the light that suddenly shone? You said your granddaughters, but it does not happen just like that.
Professor Launder: Besides that, there was a geo-engineering conference held in Cambridge in 2004 and I went along to that and was persuaded that it was very important.
Dr Gibson: Has Prince Charles found out about this yet? He has not pronounced on this yet, but I bet he will.

Q18 Chairman: Before we get on to Prince Charles, you mentioned earlier about the issue of scaling up, Professor Launder, and so far there have been a number of laboratory experiments, and we have obviously got evidence about some of those, which seem to be incredibly interesting.

Professor Launder: Laboratory and field trials.

Q19 Chairman: If I can be frank with you, a few years ago this Committee did a piece of work on carbon sequestration long before that became a popular move, and we were looking forward to one large scale demonstrator plant at Peterhead, which never came off. That was a proven technology which we knew could be scaled up. Scaling up geo-engineering on a global scale seems to be the most incredulous challenge and yet you feel it is possible.
Professor Launder: Yes, I do, but on the point you raised there is still a huge gap between the PhD type of research that Dr Gibson was mentioning and actually putting it into practice. There is an awful lot of development and detailed design activity.

Q20 Chairman: But we have not time, have we, if what you are saying and, indeed, what I think Greenpeace would accept, is the current scientific consensus?
Professor Launder: We have not time not to, Chairman.

Q21 Chairman: That is a very good point. You think there is time to do this developmental work to get large-scale demonstrators up and running so that this is a serious technology which could be deployed?
Professor Launder: Indeed. I mentioned in my submission the Carbon Trust as a source of support for that. The Carbon Trust currently seems to be focused on carbon-free power generation. I think a proportion of its budget should be earmarked for the type of geo-engineering activities that we are discussing.
Chairman: We will come on to funding in a minute because I think that was behind Dr Gibson's comment, that you are not getting any funding, this is your own interest at the moment.

Q22 Ian Stewart: Good afternoon, both of you. Brian, the Chairman pressed you a little bit about scaling up and buying time. Will there come a point where buying time is no longer possible?
Professor Launder: This is a personal view. My feeling is that one can only rely on this to buy time if we are looking at decadal timescales of a few decades. If we continue to accumulate carbon dioxide in our atmosphere faster than we can take it out or it diffuses out into the sea or vegetation then we have the most gloomy prospects for the planet. I think some of the people you will be speaking to have a somewhat different view, but personally I would see geo-engineering as something that we might do for three decades, at most five, and we must ultimately get a way of living, perhaps a much reduced population on the globe, powered by nuclear fusion and direct solar power. We will have to look at routes like that.

Q23 Ian Stewart: Do you agree with that, Dan? Also, how do we guard against some of this stuff becoming almost like a global climate insurance policy?
Dr Lunt: First of all, I do agree that it is of the order of decades probably that we are looking at if we do want to use geo-engineering, it is probably along those timescales. In some ways what is necessarily wrong with having an insurance policy, a back-up, in case? At the moment geo-engineering is in a situation where it could not be used tomorrow, we could not turn it on tomorrow, there needs to be some sort of spin-up in terms of research and development before it could be used, but if that research and development does happen it does not necessarily mean that it has to be used at the end of that if it is deemed not necessary at the time. To have it as an insurance policy is maybe not a bad thing.

Q24 Ian Stewart: Do you agree with that as well, Brian?
Professor Launder: Indeed, yes.

Q25 Ian Stewart: The public money that is going to be spent on known mitigation technologies, would we not be better spending the money on the existing known technologies rather than risk it being put into supporting geo-engineering? In any case, has anybody got any idea of how much the geo-engineering stuff might cost?
Professor Launder: I am sure some of the speakers you will be coming to a bit later on for the particular technologies they are advocating will be able to give pretty precise sums for costs. When I say "pretty precise", within an order of magnitude.

Q26 Ian Stewart: A guestimate.
Professor Launder: I do not think I should trespass on areas where they are—

Q27 Ian Stewart: Is it a good use of money then?
Professor Launder: Is it a good use of money? Undoubtedly, I believe it is.

Q28 Ian Stewart: Why?
Professor Launder: Because if the climate gets out of control all of the other ways of spending the money are worthless.

Q29 Ian Stewart: You believe it is that big, do you?
Professor Launder: I believe it is that big, yes.

Q30 Dr Harris: In some other technologies, controversial ones, they are often defended on the basis that there will be spin-out effects that will be beneficial even if the ultimate aim does not come to fruition and, secondly, the research and development, even short of implementation, will create jobs. Is this a job intensive field in the development even if it is never implemented? Can you argue that you are going to invent something and produce products useful out of it even if you do not get the ultimate end product?
Professor Launder: I am sure there will be beneficial spin-offs. I think we are too near the beginning in our attempt to get towards a point where we implement it to be able to see many of them. One as an example: for deploying cloud brightening techniques, Stephen Salter has developed a lot of interest in Flettner

vessels, vessels that are powered by spinning cylinders. I am sure his work on that will stimulate a lot of interest in reverting—I say reverting because at the end of the 1920s such a vessel crossed the Atlantic—to a means of providing much cheaper power than normal ship propulsion.

Q31 Dr Harris: Professor Lunt, do you know of ay collateral benefits?
Dr Lunt: Apart from the one that Brian has mentioned I cannot really think of any. I guess the only thing that would come into my head is if maybe there was a natural climate disaster, something that meant temperatures raised, maybe some of these technologies could be used in that instance.

Q32 Dr Harris: So it is different from fusion because fusion is creating a lot of useful stuff anyway, albeit we are still some way away from practical use, but it is different, it is more of a binary decision. You are going to work on this in order to implement it really.
Dr Lunt: I think that would be the primary driver, yes.

Q33 Chairman: Can I just welcome Dr David Santillo. We are sorry you have had trouble getting here.
Dr Santillo: My apologies.
Chairman: Not at all. You have come in at an interesting time. I am going to ask Dr Gibson to return to one of his earlier questions on the moral maze in just a minute, but we will go back to Ian Stewart and follow his line of argument.

Q34 Ian Stewart: Hello, David. Basically, the drift of the questions I have asked is, is geo-engineering necessary? If it is necessary, is it only going to buy us time for a set period? Even if it buys us time for a set period, is it a good use of public money, and has anybody got any idea how much it is going to cost? Take your pick!
Dr Santillo: Or all four perhaps! The fact we are having this discussion as to whether it is necessary or not is a measure of the fact that we have done too little so far to address the problems at source. I would really caution against seeing this as being an option that has yet to be developed because we are at the stage where we have very little concept as to whether a lot of these geo-engineering techniques will actually contribute to mitigating climate change. There are circumstances in which they could actually exacerbate problems. It is vital that however research is carried forward in any of these fields, it is not a barrier to, a distraction from, dealing with the real problem. I have not had the benefit of being at the first part of this discussion and those points may well have been taken up and discussed. Those sorts of fundamentals are important before you even begin to consider what some of these things may cost. If we have very little evidence that they are actually going to do anything beneficial in the first place, that is the first point to try to address.

Q35 Ian Stewart: Let me ask you a final point. One of the definitions that we have had about this issue, what is geo-engineering, runs like this: global action intended to mitigate climate change. Do you agree with that?
Dr Santillo: That seems a very general definition.

Q36 Ian Stewart: The question that arises from it is if an action is not global, is it not worth doing?
Dr Santillo: No, not at all. A lot of the actions that we can and should be taking to address climate change are not in themselves global actions, they may be very local or regional actions to address the problem. In fact, they have to be if we are going to tackle emissions at source. To have a general definition of geo-engineering simply as being global action to address climate change, from my understanding geo-engineering is more those types of activities which attempt to manipulate planetary systems and to exert their global influence in that way. There is perhaps a need for a more specific definition of what is meant by geo-engineering.

Q37 Dr Gibson: Nice to see you. I do not know what Tube it was, do tell us.
Dr Santillo: It was Great Western Trains that held us up, I am afraid.

Q38 Dr Harris: We call that a predictable phenomenon.
Dr Santillo: Indeed.

Q39 Dr Gibson: David, you have brought the phrase "moral hazard" into this on the grounds that all the speculation may lead eventually to worsening the whole thing. Can you explain that in a little more detail? What is the moral hazard?
Dr Santillo: The concern that we have is that while a lot of the discussions that are taking place are now précised by the acknowledgement that geo-engineering should not be a distraction from tackling emissions and energy efficiency, the fear we have is that inevitably it will be a distraction. At the moment there seems to be a proliferation of different discussions, projects, bodies discussing this particular issue, and we are concerned that the promise of something in the future, however speculative it may be, however unproven it may even be in terms of its effectiveness, may seem to give some kind of hope that, in fact, we can tackle climate change without tackling the real problems of emissions and greenhouse gases at source. In the public's mind there is a danger perhaps that people will favour what they see to be a solution which does not involve them changing their way of life, does not involve them having to make difficult choices, if they can simply contribute to a scheme which somehow very distant from them will engineer the climate back to its normal state.

Q40 Dr Gibson: Is this the technological fix argument?
Dr Santillo: That is right. That is the danger, that however much we wish that it will not be a distraction inevitably it will be.

Q41 Dr Gibson: How do you make the decision which technologies are worth proceeding with? I know you do not believe in GM particularly, but stem cells you might. How do you make these decisions about the morality and involvement which should allow it to go ahead or not? Is there a cut-off point?
Dr Santillo: The approach that I have suggested in my evidence to this Committee is perhaps something that could be pursued for geo-engineering in general. Just a couple of weeks ago the London Convention, which is the convention which prevents pollution from the dumping of materials in the oceans and, therefore, has an interest in ocean fertilisation schemes, came to a resolution that there had to be a way of permitting what it called "legitimate scientific research" to continue while at this point closing off any more practical applications of geo-engineering. In that case, that was specific to attempts to fertilise the oceans but it could equally well apply to attempts to manipulate atmospheric conditions or other technologies that are included under geo-engineering. The elegance of it is that it does not say no to new scientific studies, it simply says that there should be a consistent and precautionary set of rules that need to be applied by all countries in order to determine what is legitimate scientific research into these techniques and what is not. A very key part of that has to be a consideration of the commercial involvement because if there is an element of commercial interest in those experiments having a particular outcome, I think that would counter that legitimacy in terms of research.

Q42 Dr Gibson: I suppose you have thought for a long time about these problems, always worried that in the developing countries they are going to get the brunt of it and yet they need to expand their economies and so on. How do you relate your moral dilemma to that?
Dr Santillo: I think there is a danger also that for the more time that we in the richer nations look to geo-engineering solutions, the less time we are putting to exporting the good technologies and the more sustainable technologies.

Q43 Dr Gibson: Such as?
Dr Santillo: Such as renewable energy, integrated transport solutions, measures to improve efficiency of energy units. All of these things the developing world is crying out for and if we take our eye off the ball and look to future speculative solutions there is a danger that we will take our eye off the ball from that as well.

Q44 Dr Iddon: Mathematical modelling is getting exceptionally better but it is still subject to the innumerable variables that you have to put in to get into predictive mode. Where climate change is concerned we know so little about certain of the variables that you need to plug in. For example, very little is known about the behaviour of the sea, which is a huge player in climate change, we all accept that. How sophisticated would modelling have to be to predict the effects of geo-engineering? Have we got to that stage at the moment?
Dr Lunt: We are at that stage. A number studies have been carried out in a mathematical modelling framework that have looked at this problem. In terms of are the models suitable?, the models that can be used to predict the outcome of some of these geo-engineering schemes are exactly the same models that are used to predict unmitigated climate change. The predictions by the Intergovernmental Panel on Climate Change are carried out by the same models. I would argue that these models are at a stage where they can be used in predictive mode. These models do a very good job of predicting, for example, the climate change that we have seen over the last hundred years. If you compare these model estimate of climate change from 1900–2000, they are actually very good and agree very well with the observations. I would argue that they are in a good state for being used for this purpose to look at the geo-engineering problem.

Q45 Dr Iddon: What I am saying is that I do not believe that the modelling that places like the Hadley Centre are doing at the moment are sophisticated enough to predict even climate change, although they are getting there but there are still lots of variables that I think they do not understand that need plugging into their systems. How on earth can you use something at that stage to predict something beyond predicting climate change?
Dr Lunt: To make a prediction about a geo-engineered world you do not have to change your model very much at all. Your mathematical model will be exactly the same as the one that is used to predict just normal future climate change.

Q46 Chairman: I think the point Colin is making is that that is imperfect.
Dr Lunt: Yes, it is certainly imperfect. The question is how good is good? How good do you need your model to be before you start interpreting the results? All I can say is that it does a good job compared to the observational record that we have had so far. There cannot really be any other test. We can go further back in time and look at how well these models predict, for example, the last ice-age and again they do a good job, but how good is good? How good do you want your model to be? The general consensus among the climate community is that the models are obviously getting better and they are including more and more parts of the earth's system. At the moment there is a lot of work going into putting a representation of Greenland and Antarctic ice-sheets within these models and a more complete representation of vegetation. We are getting to the point where we have earth system models now that represent every part of the earth's system. I think these models are of sufficient quality, they do a good job compared to observations and they could be used for this task.

Q47 Dr Iddon: One of the ideas is to put mirrors into space to reflect the sunlight. Do we know how many mirrors we would have to put up there and the extent of the coverage of those mirrors in terms of reflection to lower the earth's temperature by just one degree?
Dr Lunt: There is one study of which I am aware that looked into the engineering aspects of mirrors in space and the idea was a number of discs, each about 60cm in diameter, and there would be several trillions of these up in space placed in orbit between the earth and the sun about five times further out than where the moon is.

Q48 Dr Iddon: That is a huge cost. Can I put it to you that if I was making mirrors I would put them in the Sahara Desert and I would generate steam in the way that can already be done. There has been a development project that, so why bother to go to all the cost of putting the mirrors up there when we can generate our power down here without using fossil fuels.
Dr Lunt: I agree with you. Of all the geo-engineering solutions that have been proposed, I am sure it is not the most cost efficient. The person who did the study estimated the cost—it was quite a broad number he came up with—to be several trillion dollars which, according to some estimates, is not much more than the Iraq war.

Q49 Dr Iddon: We have to develop Africa yet. We cannot even feed the people in Africa. Let's put the geo-engineering ideas into some kind of priority. If you say that is not a priority, what is a priority in terms of geo-engineering?
Dr Lunt: If you were definitely going to go down the line of geo-engineering, if that had already been decided—a real costs benefit analysis has not been carried out yet so that is one thing that I think would have to be done first and I do not actually know what the answer is—some of the solutions that Stephen Salter has been suggesting about sea spray and cloud condensation might be more economically feasible. If that costs benefit analysis was carried out it should also be carried out in the framework of looking at other solutions to climate change and mitigation and adaptation, because to do geo-engineering on its own does not make any sense; it needs to be compared to other solutions.

Q50 Dr Iddon: You are interested in sunshades. Could you guide us through as to how you believe that sunshades would work?
Dr Lunt: We did one study on sunshades. I would not say that means that I necessarily advocate them, but in terms of how they would work, they would reduce the incoming radiation from the sun. We found that you could reduce the amount of solar radiation to offset a four times increase in carbon dioxide in the atmosphere. You would probably try and match the global average temperature to be what it was maybe in pre-industrial times. One of the things that we found, and Ken Caldeira found before us, was that you do not retrieve exactly this pre-industrial climate that you are searching for. You might get the global average correct, but what you find is that there were residuals in that the Arctic would be warmer than in pre-industrial times whereas the tropics would be colder.

Q51 Dr Iddon: What are these sunshades physically?
Dr Lunt: In this proposal they were thin discs 60cm in diameter made of some sort of silicon-based product, I expect. I am not sure about the engineering details.

Q52 Dr Iddon: If things went wrong could we retrieve them?
Dr Lunt: I do not know the answer to that question.

Q53 Mr Marsden: Professor Launder, your colleague, Dr Lunt, has just referred to the Iraq war and so perhaps I can be forgiven for referring to one of its architects, Donald Rumsfeld, who said that there were known unknowns and unknown unknowns. I would like your view as to which of those two categories geo-engineering fits into? We talked about how new geo-engineering is as a science. Is it a known unknown or is it an unknown unknown? Is it something that is completely off the wall or something that there are basic principles that we can understand?
Professor Launder: There are many basic principles that are known and there are many unknowns in the whole science. The previous questions related to how good is the theory. You may have looked at predictions of the way global temperatures will increase and from the present they fan out. There are many different models giving somewhat different results but they all go in one direction. The urgency is not entirely established. [1]

Q54 Mr Marsden: It has been reported in a small scale that countries like China, even as recently as the Olympics, and the Soviet Union have experimented with all things that will actually change the climate temporarily. Do we know if there are any national governments that are currently pursuing an active programme of geo-engineering research?
Professor Launder: In the free world research sponsorship is done by agencies which are not closely tied to governments and certainly there are such projects in the US, the UK and elsewhere.

Q55 Mr Marsden: What about those countries which are not subject to the same sort of vigour and democratic scrutiny, like Russia and China? Surely they are going to be as affected by the issues of global warming as anybody else?

[1] *Note from the witness:* "You may have looked at predictions of the way global temperatures increase with time: the temperatures predicted from the present into the future by different computer models fan out. There are many different models giving somewhat different results, but they all go in one direction: upwards. Because of the differences in the rate of increase of temperature given by different models, however, the degree of urgency is not entirely established."

Professor Launder: Indeed, yes. I know that China is doing a lot of work on essentially trying to de-carbonise its society. It is investing a lot of money there but I do not know what it is doing in the area of geo-engineering.

Q56 Mr Marsden: Dr Lunt, our own government, both DIUS and Defra, have indicated in their submissions to us that geo-engineering technologies may play a role in future efforts. Are you aware of that being anything more than just a pious hope, or is anything going on in government that might give you and your colleagues some comfort?
Dr Lunt: I am not aware of any major projects that are planned in terms of geo-engineering. I noticed in one of the written submissions from the Research Council of the UK that one of the things they are considering, it said, was a geo-engineering IDEAS factory, but I do not know any more than having seen that.

Q57 Mr Marsden: I ask that question because the history science is, so far as I can see, never just a question of top down, and it is certainly never just a question of bottom up; it is a question of the interrelationship between those two things. Is it not the case that if you expect to get your ideas seriously on the public agenda that those people who are in support of geo-engineering research have got to put their head above the parapet a little more and have got to get things out more into the public arena and get a major debate going? Professor Launder, is there any evidence that you have got the critical mass to do that?
Professor Launder: I would say that the critical mass has been reached. The fact that this Committee is inquiring into it is some signal. The Royal Society took upon itself to publish a special issue of the philosophical transactions devoted to this subject. The Royal Society is currently developing independently of that a position on geo-engineering. I believe that it will be producing a paper next year on this.

Q58 Mr Marsden: How are people in this area communicating all of this with policy-makers? We had Professor John Beddington before us recently. What are you doing to get the ear of people like him in government?
Professor Launder: I have to say that I do not know.

Q59 Mr Marsden: You are coming along here today saying that this is in its infancy but we have some interesting ideas to be taken forward. Unless you are able to create that critical mass of involvement and to grab the policy-makers, then you are not going to get very far, are you?
Professor Launder: The policy influences on government tend to be made through scientific groups. The Royal Academy of Engineering is pressing in that direction through its president; the Royal Society is pressing for progress in that direction; I know the Institution of Mechanical Engineers, to which I belong, is very active in that.[2]

Q60 Mr Marsden: You think that, relatively soon, we are going to have a critical mass of evidence of argument that government departments, like Defra and DIUS, will have to take notice of?
Professor Launder: Partly I would say we do not have all the evidence but we cannot afford to wait. We must get involved in field trials and experiments that will enable us to discriminate between the techniques that do not really work as effectively as others.

Q61 Mr Marsden: Dr Santillo, does not what Professor Launder has just said sound to you like a reasonable basis upon which to proceed? I have read the evidence submission you have made and I have heard what you have said today. Some might say that, 20 or 30 years ago, your ideas might have been regarded as fairly off the wall, so why today are you being so down on geo-engineers? Is it not perhaps because you are the new orthodoxy?
Dr Santillo: I think if any of our ideas were considered to be off the wall 20 or 30 years ago, they are certainly not now.

Q62 Mr Marsden: That is exactly the point that I am making.
Dr Santillo: Perhaps we shall need to see where some of this research goes. The critical mass that we have at the moment is simply a reflection of the fact that more people are talking about geo-engineering techniques. It is not in itself an indication that we have greater evidence that these techniques are actually going to do anything productive and I think that is a very important distinction to make to come back to your earlier question on known unknowns and unknown unknowns. We are dealing clearly with a spread here but I think there are rather a lot more unknown unknowns than there are known. When we talk about something as complex as planetary systems—my expertise is mainly in the area of ocean systems—I think the fact that we have better models of the way in which these things will happen is sometimes misinterpreted as being filling in all of the gaps, that a model somehow fills in the gaps in our knowledge that we have. Of course, models will always be limited. We are dealing with systems where we are not simply going to answer all of the questions with further and further research. At some point it needs to be a policy decision as to whether this is an appropriate way to go or not.

Q63 Mr Marsden: You do not even think they should get started, do you?

[2] *Note from the witness:* "The policy influences on government tend to be made through scientific or engineering institutions. The Royal Academy of Engineering is pressing in that direction through its president; the Royal Society will also be producing a policy statement; the Institution of Mechanical Engineers, to which I belong, is also active."

Dr Santillo: What I have said is that if there are proposals that people wish to bring forward for research into geo-engineering techniques, what we need is a globally harmonised system for evaluating those to make sure that they are actually legitimate proposals and that they will not in themselves have a negative impact on the very planetary systems that they are studying.

Q64 Dr Harris: You have set that out in your evidence, which we have read. Do you think the British Government agrees with you or does it agree with the enthusiasts, or do you think its view is somewhere in the middle from what you know of government opinion from innovation or Defra or the new climate change department?
Dr Santillo: I think it is difficult to say. I suspect the view is somewhere in the middle. My feeling is that from policy-makers they can see a huge scepticism and understand that scepticism around geo-engineering techniques. I do not think there is a lot of appetite for them at the moment, but there is a danger that the more the commercial community, and to some extent the research community, talks up geo-engineering as a solution, some of those assumptions will begin to be set in policy that it is only a matter of time before these things will work.

Q65 Dr Harris: If one of these solutions looks viable, the logic of your position is that you will be even more opposed to it because it will look even more tempting for policy-makers to shelve the action that is needed to, for example, reduce emissions because one of these is looking viable. You have an interest in this not working.
Dr Santillo: Not at all. The position that we put forward is that at this point, given the huge uncertainties and unknowns regarding even the effectiveness of some of these proposals, that at this point none of them are a viable option and we should focus our efforts where we need to put them.

Q66 Dr Harris: You do not think people will start wrecking field trials of this technology like some people did for GM? I know with your formal backing you would never back illegal vandalism, but some people identified with your cause there. You are not envisaging that sort of reaction to this technology, are you?
Dr Santillo: I have no idea how people other than myself will respond to these issues, but I do not think we are in that same sort of debate. In this situation we are talking about something that could possibly happen 20 or 30 years from now that people are talking about researching at this stage. All I am saying in our evidence is that we need to not provide a barrier to that research but it has to be done in a legitimate, transparent way and in a way which follows a set of very clear and precautionary rules.
Chairman: I think Dr Harris would agree with that. Can I thank Professor Brian Launder, Dr Dan Lunt and Dr David Santillo for being our first set of witnesses on this particular inquiry; thank you all very much indeed.

Witnesses: **Professor Stephen Salter,** University of Edinburgh, **Professor Ken Caldeira,** Carnegie Institution, **Professor Klaus Lackner,** Columbia University (via video-link) and **Dr Vicky Pope,** Met Office, gave evidence.

Chairman: We have a video-link from the United States in this particular section where we have Professor Klaus Lackner from Columbia University who will be giving evidence as well. We welcome Professor Stephen Salter from the University of Edinburgh. We welcome Professor Ken Caldeira from the Carnegie Institution and we would like to thank you for coming all the way from the United States. Welcome to the House of Commons and to the Select Committee Inquiry. Finally, I welcome Dr Vicky Pope from the Met Office. The Met Office has been a good friend to our Committee over many inquiries and we are very pleased to have you here.

Q67 Mr Marsden: If I may start by getting a quick summary from all three of our professors this afternoon on how you have actually funded your programme on geo-engineering research to date and what has been the biggest challenge in taking them forward.
Professor Caldeira: I have the good fortune of working for the Carnegie Institution which is funded by an endowment left by Andrew Carnegie in 1902. My funding is covered by that and I also get some philanthropic funding to support post-doctoral researchers in this area but I have no federal or public funding at all.

Q68 Mr Marsden: What has been the biggest challenge in taking your research forward?
Professor Caldeira: I am a big advocate of research. I do not really consider myself an advocate of geo-engineering. I think these schemes have the potential to diminish environmental risk. We do not really know whether they will or not. I think the politics around this makes it difficult to discuss these issues in a neutral and balanced way. What I would like to see is more research that focuses on this topic in a balanced way on empirically answerable questions.
Professor Lackner: Thank you for inviting me to be part of this. I am the director of the Lenfest Centre for Sustainable Energy here at Columbia University and so a good fraction of my funding is actually derived from the generosity of a single individual, Mr Lenfest, a trustee of the university, who has endowed and supported the Centre. At the same time we have small amounts of money from government funding to deal with what I would call

the carbon cycle engineering. A few years back in 2003 we managed to get a small company started which got its money as a start-up from what is called Angel funding in order to demonstrate that the capture of carbon-dioxide from the atmosphere is really possible.
Professor Salter: I have had no money at all. I have had a promise from Ken Caldeira that he will pay my travel for going to some conferences but that is all I have had.

Q69 Mr Marsden: What has been your biggest challenge? Clearly money is a challenge, but are there others?
Professor Salter: The biggest challenge is there are only seven days in the week.
Professor Caldeira: I have had advertisements posted for post-doctoral researchers in this area and I have been unable to find good qualified people who have the technical skills to work in this area.

Q70 Mr Marsden: What is interesting from the range of responses that the three of you have given are a couple of references to public funding in small amounts, but the majority of what we are talking about has been private entrepreneurial activity. Professor Salter, looking at it from the UK perspective, do you think that is the most appropriate mechanism to take this research forward?
Professor Salter: It would be sensible to have the normal grant-giving process allowed to cover geo-engineering. I have applied to the Engineering and Physical Sciences Research Council and they turned it down.

Q71 Mr Marsden: Do you know why?
Professor Salter: Yes. One of the referees said that we had not put enough effort into how we disseminate the results. You only need one tiny negative comment for it to be thrown out and it does not even get to the panel. I am trying again at the moment from the Environment Research Council and I have to put a proposal into them for early December.

Q72 Mr Marsden: From the US perspective, again the majority of your funding appears to have come from private sources. Is that realistic, given the huge scale of the potential that that should remain in the private sector?
Professor Caldeira: Because climate engineering has the potential to reduce climate risk cost-effectively, I think it is important to research it as a possible kind of emergency response approach and it will need public funding and it should be public funding because there should be no real commercial market for these technologies. It will be the public sector that should deploy it and policy-makers need unbiased and accurate information and I think public funding is the best way of achieving that.

Q73 Mr Marsden: Professor Lackner, the new President Elect of the United States appears to be far more positive and responsive in some of these areas of climate change than the existing one. Would it be your expectation that there might be a role for more public funding in this area under the new administration?
Professor Lackner: I would expect so and hope so, but let me make a distinction between climate change engineering, which is what first comes to mind when people talk about geo-engineering, and contrast it with what I would call carbon cycle engineering. I think climate change engineering is a last resort and should be treated like that. It is like if I had a fire and the house burns down you will accept the water damage and in many ways if carbon dioxide were smelly we would not solve the problem by giving out nose plugs; we would stop putting carbon dioxide out because it is actually the approach. I would emphasise that end capture, for example, has been considered. A geo-engineering method is quite different because it goes to the root of the problem so I do believe we need to have public researched support for all of these issues, but they have to be put in perspective for what the goals are. I do believe it is necessary to effectively reach a carbon neutral energy infrastructure.
Professor Caldeira: To support what Klaus said, these various climate engineering approaches might reduce risk in some ways and introduce new elements of risk, whereas I do not see the kind of thing that Klaus Lackner is working on removing CO_2 from the atmosphere as introducing new elements of risk in the same way that climate engineering does. Personally I do not even consider what Klaus does to be in the realm of climate engineering. Basically removing carbon dioxide from the atmosphere should be uncontroversial, whereas I think well-informed, intelligent people can differ on the wisdom of focusing on direct climate manipulation.

Q74 Dr Iddon: Professor Lackner, is there a national geo-engineering research programme established in the States?
Professor Lackner: No, there has not been. Are you asking me whether it should be?

Q75 Dr Iddon: Yes.
Professor Lackner: I would again treat it with caution. I would view this as the backstop. We need to consider what happens if climate change runs away much faster than we thought, but I think it is very important also in public discourse to make clear that, by itself, it does not solve the problem and only allows you to tie over until you have really solved the problem in a direct manner, namely dealing with the carbon dioxide.

Q76 Dr Iddon: I ask the same question of the people in the room here. Do you think a national geo-engineering programme should be established and how should it be structured, if you agree?
Professor Salter: Yes, you should certainly have it. I think you could probably build it onto the existing research councils with perhaps some ring-fenced money that the government decides on the amount.

Q77 Dr Iddon: Is that agreed by our other two guests or do you have different views?
Professor Caldeira: I am basically in agreement. Dan Lunt is an example of a scientist who is working primarily on other sorts of climate change problems but focuses some of his energy on climate engineering. I think that is a good model. We do not need to create a cadre of climate engineers. I think we need climate scientists and good engineers who can then apply their skills to this problem too. I do not think we are looking to develop people with a vested interest in specific outcomes.

Q78 Dr Iddon: Dr Pope, do you agree with those views or do you have a different view?
Dr Pope: Yes, I would agree with those views. The focus has to be on science to improve mitigation and obviously adaptation to unavoidable climate change. Many of the techniques that are available for looking at the impacts of mitigation can also be used to look at geo-engineering as well.

Q79 Dr Gibson: Is this kind of research better done in a university environment or should you have a kind of hub mentality where it is all concentrated in one place and little bits spew out now and again? It may be different in both countries because the university environment in Britain is kind of like that at the minute in terms of its funding. What do you think in the States and/or in this country, Professor Caldeira?
Professor Caldeira: I admit a vested interest since I am located at Stanford and have a new position at Stanford as well, but I am a big advocate of university competitive funding. I also think that the big research centres like NCAR and the Hadley Centre have made incredibly valuable contributions. On the climate science side I think there are existing institutions and it is a matter of increasing the scope of the research and the funding. On the engineering side it is very different because there is nobody trying to build deployment systems today and this might need to be treated in a different way.

Q80 Dr Gibson: You would support from your experience Tyndall Centres and Hadley Centres doing this kind of work?
Professor Caldeira: Yes.

Q81 Dr Gibson: In a competitive way?
Professor Caldeira: I am a big fan of the competitive peer review process. I think all of this research should be in open literature. There should be nothing classified or closed. I would like to see it as an open and competitive process as much as possible.
Professor Salter: I have had a great deal of help from the National Centre for Atmospheric Research in Boulder, Colorado, with suggestions and numbers for the work I have been doing. I think you can mix big laboratories and universities. I think universities probably have a more rapid response and can come up with ideas a bit more flexibly than a laboratory where people are told what to do. I feel, and maybe I do not have any evidence here, that places like the Hadley Centre would be more effective if the individuals there could have a fraction of their time—say 25%—to do exactly what they wanted to do rather than being told what the government department wants.

Q82 Dr Gibson: There is a challenge for you. I am sure you agree with that.
Dr Pope: Maybe I should just introduce the Hadley Centre and my role. I am Head of Climate Change Advice at the Met Office Hadley Centre. I am sure you all know that the Met Office provides the weather forecasts everyday but it also hosts the institution that provides climate science to underpin government policy. We are commissioned in the Met Office Hadley Centre by DECC now, formerly Defra, and the MoD to provide independent climate research to underpin policy. A very large part of that work is to develop one of the world's leading climate models and these climate models, as was mentioned earlier, are now getting into the earth system realm so they can represent both biological and chemical processes as well as the main climate processes in the atmosphere, the ocean and the land surface. We do have the tools available to look at many of these sorts of issues. My role is to provide the interface between the science and the policy-makers. I am the person that tells the scientists what to do but, believe me, they are scientists and they do what they want as well. They will challenge the steer from policy makers and say these are the important issues as well and come back to the government departments and say should we not be looking at this. It is very much a two-way process and I am very much in the middle of that. If we believe that something is important for climate change we will look at it. I wanted to give a couple of examples of two recent studies that have not been published yet. One has been accepted for publication and another one has just been submitted that look at some of the issues involved. One study showed that if you take short term intervention—the direct climate engineering that people were talking about that act in the short term—it could actually mask climate change and when those interventions stop you will actually end up with higher levels of climate change than you had before. Really you need to look very carefully at these things. Another example is if you make changes to the climate on a regional scale they can have adverse effects in other regions of the globe. The climate system is very interlinked, so changes in one place affect other places, and it is only by running climate models that we can assess those impacts. Even if you switch the engineering off, the impact could be irreversible, so you could have a long term detrimental effect that you perhaps had not anticipated.

Q83 Dr Iddon: Dr Pope, we believe that one of the things that your organisation has been looking at is the consequences of cloud albedo enhancement. Could you tell us what that is and how you have been going about it? Is it modelling, or real experiments, and what are the main lessons of that research?

Dr Pope: We took the proposal that Professor Salter came up with to alter the properties of the clouds and essentially we did not look at any of the engineering issues; we just assumed that it would work and make a large impact on the stratocumulus clouds. These are clouds off the coast of Africa and South America. We looked at what the consequences of that would be for the climate as a whole. What we found was that if you changed the cloud sufficiently to have an impact on climate to actually reduce the warming that will also have consequences right the way round the world, particularly in the tropics, so it could change the El Nino, for example, which is very important for climate variability. It could enhance the destruction of the rain forest. We already know that climate change is likely to cause die back of the rain forest and it could make that worse. If you then switch that engineering off and stop producing the aerosol and you stop brightening the cloud, the cooling goes away and you get enhanced warming, but the changes in the rain forest could effectively be permanent because it takes many thousands of years for it to recover.

Q84 Dr Iddon: Is this virtual work or actual work?
Dr Pope: It has to be virtual. What we are looking at is not a prediction of the future; it is a projection of what might happen, so it is about looking at the danger inherent in the change that you are making. When we look at projections of climate change and we look at the worst case outcomes of an unmitigated world, we are looking at the dangers of that happening. We are not looking at something that will definitely happen. In this case we are saying if we made this intervention on climate what is the danger from that?
Professor Lackner: I would argue that we are not ready to do serious climate engineering in this day. I do hear people who say we should not even study it for that reason. I am opposed to that and the answer is, as you have just heard, there are all sorts of side-effects and I think it is therefore very important that we do basic research and most of this will, by its nature, be virtual. It is important to do that because if there is a crisis we will not have time to do it and we might go down a road which might be potentially far more dangerous because we refused to look at it earlier. It is better to know what the consequences would be so that when there is a crisis we know how to act because in a crisis we will take the easy way out of whatever it may be, even if it turns out to be a bad idea.
Professor Caldeira: If we take the risk of dangerous climate change seriously and the risk of a climate emergency seriously, if a climate emergency did occur there could be great pressure on politicians to do something right away. Transforming our energy system and reducing greenhouse gas emissions takes a long time, whereas it is thought that we could put dust in the stratosphere within a few years and start changing climate right away. If it turns out that these proposals do not really reduce climate risk, but merely create new forms of risk, there could be political pressure to do something right away and then we do something that is a big mistake and so it is important to do the research now, even if it is just to show that these proposals do not really make sense.[3] I would point out that while these simulations have shown that climate engineering is unlikely to reproduce the status quo ante, nearly every simulation has shown that there is the potential to reduce overall amounts of climate change.

Q85 Dr Gibson: There are still arguments, are there not, about the models to use for albedo enhancement and so on. You are not agreed on one model but on several and scientists are arguing about particular models. Is that the state of affairs?
Dr Pope: There are obviously uncertainties in the science and I think this was discussed earlier. All of the models show that climate is warming. They all share very many characteristics. What they differ in is the degree of the change and the details of the regional change. By using a number of different models that make different assumptions about the science, you can actually look at the range of possible outcomes and we are now able to start looking at the probabilities of different outcomes so that we can assess risk. It is really about risk assessment. No prediction of the future can give you an absolute prediction of any sort. What we are really doing is assessing risk.

Q86 Dr Gibson: So you need that variability.
Dr Pope: We do, yes.

Q87 Dr Gibson: What is your interaction with academic centres and commercial organisations?
Dr Pope: Our interaction with academic centres is very strong.

Q88 Dr Gibson: Which ones?
Dr Pope: Let me explain how a climate model works. No one centre anywhere in the world has all of the expertise that is required to develop an earth system model. We have to work very closely with people in the academic community. We work very closely with people in the UK, for example, experts on the biology of the oceans, experts on the land surface, and we have joint projects. We are formalising that much more mainly through the Natural Environmental Research Council and the universities in many parts of the UK get funding from there.

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3 *Note from the witness*: "It should be noted that a climate emergency could occur far sooner than generally recognized. Arctic sea ice has been declining more rapidly than had been foreseen. Some scientists believe that we may already be committed to losing much of the Greenland ice sheet, committing us to several meters of sea level rise. There is also a risk that large amounts of methane could be emitted by thawing permafrost in Siberia, accelerating global warming. Thus, it might be that environmental risk reduction would require deployment of climate engineering sooner rather than later. Consequently, there is a high degree of urgency to do the research now to understand potential options for reducing these risks. Emissions reductions can reduce longer-term risks, but cannot significantly reduce climate risks we face over the next decade or two. We would be remiss if we did not address this near-term risk reduction with a high degree of urgency."

Q89 Dr Gibson: Am I right that the Tyndall Centres are ripe within university structures?
Dr Pope: The Tyndall Centre is a distributed centre of researchers across the university sector with its hub in the University of East Anglia. They are not really involved in climate modelling.

Q90 Dr Gibson: I never know the difference between you and the UEA. It is either you or the UEA in *The Guardian* first. You seem to be saying very similar things.
Dr Pope: We say very similar things because of the broad consensus. If you look at the IPCC report there is a consensus of all scientists but the structure of the work that we do is very different. It is very complementary.

Q91 Dr Gibson: What about commercial interests?
Dr Pope: The Met Office does a small amount of work for commercial organisations but certainly not in this area.

Q92 Dr Gibson: Is it insurance companies?
Dr Pope: That kind of thing.

Q93 Dr Gibson: Or really that kind of thing? The scope of the Environmental UEA was to work with Norwich Union in the beginning. I remember it well because they wondered what the weather was going to be like in Pakistan in 20 years' time. Do you have that kind of interaction?
Dr Pope: We have some interaction with the insurance industry and a lot of interaction with the energy industry, for example.

Q94 Dr Gibson: Do you feel that your work is independent from what they want?
Dr Pope: All of our scientific research is published and is independent.

Q95 Dr Gibson: Is it funded by them?
Dr Pope: Not work in climate change, no, or in this sort of area.

Q96 Dr Gibson: But in other areas?
Dr Pope: In other areas, yes.

Q97 Dr Gibson: How much?
Dr Pope: I am not sure of the exact figures but we can get that for you.
Professor Salter: I wanted to say something about the particular study that Dr Pope mentioned. What they did was to pick the three most sensitive areas in the world for doing the cloud albedo change and put a very large stimulus into those. This produced some interesting effects in other places as well as what you would expect to get locally. They were not quite the same as the predictions from another model that was done in America at Boulder. One of the differences was that they used what is called a "slab" ocean model whereas the Boulder one allowed the ocean to respond to what you had done to the air above it. The comparison with what we would like to do compared with what they have analysed is much more like somebody who says he thinks he can cure back pain with the right kind of massage and this is tested out by a terrible punch in the solar plexus. We would not want to do the distribution of the spray in that particular way. We are not surprised that it produced funny things in other places. I think what you do depends on where you do it and the time of year that you do it. I would love to see an experiment where I did one thing on one side of the pacific and then on the other and see how I could adjust this musical instrument to produce nice chords rather than the first rather nasty sound that we got when we just did that to it.

Q98 Chairman: I am getting quite depressed now. I am sorry, Professor Lackner, it is a feature of my personality, but I expected this afternoon there to be a great deal more enthusiasm for geo-engineering coming over. Professor Lackner, there has been a number of companies in the United States who actually have seen that they can make a profit out of putting iron filings into the sea. For instance, Climos, a company that is still trading in the United States, believes that they can actually make a profit there. Do you think that any of these commercial companies have a hope in hell of making a profit out of this particular geo-engineering technique if, in fact, carbon starts trading on the world markets?
Professor Lackner: If your goal is to put sulphate in the atmosphere I do not see how you are going to do that.

Q99 Chairman: Let's put iron into the oceans. Is that going to bring me a return on my investment?
Professor Lackner: In this particular case I doubt it because the environmental consequences are hard to understand but, if you start getting into carbon capture and storage more broadly, I think it is very likely that people can make money provided there is the political will to put a price on carbon. I do believe you have already started that in Europe successfully, so it is possible to build things around this model but you have to show the carbon and you have to put it somewhere and demonstrate that it is indeed put away. The particular issue you raised with the iron fertilisation is: is it really put away, or is it coming back in 20 years from now? What are the environmental consequences of doing it? I do believe there is a large spectrum of options. Maybe I am biased because I am involved in one of them, but capturing carbon dioxide in a power plant or from the air by biomass, or by chemical means, is feasible and does not have to have a big environmental impact. In that sense we can be enthusiastic that the world can move towards a zero carbon energy infrastructure which may still, to a large extent, be driven by fossil fuels. This is quite possible and quite real. Frankly, it has to be what we do because it cannot keep going up every year for the next 150 years. This is the trajectory we are on and even holding that rise constant requires drastic changes in our energy infrastructure, so it is absolutely necessary that we focus on carbon capture and storage in managing the carbon cycle. I think there is no way around that and it is feasible and possible.

Q100 Chairman: If we leave carbon sequestration to one side as a technology, because I think most of us would accept that that is a very sensible technology to use, are there any other geo-engineering solutions that you feel have a commercial potential, Professor Caldeira, which ultimately might drive this science?
Professor Caldeira: I think there are potential areas of research where there could be co-benefits. One example, and this might also sound as far out as climate engineering, but a number of people are looking at the potential for extracting wind energy from high altitude winds where the wind is much stronger and blows more steadily. One of the big challenges of that is maintaining a tethered platform at altitude. This could not only affect high altitude wind power, but if you are going to disperse particles up high you would like a platform there; also to recharge electrically powered surveillance planes you might want a platform up there also. There might be research into maintaining high altitude platforms that could have co-benefits where climate engineering would be one of the benefits. I would like to take the opportunity to comment on your point about the lack of enthusiasm here. I think that thoughtful people are not enthusiastic about climate engineering. Thoughtful people would like us to see deep reductions in carbon dioxide emissions and see those reductions soon. It is really a certain sense of despair that we are not seeing those cuts quickly that is pushing us to consider these things. I really look at Klaus' proposals as a form of carbon capture and storage and personally I would not classify what Klaus Lackner is researching as geo-engineering.

Q101 Ian Stewart: There are bodies like the Tyndall Centre who argue that attention needs to be paid to the phasing in of schemes in relation to geo-engineering running alongside other abatement measures. As I understand it, Professor Salter, amongst others, has argued that it may even be too late to deploy geo-engineering technologies in line with this. Bearing that in mind, can you say whether we still should go ahead with the development of geo-engineering schemes? If so, do we have the skills in the undergraduates and graduates that would allow us to do that?
Professor Lackner: If your question is with respect to manipulating the climate, I do not think we have the skills to do this today. We should learn about it and we should have it ready in case we need it, but I would very much view that as an effort of last resort. We cannot solve the problem. We cannot stop the CO_2 from accumulating by changing the climate and I would argue that this is such a complex system that you really do not want to do that unless you really have no choice left. If the glaciers in Iceland are falling into the ocean maybe you have no choice, but you should not think of this as the way you stabilise the system. That, in a way, answers your previous question. I do not expect people to make money out of the Fire Department so I really do not expect people to make money out of those kinds of geo-engineering efforts.
Professor Salter: The most urgent thing is to try to save the Arctic icecap because, if we lose that, we have now got another very large input of warming coming in from the sun. I think that is particularly urgent. The ice is vanishing much more quickly than the first studies of climate change predicted; it really is going frighteningly fast. It is also possible that if we get very large amounts of methane released from the seabed in the Arctic, and also from the permafrost, that they could take over from carbon dioxide as the main driver for global warming and then it would not matter how much carbon we reduced, we would still have a climate change problem. I would rather have it available too early than too late.
Professor Caldeira: To address the moral hazard issue from before, it is not clear what an ethical course of action would be. If we did find that the sea ice is melting and threatening polar bears and arctic ecosystems with extinction and Greenland is sliding into the sea, is it better to say let's have that ecosystem go extinct, let's lose Greenland and that will be a good motivator for people to reduce emissions, or do you say no, we actually care about these ecosystems, we care about Greenland and maybe we should put some dust in the stratosphere to prevent this from happening while we are working on reducing emissions. I do not think the ethical and moral high ground is necessarily to say let's allow environmental destruction to proceed unimpeded while we are trying to reduce emissions.

Q102 Ian Stewart: Professor Caldeira, let's take this example that Professor Salter has given and you have carried on with. If we were to address that issue, how long would it take us to develop the geo-engineering and how much would it cost? Does anybody have any idea?
Professor Caldeira: Nobody really knows but the estimates in terms of cost are in the order of, within a factor of ten, a billion dollars a year. It is the low cost—I am thinking now of dust in the stratosphere scheme—of this that makes it somewhat frightening because it might be so cheap that people might want to do it because it is cheap and easy. I think within a few years we could start getting the stuff up there using aeroplanes or artillery shells or something while lower cost strategies are developed. It is something that could be deployed at relatively low cost and relatively quickly. The question is are there unanticipated damage or even anticipated damage that doing that would create? It is important to do the research up front so that if you do find that there are environmental consequences of global warming that you would like to prevent using these approaches then you are not just creating bigger problems and that is why we need the research.

Q103 Ian Stewart: Is there a technology that seems to hold the most promise in relation to these matters?
Dr Pope: I wanted to come back to the point that Professor Caldeira made that what we need to be concentrating on is removing the greenhouse gases from the atmosphere. Whether that is by reducing emissions or removing them artificially, those are the

key to solving the problem. On the point about climate engineering—trying to alter the climate to compensate and of course there is the question of unintended consequences—many of the changes that we are talking about are temporary. If we put aerosol into the troposphere, for example, to seed clouds it only stays in the atmosphere for a couple of weeks, so you have to keep putting more aerosol in. If you put aerosol into the stratosphere it stays much longer, perhaps for a couple of years, but you still have to keep putting the aerosol in. When you put carbon dioxide in the atmosphere it stays around for hundreds of years. If you are going to use geo-engineering as a solution you have got to keep doing it for hundreds of years because as soon as you stop doing it the warming goes up again, so either you have to decrease the emissions much more quickly or you have to put up with even higher warming. You have to bear that in mind in looking at the consequences.

Q104 Chairman: We are asking you to stargaze now in terms of which of the geo-engineering techniques that have been mooted so far if you were a government minister would you be urging resources to be put into? You have a new President, Ken. What would you ask him to do?
Professor Caldeira: First of all, if I was the new President I would be putting a small fraction of my total effort into climate engineering, but within that effort putting small dust particles into the stratosphere seems to be the most promising and cost-effective approach and I would also put some resources into looking at the sorts of things that Steve Salter has been talking about. I would also be hesitant to pick winners at an early stage. It is important to fund a broad diversity, a wide portfolio, of research options and not think that we have already thought of the best approach or even thought of the most important negative consequences that could occur.
Professor Salter: I would agree completely with that. I think we might need to have all of them. In particular, we might want to have the widespread effect that you can get from stratospheric aerosols where they are doing a very big area which you might, in hi-fi terms, describe as a woofer. You might also want to have a tweeter, which is the local effect we can get from treating clouds locally. We might have the Arctic ice to recover; we might have a particular coral reef, perhaps the Great Australian Barrier Reef where we focus particular amounts of cooling in one particular sea area so that the water that flows from there keeps the coral. At the moment, however, I would be very hesitant to attack any scheme that I did not know a great deal more about than I do now.
Professor Caldeira: May I amend my statement that I would also fund the kind of work that Klaus Lackner is doing but I would fund it out of a carbon capture and storage programme because I would not consider it climate engineering.

Q105 Chairman: The last word to you, Professor Lackner.
Professor Lackner: I would emphasise the carbon capture and storage and I would advise against large scale experiments until we really understand how it works. We are embarking on something mankind might do over the next 200 years but I doubt that we really understand what we are doing here.
Dr Pope: Of all the solutions that people might want to look at, it is very important to look at all of the consequences of any solution that people might come up with, so I would not advocate anything in particular. It is important to try and work out what those unintended consequences might be so that we are in the best position to make decisions.
Chairman: On that note of unanimity, could we thank you very much indeed Professor Klaus Lackner from Columbia University, it has been a pleasure to have you on the video-link; to thank Professor Ken Caldeira from the Carnegie Institution, thank you for coming to see us this afternoon; to Professor Stephen Salter, the University of Edinburgh, thank you very much indeed, and last but by no means least, Dr Vicky Pope from the Met Office. We are in your debt for joining us today.

Written evidence

Memorandum 140

Submission from the Department for Innovation, Universities and Skills (DIUS)

Introduction

1. The Department for Innovation, Universities and Skills provides funding from the Science Budget to the Research Councils, which are responsible for funding basic, strategic and applied research and related postgraduate training across the range of scientific and engineering disciplines, and has developed a close working relationship with the UK engineering community to meet the needs of this important sector to UK society.

2. The Research Councils are submitting a separate memorandum on this to the Select Committee.

Current and Potential Roles of Engineering and Engineers in Geo-engineering Solutions to Climate Change

3. Geo-engineering solutions to climate change that refer to a diverse range of individual approaches that have been floated that, broadly, would involve either taking CO_2 directly from the atmosphere or reducing the amount of sunlight that is absorbed by the Earth's atmospheric system by increasing its reflectivity, or "albedo".

4. Understanding of the science and potential of geo-engineering options for mitigating climate change is currently limited and there is not strong agreement in this area. In its Fourth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) highlights that the options put forward, to date, remain largely speculative with little known about their effectiveness and costs and with a risk of unknown side-effects.

5. Also, it is important to note that those options proposed that could increase the Earth's albedo might have the effect of reducing temperature whilst in place, but would not affect other impacts from increased CO_2, such as ocean acidification.

6. Nonetheless, the scale of the challenge posed by climate change suggests that less conventional approaches and technologies should continue to be explored, whilst the key priority remains the development and deployment of technologies to drive the urgent and radical shift required to a low carbon economy. The transformation to a low carbon global economy represents a major, long term challenge and, even at the most optimistic stabilisation ranges suggested for greenhouse gases in the atmosphere, the risks of dangerous climate change impacts remain. It is conceivable, therefore, that some of those geo-engineering approaches currently proposed, or others that may yet be put forward, may offer bridging solutions to mitigate, probably to a limited extent, global warming impacts over the period until stabilisation of emissions at a "safe"[1] level can be achieved.

Background on Individual Geo-engineering Options

7. Ideas considered in the Fourth Assessment Report include:

— *Ocean Fertilisation*—This describes stimulating the growth of phytoplankton, which, in turn, leads to increased volumes of CO_2 being sequestered in the form of particulate organic carbon (POC). Growth is stimulated by "fertilising" the ocean surface with a limiting nutrient to phytoplankton growth, such as iron or nitrogen. It should be noted, though, that the limiting factor will vary across the oceans—additions of iron, for example, will only stimulate growth in around 30% of the oceans where iron depletion prevails. The potential negative effects of ocean fertilisation include the increased production of methane and nitrous oxide, de-oxygenation of intermediate waters and changes in phytoplankton community composition. This may lead to toxic algae blooms and/or promote further changes along the food chain.

— *Deflector System between the Earth and Sun*—The principle of this approach is to install a barrier to sunlight between the Sun and the Earth which would filter/deflect a pre-determined fraction of the incident solar radiation.

— *Stratospheric Reflecting Aerosols*—This involves the controlled scattering of incoming sunlight with airborne microscopic particles, which, once deployed, would remain in the stratosphere for around five years. The particles could be:

(a) dielectrics;

(b) metals;

[1] Noting that even at current levels, some adverse climate change impacts are unavoidable and will require adaptation measures.

(c) resonant scatterers; or

(d) sulphur.

The implications of these schemes require further assessment with regard to stratospheric chemistry, feasibility and cost.

— *Albedo Enhancement of Atmospheric Clouds*—This scheme involves seeding low-level marine stratocumulus clouds with atomised sea water. The resulting increase in droplet concentration in the clouds increases cloud albedo, resulting in cooling which could be controlled. The costs of this would be less than for schemes involving stratospheric aerosols, but the meteorological ramifications need further study.

8. Defra's submission to the Committee will provide a more detailed consideration of the individual geo-engineering approaches floated, informed by the Department's polling of experts earlier in the year.

Provision of University Courses and other Forms of Training Relevant to Geo-engineering in the UK

9. The HE Academy Engineering Subject Centre does not have a comprehensive knowledge of the provision of Geo-Engineering in the UK.

10. There are, though several UK Universities that provide courses with a possible geo-engineering content and the University of Durham (along with teaching) undertakes research in geo-engineering.

11. The Institution of Civil Engineers, the professional body for Civil Engineering, also has a number of specialist knowledge groups, including geospatial engineering.

Geo-engineering and Engaging Young People in the Engineering Profession

12. The Government recognises the important contribution that engineers make to society and the role of engineering in developing practical solutions to some of our most pressing societal, economic and environmental challenges. But this view is not yet shared by all sections of our society. In 2007, the Engineering and Technology Board and the Royal Academy of Engineering jointly published the findings of the first national survey of public attitudes and perceptions towards engineers and engineering and these revealed fundamental misconceptions of engineering among young people in particular that could worsen the UK's shortfall in engineers if it affects their future career choices.

13. Government policy on science and engineering education, and on public engagement in this area, is mainly focused on increasing the number of people coming through schools and colleges with the right GCSEs and A-levels to enable them to study science and engineering in Higher Education—then to pursue engineering careers equipped with the necessary skills—and on improving public perceptions of engineering. The Government, in partnership with key delivery agents, has made major policy commitments in this area—much has been achieved but there remains more to do (see Departmental submission—with input from DCSF and BERR—to the first tranche of written evidence, already published by the Committee: http://www.parliament.uk/documents/upload/ENG%20Ev%20for%20internet.pdf).

The Role of Engineers in Informing Policy Makers and the Public Regarding the Potential Costs, Benefits and Research Status of Different Geo-engineering Schemes

14. There are various ways in which the UK engineering community is helping to shape public policy on issues with an engineering dimension and to encourage public engagement with these issues. While not currently focused on geo-engineering, these same mechanisms can readily be employed as Government policy in this area develops.

15. The Royal Academy of Engineering is a major source of authoritative impartial advice for Government on issues with an engineering dimension. As the UK's national academy for engineering, it provides overall leadership for the UK's engineering profession, along with the engineering institutions. The Academy's membership of 1,424 Fellows brings together the UK's most eminent engineers from all disciplines.

16. There is a growing enthusiasm on the part of the Academy, supported by the leading engineering institutions, to work more collaboratively and with Government to better promote the UK engineering profession. Regular meetings with the Government Chief Scientific Adviser, Ministers and senior officials help ensure that the engineering community has high-level input to policy making in a wide range of areas.

17. Working closely with the main engineering institutions, the Academy is co-ordinating the response of the UK engineering profession to the public consultation, launched by DIUS on 18 July, on developing a new Strategy for Science and Society. The aim is to realise the vision of a society that is excited by science; values its importance to our social and economic wellbeing; feels confident in its use; and supports a well-qualified, representative workforce.

18. The Academy is expected to provide its own written evidence, but advises that geo-engineering, as such, is not currently a focus for its activities—it regards geo-engineering as being mainly at the "blue skies" stage. But the Academy, together with the engineering institutions, will play an important role as Government policy in this area is developed.

October 2008

Memorandum 141

Submission from Professor Ian Main and Dr Gary Couples Director and Co-director, Edinburgh Collaborative of Subsurface Science and Engineering (ECOSSE)

TODAY

1.1 Many of the greatest challenges facing society today will require innovative solutions at the interface between the GeoSciences and Engineering. Examples include the response to Climate Change (including underground carbon storage, and dealing with rising sea levels) efficient exploitation/management of Earth resources (minerals, oil and gas, groundwater); Energy (oil & gas, underground storage of nuclear waste); and Natural Hazards (earthquakes, volcanoes, storms and storm surges). Some apply directly to the UK, and some to countries where the UK has significant business/cultural exchange interests.

1.2 To respond to the challenges, some universities have set up mechanisms to co-operate across the GeoSciences and Engineering, including ECOSSE, a four-way partnership between scientists and engineers at the University of Edinburgh, Heriot-Watt University, the British Geological Survey and the Scottish Universities Environmental Research Centre, part of the wider Edinburgh Research Partnership in Engineering and Mathematics (ERP), funded as a research pooling initiative by the Scottish Funding Council. This summary is based on the practical experience of formally setting up this partnership.

1.3 Such partnerships have operated effectively as an incubator of large, new, globally-competitive initiatives, including the Scottish Carbon Capture and Storage Consortium (SCCS: www.geos.ed.ac.uk/sccs) and Edinburgh Seismic Research (ESR: www.geos.ed.ac.uk/seismic/). SCCS is based on the philosophy of using oil-related geoengineering skills and facilities built up over decades to focus on the R&D challenges of CO_2 management based on subsurface CO_2 storage, and ESR in applying subsurface imaging techniques to exploring and monitoring the subsurface to inform engineering decisions.

1.4 The funding environment from UK Government is already evolving to respond to such challenges, with NERC strongly supporting initiatives in living with climate change and natural hazards, albeit at the expense of subsurface science. At the same time EPSRC and other avenues such as the Treasury Science and Innovation scheme has funded significant research and staff posts in subsurface geoengineering.

1.5 Many universities are responding to the change in funding environment with new staff appointments in the relevant areas, some as matching funding for government-supported initiatives such as ECOSSE and ERP.

1.6 Industry is increasingly aware of the need to engage, with long-term commitment to funding research in exploration and production of oil and gas, but also more recently in minerals and in terms of supporting new areas such as carbon capture and storage.

1.7 Much of the "pull" from industry in this area is in recruitment—the UK simply does not produce enough of its own quantitative geoscientists or engineers to fill current vacancies, and even fewer graduates who are literate across elements of both disciplines. This is a global problem.

THE FUTURE

2.1 The challenges listed above will become more acute with time.

2.2 Action is needed now to inspire young people to engage with the big issues. This could be encouraged by inclusion in School curricula of concrete worked examples to illustrate general principles in mathematics, physics, geography, geology, and also from a greater direct engagement of practitioners with Schools, media etc.

2.3 Solutions must be sought over a spectrum of resource allocation, from large-scale engineering and monitoring programmes in coastal defence and carbon storage to working more with nature in preserving wetlands, or low-cost engineering solutions where funds are limited.

2.4 More explicit collaboration and demarcation between NERC and EPSRC would be welcome to ensure no funding gap exists between GeoSciences and Engineering. No competitive integrative proposal in geoengineering should fail because it 'falls between two stools'.

2.5 Likewise universities should be encouraged to continue to develop procedures and possible joint staff appointments that encourage links and integrated research in geoscience and engineering, reaching out to all relevant agencies, including industry, government-directed programmes (British Geological Survey, Centre for Ecology and Hydrology etc.) and regulatory agencies (eg SEPA).

2.6 Continued/increased targeted government support of this effort, beyond that provided by individual research councils, directed explicitly at geoengineering (Treasury S&I Scheme, DBERR) would be welcome.

2.7 Geoengineers must be encouraged to interact more with society as a whole, in a subject increasingly driven by a regulatory framework (hence requiring an engagement with environmental law), with solutions that may involve action or buy-in by the majority (hence social sciences and science-led policy) as well as the skilled technical practitioner.

October 2008

Memorandum 142

Submission from the School of Engineering and Electronics and the School of Geosciences, University of Edinburgh

1. The Current and Potential Roles of Engineering and Engineers in Geo-engineering Solutions to Climate Change

Many of the greatest challenges facing society today will require innovative solutions at the interface between GeoSciences and Engineering. Examples include the response to climate change, efficient exploitation/management or Earth resources, energy, and natural hazards.

While many climate changes will impact on the UK (eg, floods, droughts, severe winters, and forest fires), an increase in the number of extreme rainfall or storm events is expected to have the most significant implications in Scotland.

To respond to the challenge, some universities have set up mechanism to cooperate across the GeoScience and Engineering, such is the case of The University of Edinburgh.

The role of engineering and engineers in geo-engineering is to provide solutions to adapting to the impacts of climate change, including:

— water resources management on very large catchment scale;

— flood retention structures; and

— wetlands.

The role is also to minimise emissions, applying different measures that include:

— energy efficiency and microgeneration;

— waste reduction and recycling;

— carbon capture and storage;

— conversion of biomass to gaseous fuel and biochar (carbon-negative technology); and

— optimal remediation of contaminated land.

Geo-engineers must be encouraged to interact more with society as a whole, in a subject increasingly driven by a regulatory framework (hence requiring an engagement with environmental law), with solutions that may involve actions of buy-in by the majority (hence social sciences and science-led policy) as well as the skilled practitioner.

2. National and International Research Activity, and Research Funding, Related to Geo-engineering, and the Relationship between, and Interface with, this Field and Research Conducted to Reduce Greenhouse Gas Emissions

Ongoing national and international research activity related to geo-engineering and adaptation to the impact of climate change includes:

2.1 *Flood Retention Structures (International funding—EU INTERREG SAWA)*

There are many types of Flood Retention Structures (FRS) performing various roles. However, while most of them detain runoff for later release thus avoiding downstream flooding problems, some of them do perform other tangible albeit less "visible" roles such as pollution removal, infiltration for groundwater recharge, source of raw water for potable water supply and provision of recreational facilities. A multi-functional retention structure will in principle be desirable but may not be appropriate or even advisable depending on the particular circumstances of the catchment under consideration. The absence of a classification scheme for FRS leads to confusion about the status of individual structures. A classification scheme would therefore greatly enhance communication between practitioners. A rapid classification methodology for FRS is relevant for stakeholders such as local authorities and non-governmental organizations, and it would greatly assist them with planning issues. Finally, an insight into the relative importance of variables defining different FRS for various applications such as flood management, sustainable drainage, recreation, environmental protection and/or landscape aesthetics will help practitioners to optimise the design, operation and management of FRS. Decisions such as this one are currently made *ad hoc* and are frequently based only on political considerations.

Ongoing national and international research activity related to geo-engineering and reducing greenhouse gas emissions includes:

2.2 *Second generation biofuels and local energy systems*

First-generation biofuels, mainly from corn and other food based crops are being used as a direct substitute for fossil fuels in transport. However, they are available in limited volumes that do not make them serious replacements for petroleum. Second generation biofuels from forest and crop residues, energy crops and municipal and construction waste, will arguably reduce net carbon emission, increment energy efficiency and reduce energy dependency, potentially overcoming the limitations of first generation biofuels. Nevertheless, implementation of second generation biofuels technology will require a sustainable management of energy, or development of local bio-energy systems. Locally produced second generation biofuels will exploit local biomass to optimize their production and consumption.

2.3 *Conversion of biomass to gaseous fuel and biochar (carbon-negative technology)*

Design of novel processing technology to gasify biomass using smouldering combustion leading to more efficient and smaller reactors. Biochar boost plant growth and is storage in soil layers. Production of biochar can be coupled with the simultaneous production of gas and liquid fuels from biomass to reach self-energize processing.

2.4 *Methane emission abatement via methonotrophic bacteria living in soils and compost*

Methane is a potent greenhouse gas, with a global warming potential 23 times higher than CO_2 (mole basis, 100 year timeframe), chemically stable and persist in the atmosphere over time scales of a decade to centuries or longer, and thus methane emission has a long-term influence on climate. Landfills represent a significant source of methane. Although, for new landfills, the European Community Landfill Directive 1999 imposes strict engineering requirements to capture CH_4 emissions, CH_4 escape through the landfill cover of existing, non-engineered landfills remains a significant problem in the UK. Landfill CH4 emission abatement can be achieved by methane oxidizing bacteria (methanotrophs), which may be present in biowaste compost produced from biodegradable fractions of municipal waste.

2.5 *Diversion of waste to energy*

The use of biofuels for transport is becoming of increasing importance for a number of reasons, such as environmental concerns relating to climate change, depletion of fossil fuel reserves, and reduction of reliance on imports. This is leading to international, national and regional focus upon alternative energy sources. In Europe, the European Commission has proposed indicative targets for biofuel substitution of 5.75% by 2010. A potential source for low-cost biofuel (ie, bio-ethanol) production is to utilize lignocellulosic materials such as crop residues, grasses, sawdust, wood chips, and solid waste. Additionally, European legislative pressures target for minimising landfill use in European countries, and the amount of biodegradable municipal solid waste (BMSW) going to landfill must be reduced by 25% by 2010, 50% by 2013 and 65% by 2020. Thus, the BMSW fraction may be considered an alternative sustainable source of bio-ethanol.

2.6 *Study of emissions from large subsurface fires (peat, coal, landfill)*

Large smouldering fires are rare events at the local scale but occur regularly at a global scale. These fires smoulder below ground very slowly for extended periods of time (weeks or years) and are large contributors to biomass consumption and green house gas emissions to the atmosphere. Subsurface coal fires in China alone are estimated to contribute 2–3% of global carbon emissions. The largest peat fires registered to date took place in Indonesia during the El Nino dry season of 1997 and released between 13–40% of the global fossil fuel emissions of that year. The emission from smouldering peat and coal need to be measured and quantify. Current knowledge is inadequate and hinders proper understanding of the problem.

2.7 *Effective extinction method for subsurface fires and coal fires*

Little technical research has been undertaken on this subject and understanding of how to tackle subsurface fires which are extremely difficult to extinguish. In addition to the environmental costs, associated financial costs of smouldering mines run into millions of dollars from loss of coal, closure of mines, damage to environment and fire fighting efforts.

3. The Provision of University Courses and other Forms of Training Relevant to Geo-engineering in the UK

Current university courses relevant to geo-engineering, offered by the School of Engineering and Electronics, include:

3.1 *Sustainable development and new Engineering 1 Workshops*

New workshops for Engineering 1 involve teams of students working on posters and presentation related to sustainability, global warming, energy security, carbon offsetting and renewable energy issues, as well as professional ethics and impact of technology in society.

3.2 *Infrastructure Management and Sustainability 3*

This course provides an opportunity for students to explore further sustainable development issues and to focus on the role and practices of engineers in creating a sustainable world.

3.3 *Environmental Engineering 3*

This course presents an open approach to Environmental Engineering. Particular emphasis is given to new environmental challenges and how to contribute to increasing sustainable economic growth.

3.4 *Water and Wastewater Systems 3*

This course extends the hydrology and water resources course content of the second year Water Resources course into fundamentals of water quality, and water and wastewater treatment. The content covers the practical considerations to be made resulting from the demand for water from community development by considering water consumption, water sources, water quality and disposal. Specific reference is made to fundamental water and wastewater treatment issues and technologies such as the following:

— Drinking Water Quality Standards and Water Treatment;
— Coagulation and Flocculation;
— Sludge Blanket Clarifiers; and
— Flotation Systems; Characterisation of Organic Effluent; Sewage Treatment (primary treatment units); and Biological Treatment.

3.5 *Water and Wastewater Systems 4*

The topics of water quality and water and wastewater systems are continued from the 3rd year course Water Resources. Specific reference is made to advanced water and wastewater treatment options such as the following:

— Filtration;
— Hydraulics of Filtration;
— Disinfection and Fluoridation;
— Water Softening and Iron and Manganese Removal;
— Environmental Water Microbiology;
— Biological Filtration;

— Rotating Biological Contactors;

— Activated Sludge Process; and

— Sludge Treatment and Disposal.

Relevant case studies and recent research are also discussed.

3.6 *Contaminated Land and remediation technologies*

Research of in-situ land and groundwater remediation remains one priority technology area. Significant advances are required in groundwater treatment systems to make them more efficient and reliable. Traditional pump and treat technologies, for example are very inefficient at addressing low levels of contaminants that have migrated over large areas. This course explores traditional and novel remediation technologies.

4. The Status of Geo-engineering Technologies in Government, Industry and Academia

There is a close collaboration between academia, industry and government, to develop geo-engineering technologies. Some examples include:

4.1 *Constructed treatment wetlands*

The self-organizing map (SOM) model was applied to elucidate heavy metal removal mechanisms and to predict heavy metal concentrations in experimental constructed wetlands treating urban runoff. A newly developed SOM map showed that nickel in constructed wetland filters is likely to leach under high conductivity in combination with low pH in winter. In contrast, influent pH and conductivity were not shown to have clear relationships with copper concentrations in the effluent, suggesting that the mobility of copper was not considerably affected by salt increase during winter. The accuracy of prediction with SOM was highly satisfactory, suggesting heavy metals can be efficiently estimated by applying the SOM model with input variables such as conductivity, pH, temperature and redox potential, which can be monitored in real time. Moreover, domain understanding was not required to implement the SOM model for prediction of heavy metal removal efficiencies.

4.2 *Sustainable drainage systems*

This research assesses the performance of the next generation of permeable pavement systems incorporating ground source heat pumps. The relatively high variability of temperature in these systems allows for the potential survival of potentially pathogenic organisms within the sub-base. Supplementary carbon dioxide monitoring indicated relatively high microbial activity on the geotextile and within the lower parts of the sub-base. Anaerobic processes were concentrated in the space around the geotextile, where carbon dioxide concentrations reached up to 2,000 ppm. Nevertheless, the overall water treatment potential was high with up to 99% biochemical oxygen demand removal. The research enables decision-makers for the first time to assess public health risks, treatment requirements and efficiencies, and the potential for runoff recycling. The relatively low temperatures and minor water quality data variability within the systems provided good evidence for the relatively high level of biological process control leading to a low risk of pathogen growth.

4.3 *Waste to energy*

Energy from waste is the recovery of renewable energy in the form of electricity and/or heat from residual waste. Gaseous and liquid fuels can also be recovered from waste as an alternative to electricity generation. Energy from waste can make a significant contribution to oil-independence and climate protection with clean power, heat, and vehicle fuels. Ongoing research in energy from waste technologies includes optimisation of biological and thermal processes to produce liquid fuels and added-value products from biodegradable fractions of organic waste diverted from landfill sites.

4.4 *Smouldering combustion for biomass conversion*

See 2.3 and 2.7.

5. Geo-engineering and Engaging Young People in the Engineering Profession

Many professional associations have specific mechanisms to engage young people in the engineering profession. These include:

5.1 *CIWEM, Chartered Institution of Water and Environmental Management*

See http://ciwem.org.

The CIWEM is the leading professional and examining body for scientists, engineers, other environmental professionals, students and those committed to the sustainable management and development of water and the environment.

5.2 *IEMA, Institute of Environmental Management and Assessment*

See http://www.iema.net/

The Institute's aim is to promote the goal of sustainable development through improved environmental practice and performance.

5.3 *SHG networking meetings, The Scottish Hydrological Group*

See http://www.hydrology.org.uk/about_regional_scottish.htm

The Society caters for all those with an interest in the inter-disciplinary subject of hydrology, and aims to promote interest and scholarship in scientific and applied aspects of hydrology and to foster the involvement of its members in national and international activities.

5.4 *IWA, International Water Association*

See http://www.iwahq.org/

The goal of IWA is to fulfil the present and future needs of the water and wastewater industries. This requires the continuous development of a workforce which is both adequate in size, capable in skills and strong in leadership. Young water professionals (students and professionals in the water sector and under the age of 35) are the future of the water sector, and therefore the future of the IWA

5.5 *EGU, European Geoscience Union*

See http://www.egu.eu/

EGU is a dynamic, innovative, and interdisciplinary learned association devoted to the promotion of the sciences of the Earth and its environment and of planetary and space sciences and cooperation between scientists.

6. The Role of Engineers in informing Policy-makers and the Public Regarding the Potential Costs, Benefits and Research Status of different Geo-engineering Schemes

An example of how ongoing research conducted in the academia by engineers informs policy-makers and the public includes:

6.1 *Farm constructed wetlands—"Governments" of Scotland, Northern Ireland and Ireland*

This research comprises the scientific justification for the Farm Constructed Wetland (FCW) Design Manual for Scotland and Northern Ireland. Moreover, this document addresses an international audience interested in applying wetland systems in the wider agricultural context. Farm constructed wetlands combine farm wastewater (predominantly farmyard runoff) treatment with landscape and biodiversity enhancements, and are a specific application and class of Integrated Constructed Wetlands (ICW), which have wider applications in the treatment of other wastewater types such as domestic sewage. The aim of this review paper is to propose guidelines highlighting the rationale for FCW, including key water quality management and regulatory issues, important physical and biochemical wetland treatment processes, assessment techniques for characterizing potential FCW sites and discharge options to water bodies. The paper discusses universal design, construction, planting, maintenance and operation issues relevant specifically for FCW in a temperate climate, but highlights also catchment-specific requirements to protect the environment.

Nevertheless, future needs have been identified:

6.2 *Need for close collaboration between GeoSciences and Chemical/Electrical/Mechanical Engineering to define the entire CCS chain*

It is going to be difficult to formulate an appropriate multi-objective function to optimize CCS.

6.3 *Matching of sources and sinks*

This is what makes the north of the UK the obvious place to carry out RD&D.

6.4 *Need for a regulatory framework*

It's difficult to see how someone is going to start pumping CO_2 underground if one is not sure of what liabilities will be there in the longer term. Not sure what similarities can be drawn from the disposal of spent nuclear materials.

6.5 *Need to explore all capture options (ie pre-, post- and oxy-combustion)*

Here there is a strong lobby that wishes to focus only on one technology and this is not a clever choice, given that there are no existing plants.

6.6 *Need for people trained in all of the above*

CCS MSc (planned to start from September 2009) will be developed, where we will be involved.

September 2008

Memorandum 143

Submission from PODEnergy

Applying Wikinomics to Geo-Engineering

1. Summary

1.1 Encourage and enable engineers and scientists to self-organize using principles of wikinomics.[2]

1.1.1 Strive for transparency on decisions using wikinomics concepts of mass collaboration.

1.1.2 All climate change causes and solutions are geo-engineering.

1.1.3 Sort geo-engineering technologies for eco-sustainability and effectiveness against both basic climate change impacts: trapping heat in the atmosphere and increasing ocean acidity.

1.1.4 Facilitate all people, not only scientists and engineers, to self-select roles, activity, funding, training, and status for the various geo-engineering technologies.

1.2 Consider geo-engineering as a game of football. Mankind plays on the current favorite team, the greenhouse gas (GHG) "Releasers." Mankind also plays the underdog, the "Sustainables." The Sustainables win by preventing the releasers from scoring another melted glacier, drought, or dead coral reef and score when renewable energy replaces fossil fuels, or anthromorphic GHG release is prevented.

1.3 A long time ago, the "orderly game" football officials gained the upper hand and implemented the "offside" rule. The offside rule effectively limits scoring. In our game against GHG, "zero environmental impact" is our offside rule. Many solutions have some impact: wind energy makes noise, looks ugly, kills birds, might change wind patterns when conducted on a massive scale; desert solar changes the desert; ocean iron fertilization might change ocean nutrient patterns; and reflective particles in the atmosphere address only the atmospheric heating. However, mankind needs every possible score against GHG release. It's tough enough to hit the net without an "offside rule" demanding only "perfect" solutions. On the other hand, each "shot on goal" requires substantial human effort and time. We must take high percentage shots. Mankind needs a universally inspiring and technically proficient coach. A special new wiki[3] can be that coach.

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[2] *Wikinomics—How Mass Collaboration Changes Everything*, Don Tapscott and Anthony D Williams, expanded edition, Penguin Group, 2008.

[3] The most well known wiki is WikiPedia. A wiki is software that helps people collaborate on the Internet. Most are collections of information. The wiki that organizes the information from hundreds of collaborators to continually adjust decisions does not yet exist.

2. Categories of Geo-Engineering

2.1 The International Panel on Climate Change (IPCC) identified three categories for countering GHG release.

2.1.1 The IPCC defines mitigation, "An antropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases." This includes for example; planting trees, energy efficiency, renewable energy, high-pressure anaerobic digestion, and chemical/mechanical "trees." On the necessary scale, all are geo-engineering.

2.1.2 The IPCC defines Adaptation, "Adjustment in natural or human systems to a new or changing environment." This includes for example; moving dwellings above the new river flood levels or sea levels, building new water conveying facilities, and water desalting facilities. At the global scale, this treating the local symptoms of excess GHG is geo-engineering.

2.1.3 The IPCC defines Geo-Engineering, treating one or more global symptoms of increased GHG as, "Efforts to stabilize the climate system by directly managing the energy balance of Earth…" This includes mirrors in space, insulating blankets on glaciers, adding quicklime to the ocean, and reflective particles in the atmosphere.

2.2 The Innovation, Universities, Science and Skills Committee, should not limit itself to the IPCC definitions. Because of the scale, any Climate Change cause and solution is Geo-Engineering. GHG release is Geo-Engineering. Spraying millions of tons of saltwater droplets high in the air, ocean-based high-pressure anaerobic digestion, converting millions of tons of corn into ethanol, and deploying millions of wind turbines are all Geo-Engineering.

2.3 The Committee may continue to slot various technologies into the IPCC categories for consistency sake. However, the categories do not matter in a truly transparent priority ranking system. What matters is quickly identifying and constantly reevaluating which technologies are the best players. Do not let the human tendency to characterize everything get in the way of determining the best combination of players. For example, not all Mitigations, such as corn ethanol, are automatically worthy of more funding than all Adaptations, such as desalting seawater.

2.4 The game is fluid as new players come on and off the field. Any tool attempting to prioritize technologies must be continually updated. The game will run for many generations and several centuries.

3. Transparency

3.1 Every human participates in the game of Climate Change. Only transparent, trust-building decisions will bring and keep a preponderance of people on the Sustainables for many generations. Some will be referees sorting out truth. Some will be players by championing or developing technologies. Some will be fans, buying technologies and electing managers. Some will be managers, allocating resources. All will be constantly tempted to switch teams. Many will switch back and forth over their lifetimes.

3.2 Countries need to trust each other and work together. That is buy-in by 51% of every democratic country, or the leadership of every autocratic country, is more useful than unevenly distributed buy-in by 80% of the world's people or 80% of the world's wealth.

3.3 But Climate Change is like the prisoner's dilemma, a zero-sum game, or drug doping in sport. Everyone and every country is tempted to selfishly maintain or advance their standard of living. The tremendous difference between countries' standard of living amplifies the desire to opt out of Climate Change solutions adverse to a country's economic competitiveness.

3.4 Trust is only possible with trustworthy communication. Conversely, the lack of trustworthy communication amplifies natural selfish tendencies. Fortunately, mankind has the tools for trustworthy communication of every human with every other human in a language every human can understand. The Internet allows every referee, player, manager, and fan to communicate with everyone else individually and collectively.

3.5 Unfortunately, no one has the time to listen to seven billion people. That's why we need an inspiring and technically proficient coach. The coach absorbs the observations of managers, players, and fans, the abilities of the players, and abilities of the opposing players, and infinite other factors. A good coach processes all those factors into a winning game strategy. Not a static strategy, but a dynamic strategy that adjusts constantly.

3.6 Even if we desired, no one person, one organization, one country, or partial collection of countries can be the coach. The game is too complex and exclusivity will not inspire trust. Climate Change is too complex because there are thousands of potential actions, thousands of known environmental and economic impacts, and thousands of unknown environmental and economic impacts. Even if one group could sort all this out and recommend actions, a few previously unknown impacts would appear before the suggested action, with all the reasons therefore, can be translated for everyone. Even after the suggested action is translated, those not involved in selecting the action will not trust it is indeed the best action. Corn ethanol is an example of a well-meaning play by one group that resulted in an "own goal." That is, while corn ethanol appears to make a modest reduction in local fossil fuel use, the impacts on food supply, global land use, and increased ocean dead zone area make it a better play for the Releasers than the Sustainables.

3.7 All seven billion of us can be the coach that builds trust and simplifies the complexity. We need to develop a special kind of wiki, a judgewiki. A judgewiki will combine a wiki's "many hands make light work" approach with a decision-matrix spreadsheet and other software designed to provide globally transparent decisions.

4. Sorting Technologies

4.1 A conceptual sample spreadsheet component of a Climate Change judgewiki is attached. The technologies are listed in one column. Criteria are listed in other columns. Each technology is given a score for each criterion. One can "score" every technology for each criterion and then "sort" the technologies for which are better based on each technology's total score.

4.2 A matrix also allows one to sum the ecological and economic sustainable production of each technology. People will more easily see that tremendous volumes of many technologies are needed for the Sustainables to win. That is, those inclined to impose an offside rule, can more quickly see that insisting on "perfect" solutions virtually guarantees losing the game.

4.3 We should arrange the judgewiki to avoid two pitfalls with many current decision systems, commission reports, and group web sites. One is the too-quick discouraging of out-of-box suggestions. The other is a tendency to focus too narrowly on one's mission. Both can arise when retaining only experts in a particular field. Experts may not notice, mention, or properly value new technology from areas outside their expertise. A collection of 1945 vacuum tube experts planning for the year 1965 vacuum tube factory, do not include transistors in their planning. A collection of 2003 investors and politicians narrow their focus to "immediately available American biofuel" and increased corn ethanol production increases burning of tropical forests, increases the size of the Gulf of Mexico dead zone, encourages the mining of fresh water, and only debatably reduces oil dependence and fossil carbon dioxide emissions.

4.4 Ideally, the judgewiki itself evolves, much like the open source operating system Linux is evolving. It can become more accurate and more fun. For example, social scientists are finding that market forecasting can predict outcomes better than polls or experts, particularly when the forecasters are diverse and don't stop thinking independently. Market forecasting relies on averaging the "bets" of many people to predict an outcome. Essentially, it allows people to "buy" stock in the outcome of an event. The March 2008 Scientific American provides a discussion of market forecasting starting page 38. Popular Science runs a future prediction market at ppx.popsci.com. The judgewiki may include collaboration as part of a multi-player video game, much like the Geek Squad exchanging tips while playing Battlefield 2.[4]

4.5 The judgewiki is the coach; deciding the training and positions for each player. It is a continually updating list of each technology's priority. It indicates the total resources available and how much from which sources should be spent on each technology. It may, for example, decide in February 2009, that energy efficiency efforts are best funded by private enterprise, some technologies (perhaps wind and solar thermal) only need a carbon credit or tax on the GHG releasers, and $10 billion per year is an adequate government investment in basic energy research spread over the top 100 technologies. The judgewiki may suggest maintaining a reserve for jumping on a technology that rises into the top 90 on June 2009 while government funding on whichever technology dropped to 101st ramps down quickly.

4.6 When sorting alternatives in a decision matrix, not every criterion should have the same weight. More likely, the criteria weights are adjusted depending on the situation presumed for each judgewiki. (No reason not to have many derivative judgewiki's as a sensitivity check on both criteria weights and the ranking points given each technology.) For example, a judgewiki guiding government basic research funding allotments, would favour long-term eco-system sustainability when providing more than a fifth the world's energy or sequestering more than a fifth the world's anthromorphic GHG release over economics. A judgewiki that presumes a few countries will remain major GHG releasers, or that atmospheric GHG concentrations are already above the tipping point, would emphasize quick and inexpensive means to address both atmospheric heating and ocean acidity.

[4] *Wikinomics—How Mass Collaboration Changes Everything*, page 242. ". . . But then, you know, while we're running along with the squadron with our rifles in our hands, one of the (Geek Squad) agents behind me will be like, 'Yeah, we just hit our revenue to budget' and somebody else will be like, ' Hey, how do you reset the password on a Linksys router? . . . (Robert) Stephens says the agents now have up to 384 colleagues (from all over the world) playing at one time."

5. Facilitate Collaboration

5.1 The Innovation, Universities, Science and Skills Committee should facilitate collaboration and then pay attention to the result. That is, the Committee should indicate a desire for and fund a small staff dedicated to assisting volunteers[5] to band together in building a judgewiki that:

5.1.1 Allows engineers (and others) to self-select their roles in geo-engineering solutions to climate change.

5.1.2 Guides funding national and international research activity concerning all aspects of geo-engineering.

5.1.3 Suggests university courses (and allows universities to self-select which universities offer which classes) and other forms of training relevant to geo-engineering.

5.1.4 Establishes the status (relative funding) of geo-engineering technologies in government, industry and academia.

5.1.5 Engages young people to play for the Sustainables in the engineering profession.

5.1.6 And becomes the voice of engineers in informing policy-makers and the public regarding the potential costs, benefits and research status of different geo-engineering schemes.

[5] Many Internet projects, Wikipedia, Linux, Facebook, YouTube, Human Genome Project to name a few, rely on volunteers. The volunteers determine how they would like to be compensated.

MANAGING CLIMATE CHANGE, JUDGEWIKI-MATRIX TEMPLATE, AUGUST 2008

Goal—emissions reduction or sequestration (Gt/y). 2005 world emissions of CO_2 were 28 Gt. Allowing the developing world to emerge from poverty implies the total for renewable energy solutions will increase and a goal of 40 Gt/y is appropriate.

(This is a conceptual draft decision matrix for the purposes of discussing a judgewiki. An actual judgewiki would contain multiple variations of every possible technology. The costs and scorings are fictitious, useful only to see how technologies might be scored and their combined effects added. An actual judgewiki would have links to research results and reports plus a measure of "potential" and "proven.")

Technology	*Capacity comments*	*Capacity (Gt/y of CO_2)*	*Selected effort (%)*	*Running total contribution (Gt/yr of CO_2)*	*Human cost—That carbon tax or trade which makes it competitive with the "free" dumping of CO_2*	*Net cost ($/t)*	*Cost score, 1 to 10 with 10 the least cost*
Cease burning trees	Developed countries need to pay developing countries to conserve trees	0.5	100%	1	an opportunity cost	$2	9
Ocean Anaerobic Digester, CH_4	None, fully sustainable approaching 10x 2005 world energy demand	15	30%	5	Estimated without prototype	$50	7
Energy efficiency	Using less energy for the same standard of living	5	100%	10	capital expense balances operating savings	$0	10
Ocean Anaerobic Digester, CO_2	Centuries of 2005 world emissions	15	30%	15	Estimated without prototype	$30	7
Wind energy	Limited areas for economics, inconsistent power	6	50%	18	Beyond 5–15% of grid, needs backup systems	$25	8
Move dwellings to higher ground	Equivalent CO_2 reduction by adaptation	2	50%	19			3
Solar photovoltaic	Limited hours, good for warm climate peak power, expensive.	4	50%	21	Beyond 5–15% of grid, needs backup systems	$50	7
Solar thermal	Limited hours, good for warm climate peak power, expensive.	4	50%	23	Beyond 5–15% of grid, needs backup systems	$50	7
Ocean iron fertilization	Limited appropriate ocean areas	1.0	100%	24	Needs full scale research	$5	9
Reflective roofs and roads	Equivalent CO_2 reduction by radiance	1.0	100%	25			3
Nuclear fission	Limited fuel even with recycling	3	100%	28		$100	6
Grow and harvest trees	Requires fresh water	2	100%	30	Water and food opportunity costs	$5	9

Technology	*Capacity comments*	*Capacity (Gt/y of CO_2)*	*Selected effort (%)*	*Running total contribution (Gt/yr of CO_2)*	*Human cost—That carbon tax or trade which makes it competitive with the "free" dumping of CO_2*	*Net cost ($/t)*	*Cost score, 1 to 10 with 10 the least cost*
Chemical "tree"	Mountains of materials	5	100%	35		$50	6
Plant more reflective forests	Equivalent CO_2 reduction by radiance	0.5	5%	35			7
Chemically raising ocean pH	Equivalent CO_2 reduction by adaptation	0.5	5%	35			5
Place particles in stratosphere	Equivalent CO_2 reduction by radiance	0.5	5%	35			9

Mitigation—reduce GHG emissions or remove GHG from atmosphere (potential cures)			*Adaptation—manage the impacts of GHG (local symptom treating)*			*Radiance Engineering—manage solar irradiance (global symptom treating)*			
Technology	*Appropriate Govt investment*	*Appropriate private investment*	*Persistence—A score of 1 may be less than 100 years while 10 is more than 10,000 years*	*Persistence score*	*Ecological cost—A measure of species diversity impacts*	*Ecological Score*	*Synergy—Potential to address 2+ issues simultaneously*	*Synergy score*	*Total score for this technology, higher score is better*
Cease burning trees			Infinitely persistent, constant temptation	9		10	CC & native peoples	9	37
Ocean Anaerobic Digester, CH_4			Infinitely persistent, removes temptation	10	May increase species diversity, needs work	9	Energy, CO_2, food, species diversity	10	36
Energy efficiency			Infinitely persistent, constant temptation	10	Depends on how more efficient items are produced	8		8	36
Ocean Anaerobic Digester, CO_2			Encased liquid CO_2 in deep ocean, needs research	8	Good potential, needs details	9	Energy CO_2, food, species diversity	10	34
Wind energy			Infinitely persistent, removes temptation	10	Birds, local eco	7		5	30
Move dwellings to higher ground			Move once	10	Disturbs new locations	8	Rebuild green	8	29
Solar photovoltaic			Infinitely persistent, removes temptation	10	Manufacture, low impact on roofs, higher in deserts	7		5	29
Solar thermal			Infinitely persistent, removes temptation	10	Local eco impact	7		5	29
Ocean iron fertilization			Needs research	5	Questions maturing	7		7	28

Mitigation—reduce GHG emissions or remove GHG from atmosphere (potential cures)			*Adaptation—manage the impacts of GHG (local symptom treating)*			*Radiance Engineering—manage solar irradiance (global symptom treating)*			
Technology	*Appropriate Govt investment*	*Appropriate private investment*	*Persistence—A score of 1 may be less than 100 years while 10 is more than 10,000 years*	*Persistence score*	*Ecological cost—A measure of species diversity impacts*	*Ecological Score*	*Synergy—Potential to address 2+ issues simultaneously*	*Synergy score*	*Total score for this technology, higher score is better*
Reflective roofs and roads			Routine maintenance	5	manufacture materials	9		8	25
Nuclear fission			Infinitely persistent, removes temptation	10	used fuel, local heating, water intakes and use	6		2	24
Grow and harvest trees			Fires a hazard	1	local water/natives issues	7		6	23
Chemical "tree"			Need to breakout options	8		6		2	22
plant more reflective forests			Routine maintenance	5 difficult to predict	3 5	20			
Chemically raising ocean pH			Constant maintenance	1	Alkalinity plumes	4		6	16
Place particles in stratosphere			Constant maintenance	1	difficult to predict	3		3	16

Memorandum 144

Submission from Stephen Salter, Emeritus Professor of Engineering Design, Institute for Energy Systems, University of Edinburgh

1. Summary

— At a recent energy conference Simon Vasey, trading manager of the major electricity provider Eon, said that while profits of billions of Euros had been made from the first round of the European carbon trading scheme not one kilogram of carbon had been abated.

— The monthly addition of points to the Keeling curve shows no reduction in the upward acceleration.

— Discussions of carbon emissions have used per nation rather than *per capita* data. A judicious choice of baseline date and the removal of shipping, aviation and the proxy carbon associated with imported goods has allowed at least one country to claim carbon reductions when in fact there has been an increase.

— The track record of the IPCC with regard to the timing of predicted events has been poor with several potential positive feed backs, such as the loss of Arctic ice, happening more rapidly than predicted in the earlier reports. People working for the IPCC report privately that there is intense pressure to modify wording from home governments.

— Ice core records show that have been many abrupt rises in world temperatures of a size and rate that would be catastrophic to a high world population. People who know a great deal about the problem and who have been studying it from the time when others thought it unimportant, now say that a sudden rise, perhaps at the next *el Niño* event, is likely and that, because the full effects of emissions lag their release, we may already be too late.

— Even if there are strong reasons for not deploying geo-engineering systems there is no case for not supporting vigorous research into every possible technique and for taking all feasible ones to the stage at which they could be rapidly deployed. This view is not yet shared by DEFRA and UK funding bodies.

— After 35 years work trying to develop renewable energy systems I now believe that it may not be possible to deploy enough of them quickly enough to prevent very serious consequences of climate change. For the last four years I have been working full time on the engineering design of one of the several possible techniques. The idea, due to John Latham, former Professor of Atmospheric Physics at the University of Manchester and now at the Centre for Atmospheric Research at Boulder Colorado, is to increase the reflection of solar energy from marine stratocumulus clouds by exploiting the well-accepted Twomey effect. Engineering drawings and design equations for a practical system are well advanced and can be made available to your Committee.

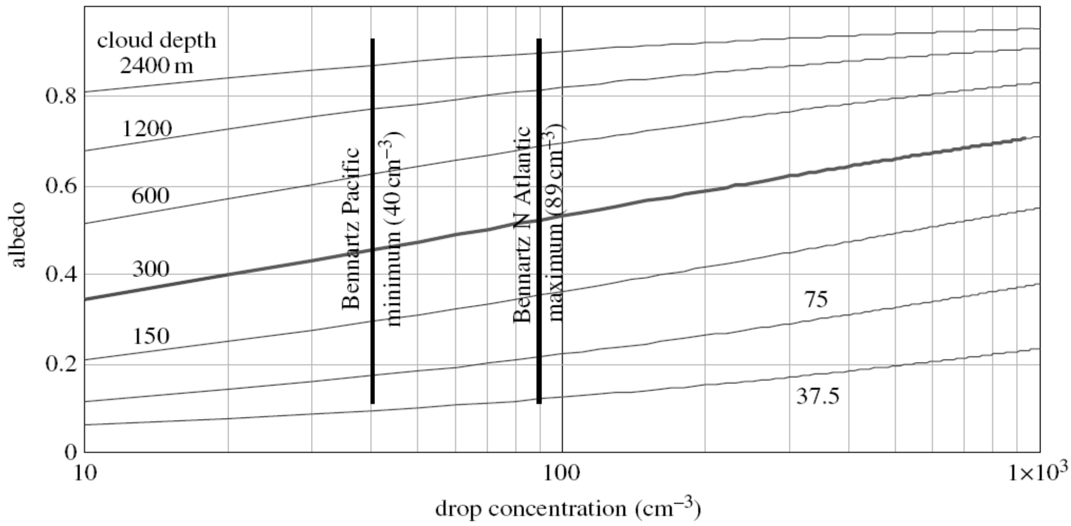
— Like everyone working in geo-engineering I do so with reluctance in the hope that it will not be needed but fearful that it may be needed with the greatest urgency.

2. The Twomey Effect

1. Twomey says that, for the same liquid water content, a large number of small drops will make a cloud reflect more than a small number of large drops. We would expect something like this from calculations of reflecting areas. We can see it with jars of glass balls of different sizes. We talk of dark storm clouds gathering when the drops become large enough to fall.

2. Even if the relative humidity goes above 100% a cloud drop cannot form without some form of condensation nucleus on which to grow. Over land there are plenty of suitable nuclei, 1,000 to 5,000 per cubic centimetre of air. But in clean mid ocean air the number is lower, often below 100 and some times as low as 10. In 1990 Latham proposed that the number of condensation nuclei could be increased by spraying sub-micron drops of sea water into the turbulent marine boundary layer. Initially the drops would evaporate quite quickly to leave a salty residue. Turbulence would mix these residues evenly through the marine boundary layer. Those that reached the clouds would provide ideal condensation nuclei and would grow to increase the reflecting area and so the cloud albedo.

3. The equations in Twomey's classic 1977 paper can be used to produce the graph below.



4. This follows the presentation used by Schwarz and Slingo (1996) and shows cloud top reflectivity for a typical liquid water content of 0.3 gm per cubic metre of air for a range of cloud depths as a function of drop concentration. The vertical bars show the range of drop concentrations suggested by Bennartz (2007) based on satellite observations.

5. If we know the initial cloud conditions, most especially the concentration of condensation nuclei, we can calculate how much spray will produce how much cooling. The method needs incoming sunshine, clean air, low cloud and the absence of high level cloud. The position of the best places varies with the seasons so sources should be mobile. Because the ratio of solar energy reflected to the surface-tension energy needed to generate drops is so large, it turns out that the spray quantities are quite practical. In the right conditions a spray source with a power rating of 150 kW can increase solar reflection by 2.3 TW, a ratio of 15 million. This is the sort of energy gain needed if humans are to attempt to influence climate.

3. Hardware

1. The need to operate for long periods in mid-ocean and to migrate with the seasons points to a fleet of remotely operated wind-driven spray-vessels. These can obtain the electrical energy needed to make spray by dragging turbines like oversize propellers through the water. Thanks to satellite communications and navigation remote operation is now much easier.

2. Rather than solve the robotic problems of handling ropes and textile sails we propose to use Flettner rotors. Flettner rotors offer much higher lift coefficients and lift drag ratios than sails or aircraft wings but their main attraction is that a computer can control the rotation speed of a cylinder far more easily that it can tie a reef knot. Anton Flettner built a ship, the Baden-Baden, which crossed the Atlantic in 1926. She won a race against a sister ship with a conventional rig and could sail 20 degrees closer to the wind. The weight of rotors was one quarter of the weight of the rig that they replaced. Flettner won orders for six ships and built one, only to have the orders cancelled because of the 1929 depression. Modern bearings with spherical freedom and materials like Kevlar and carbon-fibre would make rotors even more attractive. Enercon, the major German wind turbine maker launched a 10,000 tonne rotor assisted ship on 2 August 2008. The television company Discovery Channel has funded successful trials of a 34 foot yacht conversion. They also carried out an experiment at sea which confirmed expectations of the very high energy gain offered by the Twomey effect.

3. Design calculations and general arrangement drawing of the first spray vessel are well advanced. It has a waterline length of 45 metres and a displacement of 300 tonnes. Early vessels have space for a crew as well as the option to transfer control to an auto pilot and from land. Future ones may be a little smaller. All sensitive equipment is in hermetically sealed cylindrical canisters which can be individually and thoroughly tested on land and quickly exchanged. With three spray systems it will be possible to spray 30 kg a second as 0.8 micron drops. A fleet of 50 vessels in well-chosen places could cancel the thermal effects of the present annual increase of greenhouse gases. Work packages and costings for a five-year development programme which would provide a reliable tested design for the ocean going hardware are available.

4. The change of cloud reflectivity necessary to stabilize global temperature despite a doubling of pre-industrial CO_2 is about 1.1% globally or 6% if evenly spread in cloudy areas. The contrast-detection threshold for fuzzy irregular patterns is much higher, about 20%. It will be necessary to develop a method to convince non-technical decision makers that anything has changed. The spray generation modules have

been designed so that one of them can be fastened to the hull of a conventional ship and can produce spray at 10 kg a second, drawing electrical power from the ship system. The ship would sail to a selected mid-ocean site and then drift to a sea anchor so as to minimize its own exhaust emissions.

5. The *MODIS AQUA* satellite system crosses most of the world at the same local time each day. We would download photographs of the shortwave radiation signals (channels 1, 3 and 4). These would be translated to align the ship positions and then rotated to bring the mean wind directions to be coincident. Multiple images of the cloud system would be added over a period of a few weeks. The random clouds should average to a medium grey with contrast of the wake improving with the square root of the number of photographs. Photographic superposition will allow the measurement of the result of a very small spray release.

4. Potential Side Effects

1. Our understanding of the world's climate system is far from complete because it is so difficult to carry out controlled experiments over the size range from condensation nuclei to continental weather systems. All geo-engineers are anxious about unintended consequences. Early models show that very large spray injections can have effects in either direction at long distances from the injection site in the same way that el Nino events can influence climate far from Chile and Peru. We also know that release from different sites can have quite different results. We therefore must regard the world climate system as having a large number of possible controls set by when and where we choose to release spray. So far, we have no idea about which control does what. However it should be possible to learn by a series of very small experiments using release patterns modulated on and off at the right periods in a known sequence followed by the measurement of the long-term correlation of climate parameters with the known input. This pseudo random binary sequence technique works well with analysis of communication networks without being noticed by users.

2. Modern computers do allow increasingly sophisticated analysis and prediction. Recently there has been a great deal of progress on computer simulation of all the effects of albedo control. The leading team is at the National Centre for Atmospheric Research at Boulder Colorado and is led by Philip Rasch using the most advanced fully-coupled air/ocean model. This produces results for nearly 60 atmospheric parameters presented as maps, zonal graphs and mean values. Evenly spread releases are less damaging than large point injections.

3. The amount of salt that cloud albedo control will inject into the atmosphere is orders of magnitude below the amount from breaking waves, some of which falls on land. The difference is that albedo control uses a carefully chosen, narrow spread of drop diameters.

4. The immediate effect of cloud albedo control will be a reduction of solar energy reaching the sea. The ocean temperatures are the primary driver of world climate but oceans are a very large thermal store so the effect will be slow. Currents and winds are efficient ways of distributing energy and sharing it with the land so the eventual effects will be well distributed. A short term engineering approach to choosing a cooling strategy would be to look at historic data on sea temperatures and attempt to replicate a pattern thought to be good with regard to sea levels, harvests, hurricane frequency, floods and droughts. Rather than thinking of the side-effects of we should really be studying the side effects of NOT doing albedo control and letting sea temperatures rise. We would then decide which of the outcomes was the least damaging.

5. A first effect of warmer seas is greater evaporation. Even though it is left out of many diagrams showing the effects of greenhouse gases, water vapour contributes at least an order of magnitude more global warming than carbon dioxide.

6. The second effect of warmer water flowing north is the loss of summer Arctic ice.

7. A third effect is that surface water temperatures above 26.5 C increase the probability and severity of tropical cyclones, hurricanes and typhoons.

8. Warmer surface water increases the density difference between it and the nutrient-rich cold water below it. If nutrients cannot flow to where there is light there will be no phytoplankton to act as the start of the marine food chain or as the source of dimethyl sulphide and a sink for carbon dioxide. At present dimethyl sulphide accounts for about 90% of the cloud condensation nuclei, (Charlson 1987) and sea warming will reduce the area producing it.

9. The sea has been soaking up much of the anthropogenic CO_2. Rising temperature will release it.

10. Very large amounts of methane are stored in permafrost and even larger amounts as clathrates in the seabed at depths of a few hundred metres. The release of either could be regarded as an extreme side-effect of warmer seas and has been linked to the Permian extinction.

11. So far the only suggested negative effect of increasing cloud condensation nuclei is the possibility of reduced rainfall, something that people in Britain and Bihar would greatly welcome. The production of rain is a very complex process. A gross engineering over-simplification is that rain needs quite large drops to fall through deep clouds collecting smaller drops in their path so that they get big enough not to evaporate in the drier air below the cloud before they reach the ground. It is known that too many small drops due to nucleation from smoke from bush fires can reduce rain.

12. Clearly we must be cautious about doing albedo control up-wind of a drought-stricken region. However the driest regions are dry because subsiding air prevents winds blowing in from the sea. Perhaps a larger temperature difference between land and sea could produce a stronger monsoon effect to oppose part of the subsiding flow.

13. The effects of the nuclei that we produce will fade quickly. The marine stratocumulus clouds we will be treating are usually not deep enough to produce rain. But we could argue that if they were, the immediate effect would be to stop the rain over the sea and coastal regions. This would leave more water vapour in the air to give rain further inland where its value will be greater.

14. If we do not yet know enough about the side-effects of albedo control, at least we know more than about those of uncontrolled temperature rise. But the strongest defence is that we can start with small steps, move away from places where problems occur and stop in a week if some natural event, such as a volcanic eruption, should provide unwanted cooling.

5. Politics

1. Control of the UK climate is in the hands of DEFRA. Official funding goes to many laboratories who tend repeat the conclusions from the previous funding that the climate problem is even more serious than previously thought and argue that more funding is necessary to find out how much more serious. There is a reluctance to fund any research into technology which is "not yet soundly proven". The present DEFRA policy is that carbon reductions are the best solution to the climate problem and also that they should be the only solution on the grounds that the possibility of alternatives might reduce pressure to reduce emissions. This is strikingly close to the view of senior officers in the RFC in world war I that issuing parachutes to pilots "might impair their fighting spirit". They were not even allowed to buy their own. The geo-engineering community agrees with the rank order of desirability of emission reduction to geo-engineering but asks "what progress in emissions reduction?"

2. People from the vigorous carbon trading market are emphatic that there could be, even should be, no parallel thermal trading equivalent and so it seems that, at present, there is none of the commercial return needed to attract research funding. Many geo-engineers agree that decisions about deployment should not be based on commercial considerations.

References

Bennartz R 2007. Global assessment of marine boundary layer cloud droplet number concentration from satellite. *Journal of Geophysical Research*, 112, 12, D02201, doi:10.1029/2006JD007547, From http://www.agu.org/pubs/crossref/2007/2006JD007547.shtml

Bower K, Choularton T, Latham J, Sahraei J and Salter S 2006. Computational assessment of a proposed technique for global warming mitigation via albedo-enhancement of marine stratocumulus clouds. *Atmospheric Research* 82 pp 328–336.

Charlson RJ, Lovelock JE, Andreae MO and Warren, SG April 1987. Oceanic phytoplankton, atmospheric sulphur and climate. *Nature* 326 pp 655–661.

Latham J 1990. Control of global warming. *Nature* 347 pp 339–340.

Latham J 2002. Amelioration of global warming by controlled enhancement of the albedo and longevity of low-level maritime clouds. *Atmos Sci Letters*. 2002 doi:10.1006/Asle.2002.0048.

Latham J, Rasch P, Chen C-C, Kettles L, Gadian A, Gettleman A, Morrison H, and Bower K, 2008 Global temperature stabilization via controlled albedo enhancement of low-level maritime clouds. *Phil. Trans Roy Soc A* Special issue October 2008.

Salter SH, Latham J, Sortino G, Seagoing hardware for the cloud albedo control of reversing global warming. *Phil Trans Roy Soc A* Special issue October 2008.

Schwartz SE and Slingo A 1996. *Enhanced shortwave radiative forcing due to anthropogenic aerosols In Clouds Chemistry and Climate* (Crutzen and Ramanathan eds.) pp 191–236 Springer Heidelberg.

Websites

About parachutes: http://www.spartacus.schoolnet.co.uk/FWWparachutes.htm

Collected papers http://www.see.ed.ac.uk/ ~ shs

INDOOR DEMONSTRATION OF THE TWOMEY EFFECT

The jar on the left is contains 4 mm clear glass balls and has an albedo of about 0.6. The one on the right has glass balls one hundredth of the size and an albedo over 0.9.

September 2008

Memorandum 145

Submission from Professor Brian Launder, School of MACE, University of Manchester

1. I write first to draw the Committee's attention to the theme issue on Geo-Engineering that is to appear in the *Philosophical Transactions of the Royal Society* and for which (in collaboration with Emeritus Professor Michael Thompson) I have acted as editor. The issue is already available on-line through the Royal Society (though will not be available in print form for nearly two months). As a "sampler" of the issue I attach further files containing the preface and abstracts of the papers which members can consult if they wish. For the purposes of the Committee's work I would particularly draw their attention to papers that describe:

(i) enhancing the brightness of (ie the reflection of light from) low-level maritime clouds by Latham *et al* (considering the science) and Salter *et al* (the engineering);

(ii) the review of ocean fertilization by Lampitt *et al*;

(iii) two papers on stratospheric seeding by Rasch *et al* and Caldeira and Woods;

(iv) a paper by Zeman and Keith describing a scheme for effectively re-cycling CO_2 by combining it with hydrogen to produce a fuel for transport more compatible with the existing transport infrastructure than would be hydrogen alone.

In addition, the paper by Anderson and Bows provides emphatic evidence of the urgent need for such Geo-Engineering schemes to be brought to a state of development where they could be deployed on a "geo-scale" if (as seems increasingly likely) it becomes necessary.

2. The schemes proposed in the above papers all seem feasible and I hope that all can, over the next 10 years, be carried through the pilot phases to enable their relative potential and risks to be accurately assessed and for the best schemes to become available for deployment.

3. I would mention one further scheme that does not appear in the theme issue: "air capture"—the direct capture of CO_2 from the atmosphere through what amounts to a forest of artificial trees covered in CO_2-absorbing devices (artificial leaves). This scheme invented by Professor Klaus Lackner, Columbia University, is undergoing further development through commercial support.

4. The majority of geo-engineering approaches originate from North America. The work I know of in the UK does not seem to be impeded by lack of initial funding. There is however the risk that schemes showing potential at a PhD research level do not receive the level of developmental support needed to bring them to the stage of readiness suggested in 2 above. The Carbon Trust should be required to earmark a proportion of its budget for such geo-scale development.

5. Every geo-engineering researcher I have met does not (as your invitation for contributions wrongly seems to suggest) see geo-engineering as a solution to global warming. Rather, it offers a means of gaining two or three decades of breathing space during which the world must find routes for moving to a genuinely carbon-neutral society.

6. The term "geo-engineering" is also used by some to include geo-scale strategies for creating carbon-free energy (as well as the schemes alluded to above for preventing sunlight from reaching the earth or absorbing the CO_2 released from fossil fuel remote from the source). It is unclear to me whether the Committee is adopting such a wider view but let me assume that it does. To the writer the most attractive approach of this type of geo-engineering would be very large-scale solar power. For example, one might construct in the Sahara (or some other sparsely populated region reasonably close to the equator) huge arrays of photo-voltaic panels (say 100km x 100km) with the electrical power created used to produce hydrogen to account for the diurnal spread of power or to enable distant transhipment (perhaps after conversion to a hydrocarbon fuel via the Zeman-Keith scheme noted above). If such "electricity factories" were situated reasonably close to the coast and the array of PV cells was mounted on stilts, one could envisage using a small proportion of the electrical power generated to desalinate sufficient water to irrigate the soil beneath the PV arrays rendering it suitable for agriculture, whether to generate food or bio-fuels. (This idea was suggested by an article I read about the parking lot at the US naval base in San Diego being covered with just such an array of PV cells. Besides generating some 750kW of electrical power the parking lot users reported that the PV panels "created a pleasant shaded feel around the parked cars".)

September 2008

Memorandum 146

Submission from Dan Lunt, School of Geographical Sciences, University of Bristol

— Several geoengineering schemes have recently been proposed to mitigate against global warming.

— Current understanding related to the possible efficacy, side-effects, and cost-effectiveness of these schemes is extremely low.

— Before large sums of money are invested into any of these schemes, they need to be thoroughly assessed in a coherant national program of research.

1. There is almost universal consensus that "dangerous" climate change must be avoided. However, without radical changes in energy sources and usage and global economies, it seems highly likely that we will start to experience unacceptably damaging and/or societally disruptive global environmental change later this century.

2. Geoengineering (the "intentional large-scale manipulation of the environment") has been considered for the mitigation of such dangerous climate change in response to elevated anthropogenic greenhouse gases, at least in conjunction with other mitigation strategies. Various such schemes have been proposed, such as the removal of CO_2 from the atmosphere by locking it up in terrestrial biomass, pumping it into the deep ocean, or injecting it into geological formations, or manipulation of the energy budget of the climate system by the injection of sulphate aerosols into the atmosphere, construction of a space-based "sunshade", or modifications to the land and/or ocean surface to reflect more sunlight back to space.

3. However, many of the geoengineering schemes proposed remain un-quantified in their impact, and some are extremely unlikely to work at all. All may give rise to undesirable climatic side-effects and have hidden "costs", both economic and environmental. This was highlighted in a recent study[6] carried out at the University of Bristol, where a state-of-the-art climate model was used to assess the climatic impact of a space-based sunshade. Previously, it was widely assumed that such a geoengineering scheme could revert climate back to a "pre-industrial" state. However, this study found that although the impact of CO_2 emissions would be reduced, it was inevitable that there would still be a residual climate change of considerable magnitude, resulting in the loss of Arctic sea-ice. Additionally, such schemes leave other CO_2-related problems, such as ocean acidifcation, completely unaddressed.

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[6] Lunt, DJ, A Ridgwell, PJ Valdes, and A Seale (2008), *Sunshade World*: A fully coupled GCM evaluation of the climatic impacts of geoengineering, Geophys Res Lett, 35, L12710, doi:10.1029/2008GL033674.

4. That study, examining just one particular method of geoengineering, highlights the fact that we currently have insufficient scientific information to adequately support the debate we need to have. A DEFRA Discussion Paper circulated earlier this year perfectly illustrates the high-level interest, yet also the critical need for a more reliable quantitative understanding of the benefits, risks, and costs, together with an ethical perspective.

5. Before any geoengineering scheme is implemented, or substantial funds are invested in geoengineering technologies, we would recommend the funding of a national program designed explicitly to improve current understanding of the efficacy, side-effects, practicality, economics, and ethical implications of geoengineering. This would bring together climate scientists, engineers, economists, and philosophers. Of course, such a program would complement similar investigations into the economics and practicality of other mitigation and adaption strategies, such as improved energy efficiency, reduced energy use, and more energy production from renewable sources.

October 2008

Memorandum 147

Joint submission from: the British Geophysical Association (BGA) (a joint association of the Geological Society of London (GSL) and the Royal Astronomical Society); the Royal Astronomical Society (RAS); the Environmental and Industrial Geophysics Group (EIGG) of the Geological Society of London; and the Institute of Physics (IOP)

Brief Details of the Respondents

Geophysics is such a broad discipline, encompassing so many sciences, that UK geophysicists have not formed a single geophysical society but joined the professional society nearest to their speciality. The BGA includes geophysicists specialising in the solid Earth, geodesy and geomagnetism, who are members of the GSL and/or the RAS. It exists to promote geophysics in education, research, scholarship and practice. The RAS also represents geophysicists specialising in the physics of the upper atmosphere, Sun-Earth interactions and other planets. The BGA works closely with the EIGG, which represents applied solid-earth geophysicists working in the fields of Earth resources and civil engineering. The BGA is also working with the IOP to promote geophysics education.

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Summary

We offer a two-part response:

1. Geophysics, a predictive science from local to global level, essential for informed decisions on geo-engineering projects;

2. Education in geophysics relevant to geo-engineering.

1. *Geophysics, a predictive science*

   (a) geophysics is a quantitative, predictive science essential for geo-engineering;

   (b) without geophysics, geo-engineering projects involve unnecessary risk;

   (c) geophysics requires long-term, global data sets, and consequently political stability.

2. *Education in Geophysics*

   (a) The British Geophysical Association in 2006 published a report on the state of university-level education in geophysics, after several geophysics courses closed despite high unsatisfied demand for geophysicists in the job market;

   (b) shortages of employees with geophysical skills in the industrial and education sectors were due to profound ignorance of geophysics in schools;

(c) training of current and aspiring teachers in geophysical aspects of the science syllabus is essential;

(d) inspiring students to aim for geophysics qualifications by promoting the opportunities it brings and highlighting the need for geophysics in geo-engineering and the relevance of geo-engineering to current life and problems might help to address the shortfall.

1. Geophysics, a Predictive Science from Local to Global Level, Essential to Informed Decisions on Geo-Engineering Projects

Main points

(a) geophysics is a quantitative predictive science essential to geo-engineering;

(b) without geophysics, geo-engineering projects involve unnecessary risk; and

(c) geophysics requires long-term, global data sets, and consequently political stability.

What is Geophysics?

Geophysics is the application of physics to the study of the Earth. It encompasses seismology, including earthquakes and "viewing" the Earth's interior with seismic waves; magnetic fields of the Earth and the space around it; subterranean heat and volcanology; oceanography and meteorology, particularly ocean currents and ocean-earth-atmosphere energy exchange; geoelectricity; and microprocesses such as rock-fluid interaction and their effects on the macro-world in oil exploration and extraction, contaminant disposal and groundwater exploitation.

Geophysics as a Predictive Science

Geophysics is used to predict the future of oil and water resources, the effects of climate change and natural disasters and the evolution of engineering sites, eg, for waste disposal. Prediction is done by creating computer models of the physical processes involved, eg, tsunami travel across oceans; the global atmosphere models used in climate change prediction. Geophysicists use sophisticated statistical methods to find the "best fitting" models to real data. The following are four examples of predictive geophysics.

Example 1—Antarctic ice sheet prognosis and global sea level rise

The flow of "ice streams" off the ice caps of Antarctica and Greenland makes a large contribution to the removal of ice to the sea. Geophysical techniques, including ground-penetrating radar and shallow seismic commonly used in ground engineering investigations, are combined with geodetic surveys to monitor the flow rate and investigate the wetness of the glacier bed (Murray 2008). A wet bed is more slippery, so increased flow of meltwater into the bed of the glacier might lead to collapse and hence global sea level rise. Ice sheet collapse does not cause a uniform rise in sea level, because the unburdened land also rises, and ocean currents, modified by the influx of fresh water, in turn cause different amounts of thermal expansion of the water in different places (Milne 2007). Predicting the exact rise at a given place, eg the Thames Barrier, requires geophysical knowledge about all these sources.

Example 2—Underground methane hydrate

Although carbon dioxide (CO accepted by most scientists to be the main cause of the modern increase in greenhouse effect, methane might be more crucial. It is a greenhouse gas ten times more potent than CO much smaller quantities can seriously impact global temperature. Most of the Earth's available methane is now held in the form of "methane hydrate" in sub-seafloor sediments and permafrost (USGS 1992). The methane gas molecules are each held in a fragile "ice cage", which is stable over only a narrow range of temperatures and pressures. A modest warming disrupts the cages, releasing methane, from which a runaway effect might occur as the additional greenhouse warming caused by the methane releases more methane. This effect may have contributed to an episode 55 million years ago (the "Palaeocene-Eocene thermal maximum") (Maclennan and Jones 2006) in which global temperature rose by 6C. The amount of methane available now in hydrate is thought to be twice the carbon equivalent of the Earth's fossil fuel reserves, and its confining, capture or even use as fuel would be massive geo-engineering projects. Research is ongoing on how vulnerable this methane hydrate is to the present rise in global temperature. Geophysical surveys detect the hydrate, determine what proportion of the sediment it fills, and reveal its past release (which in itself was catastrophic: eg the Storegga underwater landslide offshore Norway has been blamed on hydrate, Bugge *et al* 1988, and may have caused a tsunami round northern Scotland, Smith *et al* 2004).

Example 3—Massive hydrofracturing to release stress before earthquakes

The stress in the Earth's crust that is eventually relieved by an earthquake affects a volume of rock many times larger than the eventual rupture zone. Cracks of all sizes between microns and tens of metres respond to this stress and can be monitored via their scattering of waves passing through them from any seismic disturbance. It has been suggested that if some of the stress could be relieved, then the eventual earthquake would be smaller, and that pumping high-pressure water into the ground in many places to widen the cracks and encourage small slippage on many small faults would achieve this. This would be a geo-engineering project dependent on geophysics: for the hypothesis, the historical seismicity record, prediction of the effect of hydrofracture based on geophysical measurements of rock properties in the lab and in situ, choice of sites and drilling techniques, and quantifying the amount of stress reduction from the effect of crack modifications on seismic waves (Crampin *et al* 2008).

Example 4—Effects of Geo-Engineering on existing and proposed facilities

The effects of geo-engineering on existing and proposed infrastructure and culture must be predicted and monitored, and possibly prevented or mitigated. This includes everything from our archaeological heritage to waste disposal facilities. Past global changes are recognised through their effects on archaeological and prehistoric remains; locating and investigating these remains is partly a geophysical task, as shown by the *Time Team* TV programmes, for which electrical and ground-probing radar were used. Geophysical monitoring with permanently installed instruments can detect pollutant leakage from landfill waste sites (White and Barker 1997). For nuclear waste sites, geophysical projects are needed (CoRWM 2006, recommendation 4) to determine site suitability (eg, Holmes 1997, Norton *et al* 1997, Haszeldine and Smythe 1996). The Yucca Mountain site in the USA (US DoE 2002a) is in an area of recent tectonic activity close to lavas erupted only 75,000 years ago (Detournay *et al* 2003). The water table is now at least 160 m below the proposed repository, but might rise in the future (US DoE 2002b). Geophysics, including measuring permeability and heat flow, dating the lavas, and modelling, is being used to predict risks to the site during 10,000 years after it is sealed (OCRWM 2003). Crucial groundwater resources worldwide are sensitive to environmental change. Geophysical techniques monitor level and salinity, and model the effect of (geo-engineered or other) change on water supplies.

The need for long data sets

Much of the prediction is based on understanding past behaviour. Weather records dating back to 1659 (Met Office website) and national tide gauge records to 1953 (Proudman Oceanographic Lab website) are part of the UK's rich legacy of geophysical observations. Globally, instrumental records of earthquakes now span over 100 years, but the return period of devastating earthquakes such as the Sumatra-Andaman (26 December 2004) one is many times that. UK seismological records spanning centuries are required for risk assessment of critical facilities such as nuclear reactors and waste disposal sites, not only from earthquakes but from decadal or longer-term trends in the weather, which can be inferred from seismic records because weather affects the "noise" measured by seismometers between earthquakes.

Possible solar activity effects on climate and effects of "space weather" (rapid large fluctuations in the magnetic field surrounding the Earth, and hence arrival of high-speed particles from the Sun), on national electricity grids and satellites (Hapgood and Cargill 1999), have highlighted the need for long data sets of observations of the ionosphere and magnetosphere. Measurements of many terrestrial phenomena need to be made continuously at fixed places (Douglas 2001): breaks in continuity, by either moving the instruments or interrupting the measurements, cause long-term effects to be lost or disguised by the "jump" in values at the discontinuity.

Another sort of long dataset is repeated surveys, for instance, satellite and airborne radar, geomagnetic and electromagnetic and radioactivity measurements, and so-called "4-D seismic", repeated high-density seismic surveys over the same target. These are needed for "before" and "after" records of the effects of single events and for the recognition of gradual effects of, for instance, oil extraction, urbanisation and coastal erosion.

Long-term datasets require political commitment of: funding for their continued collection and archiving, regulation to allow the measurements to continue undisturbed, and staffing by experienced professionals to ensure quality. Short-term grants and contracts, and funding fluctuations causing abrupt cuts and loss of "institutional memory", all threaten continuity. The recent cut to STFC funding for solar-terrestrial physics is an example. It is not clear yet whether the bidding process to be introduced by NERC for science carried out by its institutes will cause disruption of long-term dataset collection, particularly in the Antarctic.

Conclusions

Geo-engineering will waste resources or cause more harm than good if it is not underpinned by thorough, good-quality retrospective and predictive geophysics, which in turn depends in many cases on long and unbroken data sets of measurements of natural phenomena. The political climate encouraging the collection and maintenance of long-term datasets and the recognition of geophysics as a vital contribution to geo-engineering should be nurtured.

2. Education in Geophysics Relevant to Geo-Engineering

Main points:

(a) The British Geophysical Association in 2006 published a report on the state of university-level education in geophysics (Khan 2006), after several geophysics courses closed despite high unsatisfied demand for geophysicists in the job market;

(b) a shortage of employees with geophysical skills in the industrial and education sectors was caused mostly by profound ignorance of geophysics at school level;

(c) training of current and aspiring teachers in geophysical aspects of the science syllabus is essential;

(d) inspiring students to aim for geophysics qualifications by promoting the opportunities it brings and highlighting the need for geophysics in geo-engineering and the relevance of geo-engineering to current life and problems might help to address the shortfall.

What is Geophysics Education?

Since geophysics is the application of physics to the study of the Earth, it is a broad subject involving major sciences—physics, engineering, geology, environmental science, oceanography, meteorology, astronomy and planetary science. Aspects of most of these are taught in geophysics degree courses. Modern geology, including engineering geology, is largely based on geophysical observations, and Earth Science courses accredited by the GSL must contain elements of geophysics. The sophisticated interpretation by geophysicists of field observations frequently underpins engineers' planning of major developments; hence civil engineering courses also contain geophysics. Archaeology degrees use geophysics, made popular by recent TV coverage. A geophysics education followed by work experience can lead to a varied career involving:

— deducing geological structure and physical properties beneath the surface for exploration for oil, gas, geothermal energy, water, and other raw materials;

— environmental monitoring; civil engineering;

— the disposal of CO_2 and nuclear waste;

— military activity;

— the location of archaeological remains; and

— forensic science including the monitoring of test-ban treaties.

Geophysics as a predictive science, for instance in climate prediction as mentioned above, requires research-oriented graduates with strong mathematical and computing skills.

Employers' views of geophysics education

Responses from 36 employers (25 in the oil industry) strongly emphasised the need for high quality geophysicists, and pointed out difficulties in recruiting such UK graduates. A typical geophysics-dominated degree does not lead directly to an engineering qualification, but would fit the student to the role of a geophysicist in geo-engineering, working in a team with engineers or as a consultant. It provides a rigorous training in physical science and key technical and computing skills required for research and industry, as well as teamworking, presentation and other transferable skills.

To the employers responding in 2006, the "taught MSc" was the best-known and most desired qualification, and the major employers bemoaned their reduction to only one (at the University of Leeds). The more broadly based BSc is also highly favoured by some. The MSci and the MRes degrees introduced in the late 1990s were not well understood. The most desired skills were: theoretical and practical geophysics with geology and IT. Overall, there was concern about the growing shortfall in the supply of well-trained geophysicists at a time when demand is increasing. While physics or other numerate graduates can be employed in geophysical roles, their on-the-job retraining is an expensive burden to employers (G Tuckwell, pers comm, 2008).

Present and future employment destinations of geophysics graduates

At the time of the survey (2005–06), 14% of graduates went into careers in the environment sector, 3% into mining and 43% into the oil industry. The Khan report predicted that increasingly sophisticated geophysics will be needed as resources become scarcer and targets more elusive, and that there will be a growing demand for well-educated geophysicists. Three examples related to geo-engineering are:

(i) a major contractor with a CO_2-sequestration section (Gould 2008) states that hydrocarbons are becoming increasingly challenging to extract, and the shortage of engineering talent is the single largest factor stopping customers from investing more; there is an estimated $2–3 billion cost to the oil and gas industry of the shortage of skilled employees (First Break 2008);

(ii) repeatedly, disasters have occurred where underground engineering decisions were insufficiently informed by geoscience, hence modern civil engineering operations require sophisticated geoscientific preliminary investigations (Turner 2008); and

(iii) there is an increasing need to control risk from hazards like earthquakes, volcanoes and tsunamis as population grows in regions affected by these.

40% of geophysics students in 2006 were female, which is a good proportion for a physics-based science and suggests that increasing the number of geophysics graduates might have the additional benefit of increasing the proportion of women in science.

Causes of decline of UK university-level geophysics courses

During the past three decades, geophysics education in the UK has declined, with many courses started in the 1960s and 1970s being discontinued in the late 1990s. In particular, the five Research Council-funded vocational MSc courses in geophysics are now reduced to one, and in 2008 there were only seven BSc or MSci courses in geophysics and 14 others with minor geophysics content.

The 2006 report found that probably the main reason was that most students entering university were ignorant of the existence of geophysics. Universities' efforts on their own to increase awareness of geophysics were limited by resources. The MSc courses used to be the safety net for those students who discovered the subject while on university first degrees in other sciences, but the numbers applying have been decreasing rapidly. This is partly due to the discontinuation of 80% of the geophysics MSc courses over the last 15 years. Other factors include: graduate debt, exacerbated by the better quality undergraduates being encouraged to complete four-year MSci programmes in their own undergraduate disciplines before or instead of an MSc; the static numbers of physics graduates; and the wide range of careers open to them in physics, finance, IT, computing, and commerce.

Recommendations of the Report

The strongest recommendation of the 2006 report was that geophysics must be included in the physics A-level syllabus to add to the interest and encourage more students into physics, as well as to increase awareness of geophysics as a career. Training in geophysics for teachers is consequently needed. The employment of a dedicated geophysics promotions officer was recommended. Despite a warm reception from industry, this was stalled by simple lack of time of the volunteers on the BGA committee, most of whom were academics beset with the pressures of the 2008 Research Assessment Exercise. The greatest need now is to re-launch the initiative, finding a base for the proposed officer in an institution specialising in education promotion and above all, support for volunteers from the academic/industrial community (minimal money: the issue is penalty-free time) to form a committee to oversee the work.

Conclusion

UK leadership in geo-engineering will depend on a healthy and well-supported industrial and academic geophysics community, starting at school level.

References

Bugge, T, Belderson, R H, and Kenyon, N H, 1988, The Storegga Slide, Philos. *Trans R Soc London A*, 325, 357–388.

CoRWM, 2006, Managing our radioactive waste safely, CoRWM's recommendations to Government, Committee on Radioactive Waste Management, Doc 700, London.

Crampin, S, *et al*, 2008, GEMS: the opportunity for forecasting all damaging earthquakes worldwide, Proc Evison Symposium, submitted to Pure Appl Geophys.

Detournay, E, Mastin, L G, Pearson, A, Rubin, A M, and Spera, F J, 2003, Final report of the Igneous Consequences peer review panel, Bechtel SAIC company LLC, Las Vegas.

Douglas, A, 2001, The UK broadband seismology network, Astronomy & Geophysics 42, 2.19–2.21.

First Break, May 2008, Recruitment special supplement.

Gould, A, 2008, No easy solutions for meeting future energy demand, First Break, 26, July 2008, 47–51.

Hapgood, M A, and Cargill, P, 1999, Astronomy and Geophysics 41, 2.31–2.32.

Haszeldine, R S, Smythe, D K (eds), 1996, Radioactive waste disposal at Sellafield, UK: site selection, geological and engineering problems, University of Glasgow, Glasgow.

Holmes, J, 1997, The UK rock characterization programme, *Nuclear Engineering and Design*, 176, 103–110.

Khan, A, 2006, Geophysics Education in the UK, a review by the British Geophysical Association, http://www.geophysics.org.uk

Maclennan, J, and Jones, S M, 2006, Regional uplift, gas hydrate dissociation and the origins of the Paleocene-Eocene Thermal Maximum, Earth and Planetary Science Letters 245, 65–80.

Milne, G, 2007, William Bullerwell Lecture, British Geophysical Association, Astronomy and Geophysics, 49, 2.24–2.28 (April 2008).

Murray, T, 2008, William Bullerwell Lecture, British Geophysical Association (abstract at http://www.geophysics.org.uk)

Norton, M G, Arthur, J C R, and Dyer, K J, 1997, Geophysical survey planning for the Dounreay and Sellafield geological investigations, in McCann, D M, *et al* (eds), 1997, Modern Geophysics in Engineering Geology, Engineering Geology Special Publication 12, Geological Society of London.

OCRWM 2003, The exploratory studies facility, Fact Sheet, DoE/YMP-0395, Office of Civilian Radioactive Waste Management, Las Vegas, NE, USA.

Smith, D E, *et al*, 2004, The Holocene Storegga Slide tsunami in the United Kingdom, *Quaternary Science Reviews* 23, 2291–2321.

Turner, A K, 2008, The historical record as a basis for assessing interactions between geology and civil engineering, *Quarterly Journal of Engineering Geology*, 41, 143–164.

US DoE, 2002, Yucca Mountain Site Suitability Evaluation, DOE/RW-0549, US Department of Energy, Las Vegas.

US DoE, 2002a, Final environmental impact statement for a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste at Yucca Mountain, Nye County, Nevada, DOE/EIS-0250, US Department of Energy, Washington, DC, USA.

US DoE, 2002b, Yucca Mountain site suitability evaluation, DOE/RW-0549, US Department of Energy, Washington, DC, USA.

USGS 1992 http://marine.usgs.gov/fact-sheets/gas-hydrates/title.html

White, C C, and Barker, R D, 1997, Electrical leak detection system for landfill liners: A case history, *Ground Water Monitoring and Remediation*, 17, 153–159.

September 2008

Memorandum 148

Submission from the Royal Academy of Engineering

Summary

— Geo-engineering is taken to be any activity designed to effect a change in the global climate.

— There are two general approaches: indirect carbon sequestration and reducing solar insolation (the amount of energy absorbed by an area of the earth from the sun).

— All the current proposals have inherent environmental, technical and social risks and none will solve all the problems associated with energy and climate change.

— Geo-engineering is multi-disciplinary in nature, with all of the relevant issues already taught in standard science and engineering courses.

— Current levels of academic research in the UK are low with a similarly low level of interest in UK industry.

— Failure by the international community to effectively tackle climate change has allowed geo-engineering onto the agenda despite the inherent risks.

1. Introduction

1.1 Climate change is one of the defining issues of our time and one that ultimately affects everyone on the planet. To date, the efforts of scientists, engineers and governments have been concentrated on three areas: understanding the climate and how human behaviour influences it; mitigation of global warming by reducing carbon emissions; and adapting to the effects of climate change. Increasingly, scientists are warning that concentrations of greenhouse gases in the atmosphere continue to rise are approaching dangerous tipping points beyond which serious and irreversible damage to the environment will occur. This has led some to propose a fourth strand in our fight against catastrophic climate change, namely geo-engineering.

1.2. "Geo-engineering" is a loosely defined term relating to any engineering that is concerned with large-scale alterations to the earth or its atmosphere. This could include geological alterations, but for the purposes of this response we shall take the term to mean any activity designed to effect a change in the global climate. Alternatives terms such as "geo-environment engineering", "planetary engineering" and "climate engineering" have been coined and it will take some time before the terms and definitions become more widely accepted.

2. Proposed Geo-engineering Schemes

2.1 Thus far, there are two general approaches to geo-engineering: indirect carbon sequestration and reducing solar insolation. The body of scientific evidence suggests that the climate is changing because of an increase in the levels of greenhouse gases in the atmosphere so the first approach, indirect carbon sequestration, attempts to reduce the levels of these greenhouse gases. The advantage these schemes have is that, in essence, they are simply reversing the problem man has created—namely taking the carbon out that we have put in. There are a number of ways of achieving this such as:

2.1.1 *Air Capture*: Scientists such as Klaus Lackner[7] and Frank Zeman[8] of Columbia University have put forward a variety of proposals that are designed to extract CO_2 out of the atmosphere by absorbing it in a chemical solvent.[9] Once captured the carbon would then be stored underground in geological depositories. This technology relates closely to the more mainstream carbon capture and storage (CCS) proposals that are being developed to capture CO_2 from coal fired power plants. Capturing it from the power plant where it is much more concentrated is more efficient but a large proportion of CO_2 emitted is from small scale or mobile sources of emissions where direct sequestration is not applicable.

2.1.2 *Ocean Fertilisation*: By fertilizing certain regions of the upper ocean it is possible to encourage the growth of phytoplankton blooms that absorb CO_2 from their surroundings as they grow. A proportion of this plankton is made up of carbonate skeletons which upon death, sink to the seabed, thus potentially sequestering large amounts of carbon.[10] Trials of this approach have been carried out with varying results. The potential risks of these schemes, however, are great, interfering as they inevitably do in a globally crucial ecosystem.

2.2 The second approach, reducing solar insolation, tackles the problem from a different angle. Greenhouse gases cause the global temperature to rise because they trap more of the sun's energy within the atmosphere. If, however, the amount of energy reaching the earth is reduced or more is reflected this could reduce the global temperature. Again there are a variety of methods such as:

2.2.1 *Increasing the cloud albedo*: By reflecting the sun's energy away from the earth certain types of cloud under certain conditions have the effect of cooling the planet. The effect can be produced by either increasing the amount of cloud, or their longevity, or their whiteness. For example, scientists such as John Latham[11] of the National Center for Atmospheric Research in Boulder Colorado have proposed releasing tiny droplets of sea water in maritime stratocumulus clouds in order to increase their reflectivity and provide a cooling effect.

2.2.2 *Sulphate aerosols in the stratosphere*: The eruption of certain volcanoes such as Mount Pinatubo in 1991 release large amounts of aerosols into the stratosphere. These have a shading effect leading to a cooling of the planet. Attempts to mimic this effect have been put forward by a number of scientists.[12] The appeal of this scheme is its potential to have an almost immediate effect on global temperatures although, again, the risks are potentially great and irreversible.

2.3 The examples given above represent only a few of the geo-engineering schemes currently proposed. They are not necessarily the only possible technologies and as research into this field continues, more possible methods will be developed. It should, however, be pointed out that, thus far, no geo-engineering technique has been tested to any significant degree and some of them would be best described as purely speculative.

7 http://www.seas.columbia.edu/earth/lacknerCV.html
8 http://www.seas.columbia.edu/earth/faculty/zemanCV.html
9 http://www.physorg.com/news96732819.html
10 http://journals.royalsociety.org/content/t6x58746951336m1/
11 http://www.mmm.ucar.edu/people/latham/
12 http://journals.royalsociety.org/content/y98775q452737551/

2.4 It must also be remembered that none of these proposals will solve all of our energy and climate change issues. For instance, the schemes designed to reduce the amount of solar insolation would have no effect on the levels of greenhouse gases which are the root cause of the problem. They would not, therefore, stop the acidification of the oceans which may well prove to be as serious a problem as rising temperatures or sea-levels. Furthermore, none of the proposed schemes would have any effect on security of energy supply issues which are likely to become ever more serious as the population increases, countries develop and resources are strained.

3. The Role of Engineering

3.1 Engineering will clearly play an essential role in developing any of the potential technologies and, more importantly, assessing the risks and impacts associated with their deployment. In reality, the skills required to implement most of the technologies proposed are not unique and could be readily learned in standard engineering courses. Ultimately, engineers are extremely good at solving problems in a wide range of disciplines and the technical difficulties presented by most geo-engineering technologies would not present any particular problems requiring specific engineering based skills sets.

3.2 The question is therefore not whether these technologies could be implemented but whether or not they should be. In order to answer this question a number of other issues must be addressed; issues such as cost, environmental impact, sustainability and risk as well as the broader social and moral considerations.

3.3 Engineering has much to add in these areas, both independently and in conjunction with other disciplines such as climate science and environmental policy. Risk in particular is paramount when considering any attempt to deliberately alter the earth's climate. The potential consequences could be disastrous and a great deal of research, modelling and testing would need to be carried out before moving forward with any geo-engineering scheme. A good understanding of how geo-engineering would affect the complex systems it would inevitably be a part of is also something that engineers have a wealth of experience in dealing with.

4. Education and Research

4.1 In educational terms, geo-engineering is very multi disciplinary in nature. The skills needed cover a wide range of topics from the basic science of climate change to technical, economic and environmental issues. All these subjects are already part of standard university courses, and engineering courses in particular, and graduates coming out of these programmes will already be equipped to move into geo-engineering research should they so wish. Thus, at present, it is not deemed necessary for geo-engineering to be introduced into the curriculum as a topic in its own right.

4.2 On a related matter, it has been suggested that geo-engineering might be a good subject with which to engage with young people and encourage them into the engineering profession. As was noted earlier, climate change is a hugely important issue and one that garners a large amount of media attention. Young people appear particularly concerned about what mankind is doing to the planet and keen to work towards finding solutions. Highlighting the crucial role all engineering disciplines have in working out what those solutions might be and, more importantly, actually making them happen, is the key issue and should be more than enough to attract the younger generation. Focusing solely on geo-engineering would be a distraction for what would only ever be a narrow branch of engineering.

4.3 Currently, levels of research into geo-engineering are very low, even in global terms. The Academy itself does not fund any research in this field despite a strong interest in energy and climate change. That is not to say that we would not be open to the possibility of funding research into geo-engineering. Indeed, the Academy recently established a Research Chair in Emerging Technologies, aimed at research into technologies at a pre-competitive stage. This would have been eminently suitable for geo-engineering technologies and in fact, an application focusing on artificial photosynthesis was received, but in this instance it was not successful.

5. Industry and Government

5.1 The next stage after education and research would be actual field testing. This could be carried out either by universities—perhaps with support from Government—or by industry. At present, geo-engineering is barely visible to industry in the UK. Given this low level of interest and the inherent high financial risks involved it is likely that Government funding would be needed in the early stages of testing. However, depending on the particular technology chosen and the relative costs, it is possible that some forward thinking industries might take an interest, although this seems more likely to happen at this stage in the US where geo-engineering has a higher profile.

5.2 A major consideration for industry would be the potential for profit if the technology were to be successful, and indeed, how success could be measured. A globally recognised price for carbon might provide a financial incentive for some of the sequestration technologies and if this was sufficiently high or the technology sufficiently low cost the profits could be considerable. These technologies might also be eligible for the Virgin Earth Challenge prize of $25 million for ". . . a viable technology which will result in the net removal of anthropogenic, atmospheric greenhouse gases each year for at least 10 years without countervailing harmful effects."[13] This prize, announced by Sir Richard Branson and Al Gore in February 2007, could also serve as a driver to industry although the terms and conditions do limit the number of potential winners.

5.3 Neither the price of carbon nor the Virgin Earth Challenge prize is applicable to the technologies designed to reflect solar energy away from the earth. Here, the only measurable effect would be change in temperature either locally or globally. It is possible that a local effect could be measured in a reasonably short time frame and hence provide the potential for a private company to charge for such a service. But, in terms of global changes in temperature, it would be almost impossible to attribute such changes to one specific technology and it is hard to see why any private company would consider such an option without the direct involvement of a government.

5.4 This does, however, highlight one of the main differences between geo-engineering and other methods of dealing with climate change. Mitigation and adaptation require coordinated global action and, as the Kyoto agreement has shown, this requires long and difficult negotiations between the world's governments. Progress is being made politically but it is slow and the effects of climate change are already with us. Mitigation and adaptation can also be expensive (although as the Stern Review pointed out the cost of action now is likely to be a great deal lower than doing nothing and having to pay later). Also, regardless of the efforts being made on reducing greenhouse gas emissions, the inertia of the earth's climate means that we are already tied into decades of warming. With geo-engineering, the effects could be much more immediate and low cost in comparison with current approaches.

5.5 Individual governments could see geo-engineering as an excuse to continue with a business-as-usual approach and would be able to act independently, thus bypassing the sometimes tortuous path to international agreement. A number of international treaties covering the oceans, atmosphere and space would, in theory, prevent such action. However, these are not always adhered to hence the risk, albeit small, of a state acting unilaterally cannot be ignored. It is therefore incumbent on the Government to stay well informed on this issue, particularly in its international relations on climate change and the environment.

6. Conclusion

6.1 It might seem imprudent to even consider geo-engineering given the potentially enormous risks associated with it. However, despite stark warnings from climate scientists over the past decade or more about the dangers of greenhouse gas emissions and concerted government action to curb these emissions very little has actually been achieved. Atmospheric concentrations of carbon dioxide continue to rise and the predictions of climate scientists become ever more pessimistic. Geo-engineering should never been seen as an ultimate solution in any sense. Even if it could help to alleviate the effects of climate change it has nothing to add in terms of security or sustainability of energy supplies. Mitigation and adaptation are still the best long term policies but if time really is running out and geo-engineering was able to provide some breathing space it would be morally remiss of us not to at least consider this option.

6.2 Engineering would play a central role in developing any of these technologies and assessing their potential impact. It would also be crucial in addressing the enormous inherent risks. Even though geo-engineering is still very much in its infancy, a number of scientists and engineers around the globe are working seriously on such technologies and as such, it cannot be ignored. A great deal of research is required before any of the possible geo-engineering schemes should ever be contemplated on a global scale. And even then, they must not be seen as an excuse to continue on a business-as-usual path. That said, it is possible that any research carried out could help further our knowledge of the earth's climate and mankind's effect on it. Taking on board all these points, geo-engineering is a subject the Government should stay well informed on and treat with caution, being mindful of potential consequences.

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[13] http://www.virginearth.com/

Memorandum 149

Submission from the Tyndall Centre for Climate Change Research

THE POTENTIAL OF GEO-ENGINEERING SOLUTIONS TO CLIMATE CHANGE

1. *Background*

1.1 In January 2004 the Tyndall Centre for Climate Change Research (www.tyndall.ac.uk) and the Cambridge-MIT Institute (www.cambridge-mit.org) convened a special joint Symposium on "Macro-Engineering Options for Climate Change Management and Mitigation" in Cambridge, England. The purpose of the Symposium was to identify, debate, and evaluate possible macro-engineering responses to the climate change problem, including proposals for what is usually termed geo-engineering. The web-site for information on the Symposium is at www.tyndall.ac.uk/events/past_events/cmi.shtml.

1.2 This submission is based largely on the discussions and outcome of that meeting, updated with some more recent information. A copy of the summary report is available at http://www.tyndall.ac.uk/events/past_events/summary_cmi.pdf and also attached hereto (not printed).

2. *Summary of general issues*

2.1 Few (if any) of the proposals for potential geo-engineering solutions to climate change have so far advanced beyond the outline/concept stage.

2.2 Much more research on their feasibility, effectiveness, cost, and potential unintended consequences is required before they can be adequately evaluated.

2.3 In many cases it is new modelling and pilot-project scale engineering studies which are needed to make further progress, at quite modest cost.

2.4 Current schemes aim to adjust the Earth's radiation balance either by (a) modifying the planetary reflectivity (albedo) to reduce incoming radiation, or (b) to enhance removal of GHGs (especially CO_2) from the atmosphere to reduce the greenhouse effect.

2.5 Albedo modification schemes do nothing to reduce atmospheric CO_2 levels and hence (a) do nothing to ameliorate the problem of ocean acidification, and (b) create a risk of severe and rapid greenhouse warming if and when they ever cease operation.

2.6 Some CO_2 removal schemes involve major interference with natural ecosystems, or (like Carbon Capture and Storage) may require the secure disposal of large quantities of CO_2.

2.7 The environmental impacts of these schemes have not yet been adequately evaluated, but are likely to vary considerably in their nature and magnitude.

2.8 Too little is known about any of the schemes at present for them to provide any justification for reducing present and future efforts to drastically reduce CO_2 emissions.

2.9 A sufficiently high price of carbon will stimulate a host of entrepreneurial entrants into the geo-engineering market. This is probably essential in order to mobilize necessary capital and to stimulate a lively competition of technologies. However, it will brings with it difficult problems of regulation and certification.

2.10 The large uncertainties associated with geo-engineering schemes should not be regarded as reason to dismiss them. They need to be evaluated as part of a wider portfolio of responses, alongside mainstream mitigation and adaptation efforts. This should lead to a portfolio approach, in which a range of different options can be pursued, and adaptively matched to emerging conditions.

2.11 More attention however therefore also needs to be paid to the timescales (lead-times and potential durations) of geo-engineering schemes, so that they could be effectively phased, under different scenarios of climate change and alongside other abatement strategies.

2.12 The governance issues associated with geo-engineering are probably unprecedented. Who could and should control the technologies upon which the well-being of humanity may depend?

2.13 The equity issues are also likely to be substantial. There will be winners and losers associated with geo-engineering (as there will be with climate change itself). Should the losers be compensated, and if so how? Where the losses include non-market goods, which may be irreplaceable, how are they to be valued?

2.14 Geo-engineering is sometimes presented as an "insurance policy", but this analogy may be somewhat misleading. An insurance policy pays specified benefits under specific conditions, whose probability can be estimated. In the case of geo-engineering both the probability of it being required, and the benefits that it might yield are very uncertain.

3. *Observations on the role of engineering*

3.1 The principal requirement in the short term is for engineering research on the feasibility, costs, environmental impacts and potential unintended consequences of geo-engineering proposals.

3.2 In the longer term it is possible that engineers may be widely involved in the implementation and management of any schemes which come to fruition.

3.3 The range of skills involved covers the full spectrum of engineering, and there is no clear need for any particular specialisation.

3.4 Improved awareness and understanding by engineers of Earth System Science (and specifically of the the functioning of Earth's climate and ecological systems) would greatly assist the development and evaluation of potential schemes.

3.5 Most research at present is very small scale (concept development) and is mostly being undertaken in the USA.

3.6 There is no clear need for specialised university courses or training in this field: the clear requirement is rather for the provision of more supplementary interdisciplinary courses for students of conventional engineering disciplines (see item 3.4 above).

3.7 The awareness and status of geo-engineering technologies in government, industry and academia is low (often at the level of blissful ignorance) but is improving slowly.

3.8 It is possible that geo-engineering ideas may attract young people to the profession, but not very likely unless and until clear employment opportunities emerge.

3.9 Engineers have an important role to play in informing policy-makers and the public, especially about the feasibility, efficacy and likely costs of geo-engineering schemes.

September 2008

Memorandum 150

Submission from Colin Forrest

Summary

— Arctic specialists are warning that rapid massive release of methane from seabed sediments could occur at any time.

— This would cause a temperature rise of at least 6°C, with further rises from additional feedbacks. Impacts would be more severe and more rapid than those currently predicted by the IPCC.

— Some geoengineering proposals, particularly stratospheric injection of sulphate aerosols, and injection of seawater aerosol in the marine boundary layer, are sufficiently powerful, and technically feasible within the limited timescale, to avert this temperature rise.

— These ideas have been discussed and modeled within the climate community, but are untested, could be less effective, and could cause significant and possibly adverse effects on global and regional climate.

— It is an immediate priority that multidisciplinary scientific and engineering teams, with adequate funding and access to resources, test and develop these ideas, with a view to being able to implement full scale deployment within the next two decades.

— Priority should also be given to practical methods of avoiding the release of methane hydrates from the Arctic seabed, and of removing excess methane from the atmosphere.

Introduction and Overview

1.1 Recent measurements of elevated levels of methane on the shallow, rapidly warming continental shelves of Russia, where upwards of 540 billion tons of methane are vulnerable to rapid release, lend support to the worry amongst climate scientists that rapid release of greenhouse gases (GHGs) from warming and changing ecosystems could release such overwhelming quantities of GHGs that reductions in anthropogenic GHGs would make no difference to global warming. A release of 2%, or 10 billion tons, of this store would increase GMST by around 6oC, and would trigger further GHG emissions (from land based permafrost, tropical forest dieback, ocean outgassing, and increased forest fires in Asian peatlands, semi arid regions and the boreal forest).

1.2 If there is significant release of methane from the Arctic seabed, then geoengineering solutions will be our only option to prevent runaway warming. Unfortunately, earth science is still in its infancy, and has received less funding than other branches of science, eg aerospace, armaments or medicine, which have had more practical use to society (up til now). We are not starting from a strong baseline, and we might need to apply planet scale geoengineering within two decades.

1.3 Our ability to model the complex interactions within the earth/climate system is limited, as the failure of the IPCC climate models to predict the rapid melting of Arctic sea ice, underestimation of sea level rise, and rapid rise in surface temperatures (particularly in the Northern Atlantic/Western Europe region), has shown.

We need strong cooperation between existing climate scientists and practical engineers to quickly develop equipment to test and monitor geoengineering technologies on a local and regional basis, before large scale implementation.

1.4 There are many ideas and proposals, so I will concentrate on what I think are the strategically important ones. I have excluded space based proposals as unlikely to be technically achievable in the short timeframe, artificial atmospheric CO_2 scrubbing as likely to be too energy intensive and costly, and increased carbon capture from natural ecosystems (ocean fertilization/biochar/increased reforestation etc) although valid and achievable, as unlikely to produce sufficient reductions in atmospheric levels of GHGs to make a significant difference in the available timescale.

Carbon capture and storage (CCS) from power stations

2.1 This is a mature technology, which will become mainstream technology when a carbon price of around £26 per ton of carbon (or £95 per ton of carbon dioxide) is imposed on power generators, and requires mostly existing hydrocarbon exploration and refining engineering skills. I have included it partly to emphasize the need for climate engineering research in addition to rapid reductions in anthropogenic sources of GHGs.

2.2 CCS will be an essential component of any attempt to control anthropogenic GHG emissions, and a planned infrastructure of pipelines and transport infrastructure linking all large and medium sized sources of CO_2 (including biomass fired power stations) to geological storage sites, on a regional and international scale should be developed.

2.3 A target of capturing the emissions from all major new and existing power stations within two decades is technically and economically feasible, requiring only that the current generation of politicians find the courage to implement a global price of around £50 per ton of carbon emitted (whether by taxes or by cap and trade schemes). This would reduce global GHG emissions by around a third.

Stratospheric albedo engineering

3.1 The idea of injecting microscopic particles into the stratosphere to deflect incoming solar radiation has been discussed widely, and some very simple modeling has been done, showing that it could be sufficiently powerful to counteract some or all of the warming we have created, although it would likely alter radiation and precipitation patterns on the surface, and could not be used to target specific regions.

3.2 It must be stressed that our ability to understand circulation patterns, hydrology, atmospheric chemistry and radiation balance in the stratosphere is exceedingly limited, and our ability to predict or model changes due to deliberate addition of sulphur dioxide or other aerosols is minimal. Here linkages with aerospace and remote sensing engineers will be crucial, and ground based testing facilities will need to be improved.

3.3 Diurnal and seasonal variations in each hemisphere will need to be investigated. Whilst modeling might provide some initial hypotheses, large scale ground based testing facilities will provide more substantial results before field trials in the stratosphere.

3.4 Research is needed regarding the type of particles most suitable, which parts of the solar spectrum they will absorb or reflect, and their chemical and physical interactions in the stratosphere, particularly with water, oxides of nitrogen, ozone and hydroxyl ions.

3.5 (Hydroxyl ions (OH-) are the primary atmosphere scrubbers, oxidizing and removing carbon based pollutants. They are very reactive, short lived ions produced by the action of sunlight of 310 nm wavelength on water molecules, and they remove most of the methane which is produced from natural and human systems. This process is discussed further in the chapter on methane.

Marine albedo engineering

4.1 The idea of creating sea salt spray in the lower part of the atmosphere over the oceans (the marine boundary layer, up to around 500m), to increase the optical thickness and lifetime of marine stratocumulus cloud has been around for a while, and has recently become topical. It has recently been modeled at the Hadley Centre and seems to be powerful enough technique to offset much of the current anthropogenic warming, reducing the sea surface temperature, which is the fundamental driving force of the earth's heat engine. The change in surface albedo between the dark ocean surface and the enhanced cloud is quite significant, and the idea has the advantage of being easily targeted at specific locations (eg endangered coral reefs, tropical cyclone formation areas, Arctic areas where permafrost is in danger of melting), has nontoxic byproducts (salt water) and is readily reversible (the clouds have a lifetime of around a week).

4.2 The process can be easily be seen on satellite photographs, where the exhausts plumes of commercial ships, containing particles of black carbon and sulphur dioxide, leave long trails of artificially created clouds, similar to aviation contrails, behind them, where weather conditions are suitable.

4.3 Large areas of the world's oceans are suitable for cloud enhancement, but like all powerful climate engineering tools, the implementation could alter local climates, in particular the position of the Intertropical Convergence Zone (ITCZ) and associated rainfall, or lack of it.

4.4 Unfortunately, the current proponents Latham and Salter are proposing to disseminate the spray from of a fleet of unmanned, satellite controlled wind powered boats propelled by a novel form of sail; the flettner rotor, which creates three new and unusual technical problems, and reduces the credibility of the idea.

4.5 However the spray could be produced from standard ocean going vessels, solving two of the difficulties at a stroke, and leaving only the engineering problem of producing large volumes of a very fine aerosol of (filtered) seawater, between one and ten micrometers in diameter, and disseminating it into the marine boundary layer. I am no engineer, but I think the right people, with the right funding, could provide a useable solution for initial field trials within a year or two.

4.6 From my understanding of the rate of climate change, and of the possible proposals currently being discussed, I think that this is the most important single aspect of geoengineering that needs funded professional research and development. We can model the process until the cows come home, but until we start adding salt water aerosol to clouds in the marine boundary layer, we won't know how much will reach the cloud base, and what effect it will have.

4.7 Larger particles (or cloud condensation nuclei, CCN) are known to cause larger raindrops, which rain out and reduce cloud cover, and there is the possibility that large numbers of very small CCN will increase the number and surface area of water droplets, causing rapid evaporation and loss of cloud cover. CCN may coalesce to form larger drops. The number of pre-existing CCN, temperature, water vapour content, wind speed, rates of updraught and entrainment are all important factors and can only modelled approximately.

4.8 Some understanding of these processes might be gained from experimental set-ups on land, but fortunately, there are large areas of empty ocean to experiment on, and results can easily be verified by remote sensing, once we have developed suitable machinery for producing a very fine aerosol spray.

4.9 The above comments are a distillation of my studies over the last few years, a review of the work of more experienced scientists. The next sections explore what I think will be the new and important issues, which follow from the realization that we may have a summertime ice free Arctic Ocean between 2013 (the projection of the most radical Arctic expert) to 2030 (the projection of the most conservative Arctic expert). As most climate scientists work from projections of the models used in the IPCC Fourth Assessment Report, which envisage a proportion of summer ice remaining in the Arctic Ocean until at least 2100, and are not aware of the fast changing reality of the northern high latitudes, the following comments are likely to be original, and certainly well in advance of current thinking by mainstream climate scientists.

Preventing release of methane to the atmosphere from Arctic regions

5.1 The immediate danger appears to be the rapid thawing of seabed sediments in the shallow (up to 200m deep) Russian continental shelves, under the Barents, White, Kara, Laptev, and East Siberian seas, where the warm waters from the Gulf Stream/North Atlantic drift are increasingly being driven by the increased strength of the prevailing westerly winds and the funnelling effect of the disposition of the continental land masses of Greenland, Scandinavia and the North Asian continent.

5.2 Stratospheric injections of aerosols in the northern hemisphere, as discussed above, will reduce the overall SSTs in the tropical and sub-tropical Atlantic, reduce the heat brought north by the ocean currents, and reduce the incoming solar radiation in the Arctic region.

5.3 Increasing marine stratocumulus cloud cover (also discussed above) in the southern, tropical and northern Atlantic will also decrease oceanic heat transport into the area, and in the summer, could reduce direct incoming solar radiation in the region.

5.4 The Arctic is a special case in that it receives no solar radiation in winter, and clouds (and air pollution from North America and Asia) create an insulative layer, trapping heat. Raining out clouds in the autumn by injecting very large CCN may allow the Arctic to radiate more heat out to space in the winter. Seeding clouds for rain is currently is being used by countries including China, Australia and Thailand.

5.5 The other option is to mine out the layers of frozen methane in the sediments before they thaw. Methane hydrates have been successfully mined at the Malik-38 well on the McKenzie Delta on the northern shores of Alaska, and the hydrocarbon exploration industry has considerable experience of dealing with methane hydrates, which can cause drilling problems, blocked pipes, explosions etc. At present the focus is on commercial exploitation, but given sufficient financial incentive, it would be technically possible to prospect for, mine and flare off vulnerable deposits. Unfortunately the bands of frozen methane are widespread, can be in thin layers or at low pore densities, and often form a seal over free gas, which might be released catastrophically if the structural integrity of the cap is weakened. However the engineering problems are a continuation of those currently employed in seabed and Arctic exploration and the hydrates show up well in seismic surveys and well log analysis.

Removing methane from the atmosphere

6.1 In my personal opinion, even a rapid deployment of all the above techniques will be insufficient to prevent a dangerous (for global warming) increase in atmospheric concentrations of methane, given the wide distribution of methane in the Arctic, the hostile environment and the vast scale of the problem (The East Siberian shelf is the largest continental shelf on this planet).

6.2 This leaves us with the option of removing or oxidizing the methane once it has reached the atmosphere. Scientists previously thought that any released methane would dissolve in seawater and be oxidized by methanotropic bacteria, but recent air samples over the East Siberian shelf, and observations of bubbles in the waters of the Gulf of Mexico suggest that significant amounts will get into the atmosphere.

6.3 Some (possibly 25%) of current atmospheric methane is consumed by soil bacteria, and it has been suggested that genetic modification and culture could increase this, indicating a possible area for research.

6.4 Most atmospheric methane (possibly 75%) is oxidized by the hydroxyl ion, or OH radical, and this is the key determinant of atmospheric concentrations. After a substantial rise in atmospheric levels of methane from pre-industrial levels, in the last few years, methane levels have been steady, indicating a rise in the OH atmospheric sink, compensating for increased anthropogenic emissions. OH radicals are produced by sunlight on water molecules in the air, and the proposed explanation was that a warmer atmosphere could hold more water vapour, and hence allow more OH production. Unfortunately levels of methane in the atmosphere started rising again in 2007, and we don't know enough about the sinks and sources to know why.

6.5 OH radicals also oxidize carbon monoxide (40%), organic compounds eg isoprene from forests and dimethyl sulphate from plankton (30%), as well as methane (15%), and ozone (O3), hydrogen (H2)and hydroperoxy radicals (HO2).

6.6 It would seem easier to attempt to produce more OH radicals, rather than reduce atmospheric concentrations of the other chemical species which compete with methane, as we seem remarkable unable to reduce the amount of gases we produce from our activities. Also, several geoengineering solutions such as reforestation and ocean fertilization would also increase the amount of airborne carbon compounds as byproducts of increased biological activity.

6.7 The necessary ingredients would be water vapour and the high energy part of the solar spectrum (310nm). OH radicals are very reactive and have a lifetime of less than a second, so would need to be produced within air masses with high concentrations of methane.

6.8 As the oxidation of methane proceeds at a rate 100 to 1000 times slower than that of the other organic compounds mentioned above, research into a catalyst which speeded up the rate of oxidation of methane could also prove productive.

6.9 It is also worth pointing out that, even if the threat of catastrophic releae of methane from the Arctic is averted, research into the removal of methane from the atmosphere would be worth pursuing, as it would reduce global warming, and could have financial benefits within a GHG trading scheme.

Conclusions and Answers to Terms of Reference

7.1 At present engineers have minimal input into geoengineering research (with the notable exception of Professor Steven Salter.) Most work is done by established climate scientists and advanced students on an *ad hoc* basis. I know of no structured research or training, apart from one Ph D student at East Angia University, and funding is negligible. Many policymakers, and the established scientists working in quasi-political positions (IPCC, Defra and international counterparts), are unaware, or have insufficient evidence to act, regarding the possibility of global warming becoming uncontrollable, and the status of geoengineering was laughable, until the upsurge in media interest in 2008.

7.2 If geoengineering is to be successful, engineers with various specialized skills must form an integral and essential part of multi disciplinary scientific teams, including earth scientists, modellers, atmospheric physicists and chemists, geologists, oceanographers, meteorologists, biologists, remote sensing specialists, and others.

7.3 Engineers should be involved in the initial design of projects, providing limits to what is practicable or possible, and working on the building, calibrating, running, maintaining, monitoring and improving on the experimental testing of laboratory, field, regional, and full scale implementation of the above proposals. Engineers are also likely to be the best trained personnel to deal with project management, including cost estimates and budgeting, whereas generalist earth/climate scientists are likely to be best placed to advise of environmental costs and benefits, and the risks of non-action.

7.4 Key areas will include; aerospace, remote sensing, aerosol and nanoparticle production, marine engineering, geological exploration and drilling, and general design of materials and structures. Work in the harsh Arctic environment, and remote oceanic regions, will likely be needed.

7.5 Again I must stress that we still know little about the climate system, climate modelling is very complex, with considerable uncertainty over many basic parameters (including the influence of clouds and aerosols) and still omits many key processes (ice sheet dynamics, for example) and the safest and fastest way to develop effective geoengineering solutions is to provide practical field trials, scaled up as soon as practicable. Engineers will play a key part in these experiments, but we do not have the time to train up a new generation of personnel to take this forward. We must use the existing skills base.

7.6 Unfortunately, we are in the crisis management phase of geoengineering, which must be successful before a future generation of scientists and engineers can be trained up for the responsibility of ongoing management of the global climate.

September 2008

Memorandum 151

Submission from the Ground Forum

1. The Ground Forum

The Ground Forum brings together Learned Societies and Trade Associations representing most construction related geo-engineering disciplines. The Learned Societies undertake the dissemination of information and oversee professional qualifications; while Trade Associations represent the commercial interests of both consultants and contractors in the sector. The Ground Forum is therefore a single voice which draws together all construction related geo-engineering interests of both companies and individuals.

2. Summary

- For the purposes of this response, Geo-Engineering has been taken as synonymous with Ground Engineering, which is the terminology used in:
- Ground Forum's submission to the Home Office (UKBA) Migration Advisory Committee; and
- the Register of Ground Engineering Professionals which is being developed by Members of the Ground Forum for launch in 2009.

It is acknowledged that Ground Engineering is a specific sub-set of the broader subject of Geo-Engineering.

- Geo-engineering literally underpins all man-made structures but the fact that it is usually hidden from view means that it is often overlooked and undervalued.
- Geo-Engineering makes a huge positive contribution to climate change related actions via:
  - efficient use of resources and reduction of greenhouse gas emissions,
  - mitigation of the impacts of climate change, and
  - regeneration.
- The sector has not been well served by public funding for R&D and there is an urgent need for more independent, publically funded research that can be made available to the whole industry.
- The basic educational requirement to be a geo-engineer is a first degree in geology or civil engineering followed by an MSc, usually in geotechnical engineering or engineering geology. The shortage of MSc graduates is a serious problem and the industry has experienced severe and growing skill shortages for the last 10 years. The progressive withdrawal of NERC and EPSRC funding for post graduate MSc study has had a major impact.

— Because of its largely hidden nature, both Government and other industry professionals undervalue the role and contribution of geo-engineering. Consequently there is need for greater regulation to ensure that best use is made of geo-engineering skills and resources, and better recognition of the contribution it makes to the built environment.

3. Definition

Ground Engineering is a specific sub-set of the broader discipline of Geo-Engineering, which encompasses all engineering activities associated with natural geological, hydrological and climatological systems. Ground Engineering has three major, but related divisions:

— Geotechnical Engineering (a specialist branch of civil engineering);

— Engineering Geology (the application of geology to ground engineering); and

— Geoenvironmental Engineering (the identification and remediation of contaminated land).

4. The Current and Potential Roles of Engineering and Engineers in Geo-engineering Solutions to Climate Change

4.1 It is simplistic, but true, that everything rests on or in the ground and therefore geo-engineering literally underpins all man made structures. Unlike other construction materials, however, the ground is variable between sites and its properties change according in response to climatic changes. The engineering properties of the ground therefore require specific investigation and must be designed for on a site by site basis.

4.2 Geo-engineering professionals are required on a wider range of construction projects than any other construction profession. They are involved with all civil (and military) engineering works and all buildings, and are also essential for works in the natural environment such as slope and cliff stabilisation, where professions such as architects are not required, and, at the other end of the scale, with many domestic subsidence claims. This broad demand for ground engineering skills has been a major factor in the skills shortage affecting the industry (see paragraph 6).

4.3 Geo-engineering involves the investigation of ground conditions (eg geology, geotechnical properties, ground water and previous land use) and predicting how the ground will respond to specific natural and engineering changes, thereby enabling safe design and construction of foundations and other ground related structures (eg dams, tunnels, flood defence embankments, etc). The sector's roles in combating climate change, therefore, are threefold:

— ensuring efficient use of resources and reduction of greenhouse gas emissions, including pursuance of the recently launched Strategy for Sustainable Construction;

— mitigation of the impact of climate change; and

— regeneration of previously used sites.

4.4 Examples of how Geo-Engineering roles (ground investigation, design and construction) contribute to solutions for each of these areas are given below.

4.4.1 Solutions which make more efficient use of resources and thereby reduce production of greenhouse gas emissions:

— designs and construction techniques which reduce natural material usage;

— foundations for wind farms and marine current/tidal turbines;

— energy transmission, including undersea transmission of energy from wind farms and marine current/tidal turbines, pylons, and tunnels;

— hydro-electric schemes;

— carbon storage/sequestration (eg: installing pipelines to transfer captured carbon to suitable gas/oil fields);

— foundation design for nuclear power stations;

— underground storage of nuclear waste;

— design, construction and monitoring of reservoirs for water;

— heating from ground source heat pumps. (Note: These commonly comprise of horizontal and vertical trenches containing liquid filled tubes, which utilise the ambient ground temperature via a heat exchanger, to provide heat in winter or cooling in summer);

— heating from "energy piles". (Note: These also use ground source heat pumps but have tubes installed in the foundation piles of the building);

— deep geothermal energy ("hot rocks");

— re-use of existing piled foundations for subsequent developments on previously used sites (reduces concrete and steel use);
— evaluation of the carbon impact of available foundation systems;
— choice of foundation solution based on energy efficiency (based on above research);
— development of new carbon efficient foundation solutions;
— landfill management and the identification, disposal, and treatment of waste; and
— use of recycled materials and by products of other processes, including recycled aggregate, glass and pulverised fly ash (pfa).

4.4.2 Solutions which mitigate the impacts of climate change:

— repair and redesign of rail and highway embankments which are being degraded because of changes in precipitation, increased temperatures, and changes in vegetation;
— coastal management;
— upgrading/raising of the Thames Barrier;
— raising of embankments along the Thames to counter changes in sea level;
— control of inland flooding and flood relief schemes;
— control of subsidence in domestic housing and other buildings;
— increased water storage (surface and underground reservoirs); and
— design and monitoring of slope stability to reduce landslides and the effects of coastal erosion.

4.4.3 Regeneration:

— identification, evaluation and remediation of contaminated land, thereby minimizing use of greenfield sites;
— remediation and redevelopment of brownfield sites;
— environmental impact studies and remediation/mitigation;
— ground improvement to bring marginal land to a point where it can be used for the built environment; and
— improved transport and utilities—particularly those involving tunnelling.

5. National and International Research Activity, and Research Funding, Relating to Geo-engineering, and the Relationship between, and Interface with, this Field and Research Conducted to Reduce Greenhouse Gas Emissions

5.1 UK research activity in Geo-engineering is now almost exclusively conducted in universities following the (regrettable) demise of geotechnical research at the former Government research establishments—the Building Research Establishment (BRE) and the Transport Research Laboratory (TRL).

5.2 In the past, these Government funded bodies provided an independent focus which industry could tap into and partner with to undertake research into improving practice, often practical and over a number of years. The bodies provided pools of researchers who developed expertise and were able to develop practical streams of both blue sky research and research into specific applied topics of direct relevance to industry. They had huge industry support, including practical and 'in kind' support and their geotechnical research was world renowned.

5.3 The research done by the BRE on the re-use of foundations[14] is an excellent example of the need for public research. The re-use of existing foundations has obvious sustainability benefits. However, to be acceptable to industry (and to clients in particular) an industry-wide standard developed by a reputable independent body was essential. Furthermore, public funding for the research was indisputably necessary, since it would be unrealistic to expect geotechnical contractors/consultants to fund research that might ultimately reduce their work opportunities.

5.4 These publically funded facilities gave industry a means of contributing for the benefit of industry as a whole and permitted research to be undertaken that had no commercial benefit or where the benefit was to the whole sector. They were also a means for Government to put resources into independent R&D. EPSRC research grants continue to be available, but these require projects to have specific objectives and outcomes which often impose unhelpful restrictions, (eg the rejection of projects because they are linked to a single industrial partner and therefore are assumed to be for the commercial benefit only of that partner; or restrictions on the way the results are reported which make them difficult to disseminate.

5.5 Although academics might argue otherwise, from the perspective of geo-engineering consultants and contractors, blue-sky research has virtually ceased because of the withdrawal of Government funding. Research has undoubtedly been undertaken into the science of climate change, but geo-engineering practitioners have received little guidance about how this might be translated into practical solutions. There

[14] Summarised in *Reuse of Foundations for Urban Sites: A Best Practice Handbook* BRE Books 2006.

is a need for a much closer partnership between academia, industry and Government. Leaving innovation to individual companies, usually in partnership with academics, makes it difficult to share knowledge that should be in the public domain and available to the whole sector.

5.6 A significant proportion of funding of university research is geared around three year PhDs. This results in a lack of continuity and limits the scale of the issue that can be addressed.

6. The Provision of University Courses and other Forms of Training Relevant to Geo-engineering in the UK

6.1 Most professional Geo-engineers have first degrees in civil engineering, geology or one of the varieties of applied geology, and a Masters degree. Geotechnical PhDs are seldom required outside academic institutions, whereas PhDs relevant to contaminated land are useful in industry.

6.2 Civil engineering courses for students aspiring to become Chartered Engineers are now four year MEng degrees. Both three year and four year degrees are available for geologists. However, Geo-engineering is a specialism and none of the four year courses are considered adequate for Geo-engineering, because they do not focus on the specialist higher level skills.

6.3 A recent survey by GF has shown that the availability of post graduate MSc courses for Geo-engineers in the UK is acceptable but many are under threat because of a shortage of students. At the same time, and for many years, industry has experienced a severe shortage of MSc graduates. This is generally attributed to:

- high levels of student debt that make further study financially unviable;
- progressive reduction of funding for MSc's through EPSRC and NERC bursaries;
- the advent of four year MEng degrees that do not offer sufficient specialisation for geo-engineers, but make it less likely that graduates will undertake further study in order to obtain a second Masters degree;
- the availability of employment (because of the existing skill shortages) for civil engineering graduates without a geo-engineering MSc—even though the industry is totally united in the belief that this is not satisfactory; and
- the lack of substantial financial reward for those who obtain a geo-engineering MSc (ie in comparison to law or medicine where additional qualifications are perceived to lead to substantial financial benefit).

6.4 Geo-engineers have been on the Government Shortage Occupation List for work permit purposes since 2005 and continue to be so under the new regime. This has been very beneficial and much appreciated by the industry. In order to survive, the industry has also had to find alternative training solutions (in-house training; short courses, up-skilling etc). Additionally, industry has increasingly felt that even apparently well qualified graduates lack basic skills and understanding of the fundamental principles that were once regarded as normal.

6.5 Margins in Geo-engineering, as in the rest of construction, are low and training budgets compete with budgets for research and innovation, improvements in health and safety, and the myriad of third party accreditation schemes for quality assurance, investors in people, environmental management, etc which are expected from quality companies and demanded by clients.

6.6 There is a perception in the industry that offering financial support to allow staff to undertake post graduate MSc study does not necessarily result in more MSc qualified staff. Although a new graduate can be bound to remain with the sponsoring company for a short period, companies who chose to put their "sponsorship" money into higher salaries and staff benefits are able to attract staff from those companies that sponsor study. Small companies (many consultancies have less than 4 geo-engineers) anyway find the cost of sponsorship to be prohibitive.

7. The Status of Geo-engineering Technologies in Government, Industry and Academia

We find some ambiguity in the word "status" and therefore offer two observations:

7.1 The perception of Geo-engineering technologies in government, industry and academia: Generally the output of Geo-engineering is below ground and hidden from view, and therefore taken for granted, not only by the general public but also by clients and other construction professionals such as architects and structural engineers.

7.1.1 Much of past Government support for Geo-engineering (eg research funding and degree funding) has been progressively reduced and withdrawn, indicating a lack of understanding about the fundamental contribution made by geo-engineering and a failure to appreciate that its specialised nature requires MSc qualifications.

7.1.2 The status of engineering in the UK is not helped by the fact that the term "engineer" can be, and is, used by everyone from car mechanics to designers of nuclear power stations. The problem for Geo-engineering is even more difficult because personnel are split between geology, civil engineering, structural engineering and even chemistry. A system of licensing, similar to that in the USA would greatly enhance the profession. A voluntary registration system will be introduced for Ground Engineering Professionals in the next 12 months. Government support for this initiative, particularly in the planning system and Building Regulations, would be helpful.

7.1.3 Early involvement of Geo-engineers in the project team can result in value engineering that substantially reduces the risks and often the cost of the geotechnical elements—but such early involvement rarely happens. The geo-engineering sector faces serious and on-going difficulty to convince other (non geo) engineers of the need for proper ground investigation before the project begins. Problems due to unexpected ground conditions are the largest single source of cost over-runs, and designs based on insufficient knowledge of soil conditions must necessarily be conservative, and therefore more expensive. Despite this, structural engineers in particular, frequently fail to appreciate the value of proper site investigation and commission least cost investigations, often to inadequate specifications. In Scotland, structural engineers are now required to sign-off building designs, including design of the foundations of which they may have no specialist expertise; this is potentially dangerous.

7.1.4 Geo-engineering is often considered a minority interest in university civil engineering departments. Many Geo-engineering MSc courses are run with only one or two permanent staff members, and all are under pressure to be financially viable. Although a few universities have direct and successful links with particular companies for R&D purposes, this the exception rather than the rule.

7.1.5 In the past, the UK has led the world in geo-engineering expertise. As a result the UK enjoyed a large pool of experts and was able to export knowledge and consultancy services throughout the world. However, it has been estimated that 50% of UK geotechnical engineers could retire in the next 10 years. Skill shortages due to a lack of new entrants, deficiencies in the knowledge base of new graduates (see Para 6.4 above) and a shortage of MSc graduates (see Para 6.3 above) mean that this knowledge and expertise is being lost, with concomitant knock on effects for the reputation and export earning potential of the sector. There is an urgent need to re-establish and to nurture geo-engineering expertise; most professional bodies within the sector have initiatives to promote their professions in schools and universities, however these often rely on volunteers and are therefore in need of significant extra resources.

7.2 Current status of Geo-engineering technologies:

7.2.1 Within the Geo-engineering industry there is a constant drive towards greater efficiency and cost effectiveness. In recent years this has included:

- considerable and continuing improvements in instrumentation and monitoring data (eg ground movement, material behaviour, construction processes);
- the development of new technologies such as ground source heat pumps, energy piles, marine and tidal energy generation; and
- materials development including the increased use of polymers, geo-textiles, and recycled or recovered materials.

7.2.2 There is much that Government could do to improve the use and effectiveness of geo-engineering:

- Government failure to resolve the issues surrounding Soil Guideline Values (as put forward in the *Way Forward Report* (Defra, Clan 6/06) is holding back the ability of the industry to move forward confidently in the area of the remediation and development of contaminated land.
- The autonomy of Area Planning Officers and Environment Agency Officers (who have regulatory powers) creates inconsistencies and a confusion about requirements and standards that cannot be clarified or overridden by reference to a central authority.
- A requirement for adequate site investigation should be mandatory for detailed planning approval.
- Support for the Register of Ground Engineers, once it is launched, will support the identification of "Ground Engineering" as a specialist discipline, improve the visibility of the profession, and help to ensure that ground engineering is carried out by those qualified to do so.
- Better funding, via the British Standards Institution, for the development of standards in this sector.

8. Geo-engineering and Engaging Young People in the Engineering Profession

8.1 There is a particular difficulty for Geo-engineering in that people must first be recruited to civil engineering and then to Geo-engineering. Despite this, larger companies are working regularly with local schools to interest more school children in civil engineering and in earth science in particular. However, the majority of the effort comes from volunteers and skills shortages put pressure on the amount of voluntary activity that can be expected from industry.

8.2 The Ground Forum itself sponsors *ICE InSite*, a magazine published three times a year and sent, free of charge, to all secondary schools and colleges in order to promote careers in civil engineering. Articles about ground engineering are contributed regularly.

8.3 The Ground Forum notes with enthusiasm some excellent television programmes that will undoubtedly help to popularise and promote civil engineering, including the Geo-engineering sector.

9. The Role of Engineers in Informing Policy-makers and the Public Regarding the Potential Costs, Benefits and Research Status of different Geo-engineering Schemes

9.1 The Ground Forum and it Members inform policy makers of Geo-engineering issues through the Construction Industry Council (CIC) and direct communication with government via the Parliamentary & Scientific Committee and through responses to consultation documents.

9.2 It is probably true to say that the Construction Industry as a whole does not sufficiently promote successful projects to the public and the objections of protestors and those that oppose planning applications often give a negative image. The Olympics provide an opportunity to promote the industry and its role in regeneration and energy efficiency. This is not yet being seized with sufficient vigour and sadly, even when if it is, the role of Geo-engineering is unlikely to feature strongly.

October 2008

Memorandum 152

Submission from John C D Nissen

Summary

- Gravity of situation—global warming poses a threat to the survival of human civilisation.
- State of denial—few scientists are prepared to admit that there is an issue of survival.
- Role of geoengineering—it has the capability to save the day.
- Different types of geoengineering—reflecting sunlight and sequestration.
- Saving the Arctic sea ice—reflecting sunlight using stratospheric aerosols and reflecting sunlight through tropospheric cloud brightening are most promising.
- Removing CO_2 from the atmosphere—biochar has great potential.
- Geoengineering discipline—understand the climate science.
- Research and deployment—need for an engineering mentality and leadership.
- Response from government—nobody alert to the dangers.
- Conclusion—experimental trials of geoengineering with stratospheric aerosols and cloud brightening are urgently needed.

1. Gravity of the Situation

1. The earth's climate system shows signs of tipping into a new super-hot state (over 6°C warming), with barren lands, sterile seas, mass extinctions, a huge rise in sea level and almost inevitably the collapse of human civilisation. Over the past century, the earth's energy balance has been disturbed by a growing pulse of anthropogenic greenhouse gases in the atmosphere, now more than sufficient to tip the system. Even if one could halt all CO_2 emissions overnight, the acceleration of global warming towards the super-hot state would continue.

2. On top of this, there are growing positive feedbacks on global warming, acting both directly and indirectly:

- global warming melts snow and ice, allowing greater absorption of sunlight, with the effect of increasing global warming directly;
- global warming melts permafrost and frozen bogs, releasing CO_2 and methane to increase global warming indirectly; and
- global warming warms the oceans, reducing their CO_2 absorption capability, thus increasing CO_2 lifetime in the atmosphere, to increase global warming indirectly.

3. But global warming is not the only problem. If one could halt it overnight, the growing CO_2 levels would eventually lead to sterile seas through ocean acidification, already considered a serious problem for shell-forming creatures.

2. State of Denial

4. What is not generally appreciated among non-scientists is the seriousness of the situation with global warming. Scientists themselves do not want to believe what they are seeing, and certainly don't want to make others feel as scared as they may feel themselves. They shelter behind a cosy but false consensus, such as set up by the Intergovernmental Panel on Climate Change, which ignored the strong positive feedback in the climate system, especially the feedback resulting from Arctic sea ice retreat, thus giving us absurdly optimistic forecasts.[15] The real possibility of the Arctic Ocean becoming ice free in summer 2013, or sooner, is still not accepted by the Hadley Centre. Thus the sources of advice for the government are not stressing how immediate the danger is, nor how absolutely catastrophic it would be if we do not successfully counter the threat over the next few years. Martin Parry, ex-chair of the Intergovernmental Panel on Climate Change, has said that "survival is not the issue", but that's exactly what it is.

3. Role of Geoengineering

5. We define geoengineering as engineering on a large scale intended to:

— halt or reverse the rise in levels of greenhouse gases in the atmosphere; and

— halt or reverse the effects of excess greenhouse gases in the atmosphere: global warming, increased climate variability, sea level rise, and ocean acidification.

6. The immediate goal of geoengineering must be to halt the summer retreat of Arctic sea ice, since this cannot be done by emissions reductions alone. The long term goal must be to stabilise the climate and counter ocean acidification. Fortunately at least one geoengineering technique has the capability of success for both goals, and at remarkably low cost.

4. Different Types of Geoengineering

7. There are two principle types of geoengineering:

— solar radiation management (SRM) for cooling; and

— sequestration methods, including carbon capture and storage (CCS), for removing CO_2 from the atmosphere.

8. Solar radiation management involves techniques to reflect solar energy back into space, typically using fine particles or aerosols in the atmosphere, but it can include techniques such as painting roofs and covering deserts with reflective material.

9. Sequestration generally involves absorbing CO_2 from the atmosphere by photosynthesis of plants or marine creatures and then burying the carbon. This kind of geoengineering can embrace agricultural practice, bioengineering, genetic engineering, chemical engineering, constructional engineering and marine engineering to achieve particular goals.

Thus geoengineering covers an enormously wide range of disciplines.

5. Saving the Arctic Sea Ice

10. The halting the summer retreat of Arctic sea ice can be addressed by solar radiation management, but also some other techniques. There is so much at stake (including our own survival) that I believe we should pull out all the stops to restore the sea ice. We should try anything that:

— can be scaled up to have a significant positive impact;

— can be scaled up within two or three years;

— has a low chance of significant negative impact; and

— can be stopped before any unexpected negative impact becomes significant.

11. So main candidates include:

(i) creating stratospheric clouds—using precursor injection to generate aerosols;

(ii creating contrails—using an additive to aircraft fuel; and

(iii) brightening of marine clouds over the North Sea to cool the surface water entering the Arctic Ocean.

[15] IPCC Fourth Assessment Report: Climate Change Science http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf "Sea ice is projected to shrink in both the Arctic and Antarctic under all SRES scenarios. In some projections, Arctic late-summer sea ice disappears almost entirely by the latter part of the 21st century. (10.3)".

12. These all involve solar radiation management. They are all remarkably cheap to deploy, and one might only need a few million pounds to start significant experimental trials. The eventual cost for the stratospheric cloud technique has been estimated as of the order of $1 billion per annum to counter the full effects of global warming over the next few decades.

13. Other possibilities for saving the sea ice include:

(iv) covering of sea ice and adjacent land with reflective material;

(v) covering of ice and adjacent land with fresh snow to increase reflection;

(vi) prevention or removal of shrub growth in Siberia;

(vii) creation of thicker sea ice, using ice breakers;

(viii) prevention of break-up of ice, and its transport into open water;

(ix) covering of sea and meltwater with floating reflective material;

(x) removal of meltwater; and

(xi) cooling of the sea water by increase thermal radiation into space.

14. However, these other possibilities all have practical problems, mainly of being scaled up quickly enough to have a significant impact in saving the Arctic sea ice.

15. Concerning the main three candidates, the creation of stratospheric aerosol clouds (to simulate the global cooling effect over several years of a large volcanic eruption such as that of Mount Pinatubo) has the greatest backing among the geoengineering community, and should be a top priority for immediate experimental trials. A seminal paper on this subject by Ken Caldeira *et al*[16] is included in the recent Royal *Society Phil Trans* special issue on geoengineering. The scientific aspects are well considered, and much modelling has been done. However no experimental work has been done (eg on obtaining an ideal droplet size), and this is needed as a matter of extreme urgency.

16. The creation of contrails can be regarded as simply reversing what has been done by removal of certain constituents ("impurities") of aviation fuel in order to reduce atmospheric pollution. For example, sulphur compounds could be reintroduced into the fuel tanks of fighter aircraft, which would produce a contrail diffusing to a haze. This would have a known net cooling effect (significantly greater for daytime flights). This technique could supplement the abovementioned solar radiation management from aerosol clouds in the stratosphere.

17. The brightening of marine clouds is the subject of paper by John Latham *et al* in the Royal Society special issue. Some early experimentation in the formation of the spray is urgently required. Once this has been mastered, it could be deployed immediately by ordinary ships plying the North Atlantic to start cooling that part of the Gulf Stream entering the Arctic Ocean off the west coast of Norway. This would slow the melting of sea ice in summer, and speed the reformation of sea ice in winter. A significant amount of heat is transported into the Arctic via the Gulf Stream. This transport is implicated in the positive feedback on GW as the mean annual sea ice extent reduces.

6. Removing CO_2 from the Atmosphere

18. This is just a brief note, to say that Biochar techniques have remarkable potential for application in agriculture all over the world, to the benefit of farmers as well as the environment. Research and deployment should be supported by the government.

7. Geoengineering Discipline

19. As you will see from section 4, geoengineering covers an enormously wide range of disciplines. It is not clear that geoengineering should be treated as a discipline in its own right. Anyhow it is early days—there are very few people who would call themselves geo-engineers. What is important is that every engineer should understand the climate science that makes geoengineering essential.

8. Research and Deployment

20. Up till now, nearly all work on the climate has been done by academic scientists, who will want to continue research and modelling. There is a desperate lack of engineers, and an engineering mentality, to take the geoengineering possibilities and turn them into practicalities. And there is an absolute lack of leadership from the government. This has to change, and change dramatically, considering the gravity of the situation we are in (see section 1).

[16] Ken Caldeira *et al*, *RoySocPhilTrans*, 2008, theme issue "Geoscale engineering", see http://journals.royalsociety.org/content/84j11614488142u8

9. Response from the Government

21. Letters have been sent to ministers by myself, on behalf of stratospheric aerosol engineering, and by Stephen Salter, on behalf of cloud brightening. In every case the letters have been answered by officials from DEFRA who refuse to pass on the letters to politicians, despite the gravity of the situation we have described. These officials have raised many objections to our proposals, which we have been able to counter in every case. Yet still they refuse to accept the situation we describe, and the urgency for experimental trials of the geoengineering techniques we espouse. Not to use geoengineering, when it could rescue the world from the effects of global warming, is surely both stupid and irresponsible.

10. Conclusion

22. The most pressing need is for experimental trials of stratospheric aerosols, and cloud brightening techniques. Between them, these geoengineering techniques could save the Arctic sea ice, and thereby prevent a chain reaction of events leading to Armageddon. The same techniques could also be used to halt global warming and avoid the considerable costs of adaptation which have been widely anticipated (and thought inevitable).

September 2008

Memorandum 153

Submission from the National Oceanography Centre, Southampton

The National Oceanography Centre, Southampton, (NOCS) welcomes the opportunity to respond to the Engineering Case Study, "Geo-Engineering."

Summary

— Geo-engineering offers the possibility to contribute to endeavours to counteract global climate change. However the evidence to suggest it is likely to provide a sustainable, long-term solution is not yet available.

— The costs and side-effects of the various geo-engineering schemes proposed have not so far been adequately researched.

— Modelling the consequences of geo-engineering must be informed by in situ observations, monitoring and experiments and these must involve a wide selection of the scientific disciplines.

— Geo-engineering offers great scope for engagement with young people.

— Engineers, together with scientists, have a significant role to play in informing policy.

— The international legal framework does not yet exist to regulate the deployment of large scale geo-engineering activities and again this must be developed with the advice of the scientific and engineering experts.

1. The Current and Potential Roles of Engineering and Engineers in Geo-engineering Solutions to Climate Change

1.1 Whilst geo-engineering might assist in counteracting global climate change, the evidence to suggest it is likely to provide a sustainable, long-term solution is not yet available.

1.2 In order to determine the effectiveness of geo-engineering, research is required, as are pilot projects and a much better understanding of the costs and difficulties that may be encountered—especially of concern are "surprises"—the unexpected consequences of what might seem a relatively harmless intervention in the Earth system, such as adding iron to the oceans to stimulate plankton production.

1.3 There could be innovative geo-engineering solutions to excess carbon production that are as-yet unrealised—the prize is so valuable that it is worth exploring the options.

1.4 Engineers and scientists have an essential role to play in understanding the stability of captured carbon reservoirs, and identifying any side-effects that could be very difficult to rectify. For example, a leaking reservoir could affect the acidity of adjacent waters and have a harmful effect on marine life.

1.5 Modelling the consequences of geo-engineering such as iron fertilisation or geological carbon storage has to be informed by real-world observations, monitoring and process experiments.

1.6 Engineering solutions that are not informed by collaboration with other scientists will probably lead to incorrect conclusions. For example a few years ago it was suggested that excess carbon could simply be pumped into the deep ocean—in engineering terms a workable and not too expensive solution. Fortunately marine biologists became aware of the proposal and were able to point out that this approach would lead to widescale destruction of deep-ocean ecosystems which would be hard to reverse.

2. National and International Research Activity, and Research Funding, Related to Geo-engineering, and the Relationship between, and Interface with, this Field and Research Conducted to Reduce Greenhouse Gas Emissions

2.1 See submission from NERC (memorandum 15).

3. The Provision of University Courses and other Forms of Training Relevant to Geo-engineering in the UK

3.1 Geo-engineering is not taught as a separate subject at NOCS, but is covered briefly within earth sciences taught undergraduate and Masters courses.

4. The Status of Geo-engineering Technologies in Government, Industry and Academia

4.1 There is a cautious approach to geo-engineering in the academic community. There is optimism that a geo-engineering approach can deliver some much-needed answers to problems faced by the planet, but a concern that geo-engineering could be used as a "sticking plaster" to avoid difficult decisions.

4.2 Unless a holistic perspective is taken geo-engineering could potentially result in solutions that are technically feasible and affordable, but have undesirable side-effects eg by making the oceans more acidic or accidentally triggering an unexpected ecosystem response. It is essential that engineers liaise with other disciplines to avoid even bigger problems, but there are relatively few places in academia where this approach occurs.

4.3 There is a perception that multi- and interdisciplinary science does not fare well under existing science funding schemes. The peer review process tends not to favour research that crosses boundaries, and the career prospects of researchers who dare cross boundaries have historically not been as good as for those who stay firmly in their field. This situation needs to be addressed if a closer working relationship between engineers and scientists is to evolve.

5. Geo-engineering and Engaging Young People in the Engineering Profession

5.1 Geo-engineering is an inspiring subject for young people, offering hope that damage to the Earth can be repaired, and offering in the very long term the prospect of "terra-forming" other worlds so that they may be inhabitable by our descendants. Against that hope is the suspicion of the young that engineering solutions might be used to delay or prevent much-needed changes in societal behaviour—why stop polluting if you can just suck-up the gases?

5.2 On the positive side this offers an excellent area for engagement that involves science, technology, ethics, economics, politics and the understanding of the role of the engineer in society.

5.3 In our experience of outreach and education activities, climate change certainly engages the interest of young people, and although we have no evidence, it is possible that geo-engineering aspects might attract a young person into embarking on a science or engineering career to help make a difference. However engineering is perceived as a hard subject, requiring a high level of numeracy.

5.4 One issue in working with idealistic young people is that it is clear to them that the companies producing fossil fuel are likely to be the same companies that could engage in geo-engineering activities, in part because carbon dioxide injection into depleted reservoirs may also enhance oil or gas recovery. This raises significant ethical issues for young people, who are suspicious of the motives of large energy companies.

6. The Role of Engineers in informing Policy-makers and the Public Regarding the Potential Costs, Benefits and Research Status of different Geo-engineering Schemes

6.1 Engineers, engineering learned societies and professional bodies, informed by the scientific community, together have a key role in informing policy-makers and the public regarding the potential costs, benefits and research status of different geo-engineering schemes.

6.2 There is a pressing need to develop geo-engineering solutions to the problem of anthropogenic greenhouse gas production. Carbon capture and storage shows great promise, building upon proven technology developed in the oil and gas production sector for enhanced reservoir recovery. More recently Norwegian company Statoil has successfully demonstrated that carbon dioxide can be injected and stored in subsea geological formations. Engineers are gaining a realistic basis to determine the actual costs of injecting carbon dioxide into suitable geological formations, and ensuring that it stays there.

6.3 Engineers can use the data obtained from the operational nature of fossil-fuel, renewable and nuclear energy generation to provide the basis for realistic comparisons of their cost and effectiveness with geo-engineering options. This will enable the relative expense and risk of the two options—reducing emissions and masking their effects—to be properly evaluated.

6.4 Engineers working in collaboration with scientists are in an excellent position to alert policy makers of areas of concern regarding possible geo-engineering solutions, eg the possible risks of iron fertilisation in the oceans, or of adding carbon dioxide to deep ocean ecosystems.

6.5 Large scale geo-engineering will have consequences for the global community. Policy instruments will need to be developed to address ethical, legal and compensatory frameworks. International consensus will be necessary to develop geo-engineering solutions that take place in international waters or in geological structures that cross borders.

References

Lampitt, RS, Achterberg, EP, Anderson, TR, Hughes, JA, Iglesias-Rodriguez, MD, Kelly-Gerreyn, BA, Lucas, M, Popova, EE, Sanders, R, Shepherd, JG, Smythe-Wright, D and Yool, A (2008) *Ocean fertilisation: a potential means of geo-engineering?* Philosophical Transactions of the Royal Society 29 August 2008.

Shepherd, J (2008) *Journal club: An oceanographer sees potential in accelerating rock weathering to soak up carbon dioxide from the air.* Nature, 451, (7180), p 749.

John Shepherd, Debora Iglesias-Rodriguez, Andrew Yool (2007) *Geo-engineering might cause, not cure, problems* Nature 449, 781–781, doi: 10.1038/449781a, Correspondence.

October 2008

Memorandum 154

Submission from Research Councils UK (RCUK)

Bulleted Summary

- Geo-engineering is seen by some as having the potential to counteract global climate change; however, the feasibility of different conceptual options has yet to be rigorously examined, and it will be important to guard against unintended effects on the environment.
- The further development of geo-engineering ideas will require a combination of engineering, environmental and socio-economic expertise.
- Whilst sophisticated model-based simulations are essential for feasibility assessments, there may be important differences between model climate behaviour and that of the real world at both regional and Earth system scales.
- NERC and EPSRC support a wide range of research that is relevant to geo-engineering, particularly in the areas of climate dynamics and CCS (carbon capture and storage). New activities will explicitly explore the potential for geo-engineering development.

Introduction

1. Research Councils UK is a strategic partnership set up to champion research supported by the seven UK Research Councils. RCUK was established in 2002 to enable the Councils to work together more effectively to enhance the overall impact and effectiveness of their research, training and innovation activities, contributing to the delivery of the Government's objectives for science and innovation. Further details are available at www.rcuk.ac.uk.

2. This evidence is submitted by Research Councils UK (RCUK) on behalf of the Natural Environment Research Council (NERC) and the Engineering and Physical Sciences Research Council (EPSRC). It does not include or necessarily reflect the views of the Science and Innovation Group in the Department for Innovation, Universities and Skills. It was prepared in consultation with the Biotechnology and Biological Sciences Research Council (BBSRC) and the Economic and Social Research Council (ESRC). Separate written and oral evidence has been provided by RCUK and EPSRC to the Committee's main inquiry into engineering, and in relation to other case studies.

3. Both NERC and EPSRC fund and carry out impartial research and training in environmental, physical and engineering sciences within their own remits, through support to universities and, in the case of NERC, also to its Research and Collaborative Centres. Details are available at www.nerc.ac.uk and www.epsrc.ac.uk. Additional material arising from NERC discussions with its research community is provided at Annex A. A separate submission to this Case Study is being made by the Tyndall Centre.

What is Geo-engineering?

4. Geo-engineering is a term that has been used in different ways. A relatively wide definition, consistent with its etymological roots, is that geo-engineering involves the large-scale manipulation of environmental systems in order to make global changes for human benefit. Here we use geo-engineering in the climate change context, as an intervention to mediate global warming due to increasing atmospheric concentrations of greenhouse gases. It is considered distinct from mitigation (emission reduction) and is not intended to encompass all geological and soil-related technologies, such as carbon capture and storage (CCS), where capture is directly from a power station to prevent emission (ie mitigation)—a research topic that is supported by NERC and EPSRC (see Tables 1 & 2).

5. Many different ideas have been suggested as to how geo-engineering might counteract undesirable climate change, either in addition to, or as an alternative to, reductions in fossil fuel combustion. The main intended outcomes are in two groups:

(i) direct reduction in the radiant energy reaching the Earth's surface; and

(ii) slowing (and potentially reversing) the human-driven increase of greenhouse gases, principally carbon dioxide, in the atmosphere.

6. The mechanisms to achieve these outcomes may involve either physical, chemical or biological interventions, and can be conceptually straightforward; for example, shading or reflecting sunlight, stimulating plant growth in the ocean, or removing carbon dioxide from the air. However, the large-scale nature of the proposed interventions, involving up to 2% of the Earth's solar energy budget, can result in complex and far-reaching consequences, that may be unintended and unpredictable. That is because of the close linkage between climate processes and other dynamic components of the Earth's natural and managed environment, including food and water resources.

The Current and Potential Roles of Engineering and Engineers in Geo-engineering Solutions to Climate Change

7. The word engineering can itself be used broadly ("to arrange or bring something about"; eg, social engineering) or more specifically, as a physically-based scientific discipline relating to the practical problems of design, construction and maintenance of devices relating to materials and energy. Engineering as a scientific activity is frequently sub-categorised according to historical skill domains and training (electrical, mechanical and chemical), or on a more functional basis (eg aerospace, marine, civil), or in terms of applications (eg control-, nano- and materials engineering).

8. Geo-engineering could involve all of the above facets of engineering. It also potentially makes use of a very wide range of natural sciences and other technologies—the former including geology, geochemistry, soil science, atmospheric science, terrestrial ecology, hydrology, oceanography, meteorology and climatology; the latter including biotechnology, remote sensing and modelling—in addition to political science and economics. A partnership approach between engineers and others with relevant expertise is therefore essential for the development of viable geo-engineering options.

9. The engineering profession is collectively well-experienced in addressing practical challenges through a combination of theoretical advances, practical know-how and system-based planning and analyses. After the basic feasibility of a novel approach has been demonstrated, efficiency improvements can be developed, usually in a competitive, commercially-driven framework. In the climate change context, geo-engineering is a nascent industry that is essentially hypothetical: whilst many ideas have been raised, few (if any) have been subject to rigorous feasibility analyses, cost-benefit calculations or proof-of-concept demonstrations.

10. A major role of engineering and engineers is therefore to assist in the critical assessment of existing and novel geo-engineering "solutions"[17] to climate change. This exercise is already underway at various levels (eg through discussion-based initiatives by the Royal Society and the Institute of Mechanical Engineers) and will be further promoted by EPSRC. Whilst such evaluations will necessarily need to address the direct practicability of different options, they will also need to consider their other environmental implications and geo-political acceptability. The following criteria summarise the current status of national and international thinking on such issues:

— The proposed geo-engineering option must provide a measurable benefit that unambiguously outweighs the impacts arising from the full lifetime energy costs, carbon emissions and other adverse environmental consequences involved in establishing, maintaining and decommissioning the relevant technologies.

— The net benefit must be achieved relatively rapidly, with careful phasing of scale-up; otherwise initial adverse climate impacts—arising from large-scale device manufacture, new infrastructure or other set-up energy costs—may significantly increase the likelihood that natural thresholds between different climatic states (tipping-points) will be reached.

[17] The quotation marks indicate that geo-engineering cannot be assumed to provide a solution.

— The magnitude of the manipulation should be controllable, with the ability to switch off the effect relatively easily in the event of significant unforeseen adverse consequences.

— There must be public trust, long-term political commitment and international agreement on the acceptability of geo-engineering activities that are i) rewarded through international carbon-trading schemes, and/or ii) may have adverse, as well as positive, effects on globally-shared resources.

11. Table 1 provides summary information on key engineering, environmental and socio-economic issues for an illustrative range of proposed geo-engineering options.

National and International Research Activity, and Research Funding, Related to Geo-engineering, and the Relationship between, and Interface with, this Field and Research Conducted to Reduce Greenhouse Gas Emissions

12. Information on relevant research currently funded by NERC and EPSRC (and sometimes involving other Research Councils) is summarised in Table 2. Known future projects and programmes, currently in the planning stage, are also shown.

13. Relevance to geo-engineering is assessed in Table 2 as either low, medium or high. Whilst no "high" category is used for current work, EPSRC has planned activities that are explicitly directed at geo-engineering development. Note that research areas that are not here considered as geo-engineering include re-forestation *per se*[18] and emission reduction, the latter achieved through renewable energy generation, biofuels and CCS.

14. The closest link between geo-engineering and emission reduction (mitigation) is between the proposed air capture of carbon dioxide (option 9, Table 1) and CCS. Both initially involve energy-demanding techniques to remove the CO_2, and subsequently require its safe long-term storage. Whilst chemical removal processes are currently favoured for CCS, biological processes may be possible (eg involving oil-producing algae). Thus genetic engineering may have a role to play at the interface between geo-engineering and CCS.

UK Provision of University Courses and other forms of Training Relevant to Geo-engineering

15. We are unaware of any UK university courses or other forms of training that exclusively focus on geo-engineering. There are, however, several engineering and environmental science courses (eg the NERC-funded Earth System Science summer school) that consider the topic within a wider context, and hence provide relevant training.

16. EPSRC's wider approach to training is described in the RCUK's main submission to the Engineering inquiry. Current Engineeering Doctorate Centres of relevance to environmental engineering (and thus geo-engineering) include:

— EngD in Environmental Technology, Universities of Surrey and Brunel; and

— EngD in Environmental Engineering Science, University College London.

The Status of Geo-engineering Technologies in Government, Industry and Academia

17. The status and importance of geo-engineering is undoubtedly increasing—but from a low base, due to the relatively small number of groups directly engaged.

Geo-engineering and Engaging Young People in the Engineering Profession

18. EPSRC's public engagement approach is described in the RCUK's main submission to the Engineering inquiry.

19. NERC uses a wide variety of public events (eg Royal Society summer science exhibition) and other means of communication (website and publications) to introduce environmental science, including its technological and engineering aspects, to young people. NERC's research and collaborative centres do much science in society work in this area. For example, the National Oceanography Centre, Southampton (NOCS) is able to demonstrate the contribution of engineering to some very exciting science such as Autosub Under Ice (see http://www.noc.soton.ac.uk/aui/aui.html). Information technology, equipment development and model-based testing are all of fundamental importance to NERC, with Technologies being one of NERC's seven strategic science themes (see http://www.nerc.ac.uk/about/strategy/contents.asp).

[18] Re-forestation has previously been regarded as a geo-engineering option (egby US National Academy of Sciences, 1992 *Policy implications of greenhouse warming: mitigation, adaptation and the science base*) and would be needed for some carbon sequestration schemes.

20. We are aware of other initiatives (eg by the Institution of Mechanical Engineers) to use climate change as a topic to increase secondary school interest in science, technology, engineering and mathematics, and engage with these on a partnership basis where appropriate.

The Role of Engineers in Informing Policy-makers and the Public regarding the Potential Costs, Benefits and Research Status of different Geo-engineering Schemes

21. Both NERC and EPSRC give high importance to knowledge exchange, encouraging their communities to engage with a wide audience. On the policy side, bilateral meetings and other information-sharing exercises are regularly held between the Research Councils and government departments, including Defra. EPSRC and NERC both attend the Defra Scientific Advisory Committee. The EPSRC submission to the IUSSC's Engineering in Government case study specifically addresses the need to engage engineers (of all kinds) with policy-makers.

22. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)[19] is likely to provide an opportunity for the UK research community to assist in establishing international consensus on the viability of geo-engineering options.

[19] IPCC's 4th Assessment Report (2007) considered that "geo-engineering options . . . remain largely speculative and unproven, with the risk of unknown side effects".

Table 1

Summary information on key issues for some Geo-engineering options that have been proposed to counteract climate change. Options 1–5 involve decrease in received radiant energy; 6–9, removal of CO_2 from the atmosphere. additional detail in Launder and Thompson[20] and Vaughan and Lenton.[21]

Geo-engineering option	*Engineering issues*	*Environmental issues*	*Socio-economic issues*
1. Global shading in space (using mirrors, discs or reflective mesh)	Need for novel materials; design of delivery vehicles; problem of energy-intensive start-up; opportunity for energy to be collected in space?	Actions not easily reversible, hence high reliance on models to predict climate impacts—these suggest regional changes and overall decrease in precipitation; problem of space debris	Assessment of cost-effectiveness; public/political acceptability likely to be low (losers as well as winners)
2. Increased aerosols in upper atmosphere (using sulphur compounds)	Design of delivery vehicles and dispersion mechanisms; supply of sulphate; energy costs	Uncertainty in climatic effects—models suggest regional changes and overall decrease in precipitation; risk of ozone depletion and acid rain	Assessment of cost-effectiveness; public/political acceptability likely to be low (losers as well as winners)
3. Increased cloud albedo in lower atmosphere (eg using seawater spray)	Design and auto-operation of spraying devices; satellite-based verification of effect	Would effect be large enough? Need to model and monitor chemical impacts	Changes likely in regional weather patterns, with reduced rainfall downwind
4. Increasing land surface albedo by physical means (paint in urban areas, plastic surface on deserts)	Production, deployment and maintenance of surface covering—large area required for global effect	Potential for urban areas; less feasible for natural surfaces. Loss of desert dust would affect ocean productivity	Public acceptability of changes to visual landscape; assessment of cost-effectiveness
5. Increasing land surface albedo by biological means (changing vegetation)	Changing crop and/or grassland albedo, without affecting yield (via GM?)	Impacts on biodiversity, productivity, hydrological cycle and regional weather; scale of change needed for global effect	Public acceptability of changes; assessment of cost-effectiveness; regional losers
6. Enhanced carbon sequestration on land through charcoal burial in soil	Obtaining bulk charcoal; scale of (re-)forestation required to achieve globally-significant effect	Uncertain timescale and magnitude of soil storage capacity; need for major land use/land cover changes; soil fertility effects	Limited duration of effect (< 50 yr?); impacts on food production; once started has to be maintained
7. Increasing open ocean productivity through micro- or macro-nutrient addition	Obtaining and delivering nutrients, such as iron or urea	Uncertain timescale and magnitude of carbon sequestration; ecosystem effects; possible release of climate-reactive gases	UN moratorium on such work (by Convention on Biodiversity); once started has to be maintained
8. Increasing ocean productivity and surface cooling through increased mixing (ocean pipes)	Design, deployment and maintenance of mixing devices	Likely to be small or zero net effect on carbon budget (CO_2 from deep water released); cooling trivial on global scale?	Assessment of cost-effectiveness; interference of mixing devices with shipping and fishing
9. Air capture of carbon dioxide	Development of efficient devices to remove CO_2 from (ambient) air; long term storage; links to CCS	Ensuring safe long term storage of captured carbon; assessment of energetic cost-effectiveness	Assessment of economic cost-effectiveness

[20] B Launder and M Thompson (eds) *Geoscale engineering to avert dangerous climate change* Phil Trans Roy Soc A (2008) http://publishing.royalsociety.org/index.cfm?page=1814

[21] N E Vaughan and T M Lenton. *A review of geoengineering* (in prep).

Table 2

Summary of current and planned research by NERC, EPSRC and other Research Councils considered relevant to Geo-engineering. Relevance rating: X, low; XX, medium; XXX, high. Annual cost estimates (where given) are averaged over programme lifetime and may not accurately represent current spend. Note that figures are for the entire activity, not just the component relevant to Geo-engineering. Again, source-based carbon capture and storage (CCS) is not here regarded as Geo-engineering (see paragraphs 4, 13 and 14, and option 9, Table 1).

CURRENT WORK (SEPTEMBER 2008)

Activity	*Relevance*	*Duration; annual cost*	*Main links to geo-engineering*	*Support arrangements*	*RC(s) providing support*
Research Councils Energy Programme:					
www.epsrc.ac.uk/ResearchFunding/Programmes/Energy/Funding/default.htm					
— UK Energy Research Centre	X	2004–09 £2.6m pa	Energy systems and modelling	Consortium (10 institutions) led by Imperial College	EPSRC, NERC, ESRC
— Carbon management and renewables: carbon capture and storage	XX	2005–10 3.0m pa	CCS including potential for carbon sequestration by soils	Current CCS grants include consortia, smaller projects and capacity building activities	NERC, EPSRC BBSRC
Other programmes and projects					
Tyndall Centre for Climate Change Research *Themes include constructing energy futures; integrated modelling; engineering cities; informing international climate change policy*	XX	2006–09 (Phase 2) £2.0m pa (total)	Overview; policy implications	Consortium of 6 core partners, led by UEA	NERC, EPSRC ESRC
Living with Environmental Change (LWEC) *Details in development*	*X*	*2008—18*	*Mitigation and adaptation; socio-economics*	*Networking and enhanced collaborations*	*NERC, ESRC, EPSRC, BBSRC, MRC & AHRC*
British Geological Survey (BGS) *Themes include climate change, energy, land use and development, marine geoscience*	XX	Ongoing	CCS, land use, element cycling	NERC Centre	NERC
Oceans 2025 *Themes include marine biogeochemical cycling; next generation ocean prediction*	2007–12 £24.0m pa (total)	Ocean carbon uptake/ release; acidification risks from CCS	Coordinated programme at 7 NERC-supported marine centres, including NOCS, PML and POL	NERC	
National Centre for Atmospheric Science (NCAS) *Themes include climate science and climate change; weather, atmospheric composition, and technologies*	XX	Ongoing £9m pa	Regional and global atmospheric behaviour; climate predictions using state-of-the-art high resolution models; cloud physics; aerosol behaviour and properties	NERC Collaborative Centre involving 7 centres and facilities	NERC
Centre for Ecology and Hydrology (CEH) *Themes include land/ climate feedbacks and biogeochemical cycling* XX	Ongoing £2–3m pa	Land surface modelling and linkage to Earth System Models to predict impacts.	Core programme of NERC Research Centre	NERC	

Activity	*Relevance*	*Duration; annual cost*	*Main links to geo-engineering*	*Support arrangements*	*RC(s) providing support*
Quantifying and Understanding the Earth System (QUEST)	XX	2003–09 £3.8m pa	Modelling climate impacts	70 grant and fellowship awards; Core Team at Bristol	NERC
Aerosol properties, processes and influences on the Earth's climate (APPRAISE)	XX	2005–11 £1.1m pa	Atmospheric dynamics and albedo	Directed programme: 7 awards at 5 institutions	NERC
Surface ocean—lower atmosphere study (UK SOLAS)	X	2003–10 £1.5m pa	Ocean carbon uptake/release; atmospheric chemistry	Directed programme: 28 awards at 14 institutions	NERC
Sustainable agriculture and land use	X	Ongoing	Land-based carbon sequestration	Support via Rothamsted Research, other Centres and HEI awards	BBSRC

Plans for Future Work (September 2008)

Activity	*Relevance*	*Duration; annual cost*	*Main links to geo-engineering*	*Support arrangements*	*RC(s) providing support*
National strategy for Earth system modelling	XX	tba	Modelling climate impacts	Capacity building/start-up initiative	NERC
CCS: capture, transport, storage, whole systems and sustainability of carbon capture and storage	XX	tba	CCS	Wide ranging activities including consortia support, capacity building and start-up initiatives. Some E.ON co-support	EPSRC, NERC, ESRC
Ocean acidification	X	tba	Ocean carbon uptake/release; CCS	Large-scale research programme	NERC
UK contribution to VOCALS (VAMOS Ocean-Cloud-Atmosphere-Land Study)	XX	− £2m pa	Cloud seeding; cloud formation (via sulphate aerosol) and their albedo effect	Consortium	NERC
Geo-engineering IDEAS Factory	XXX	− £3m total	Focus on geo-engineering	tbc	EPSRC
Doctoral training in CCS	XX	− £5m total	CCS	10 students pa for 5 yr	EPSRC

September 2008

Annex A

Additional Scientific Background Provided by NERC

In preparing its contribution to this submission, NERC held discussions with its environmental research centres, including the National Centre for Atmospheric Sciences (NCAS), the National Oceanography Centre Southampton (NOCS), Plymouth Marine Laboratory (PML), the British Geological Survey (BGS), the UK Energy Research Centre (UKERC) and the Centre for Ecology and Hydrology (CEH). Additional comments arising from or endorsed by those discussions are provided here.

1. The feasibility of geo-engineering warrants attention on the basis that such an approach might 'buy time' or provide a future safety net. However, geo-engineering alone is unlikely to provide a sustainable, long-term solution to climate change. That is because the scale of geo-engineering interventions would need to be increased year-by-year to keep up with increased emissions (currently rising at more than 3% pa), and that ocean acidification would continue unabated if no measures are taken to limit the increase in atmospheric carbon dioxide.

2. Furthermore, there are concerns that over-optimistic reliance on geo-engineering might prove to be chimeric and diversionary. Thus attention given to "technological fixes" could attract resources and effort away from more fundamental ways of tackling the problem of global warming, through a rapid transition to a low-carbon economy.

3. In paragraph 9 of the main text, four (bulleted) criteria are given for the evaluation of geo-engineering options. The first of these—the unambiguous demonstration of net benefit—is likely to be highly demanding, with major investments needed to scale-up from proof-of-concept to pilot trials and full deployment. The use of state-of-the-art climate models, including a range of biogeochemical feedback processes, is clearly necessary for "safe" global-scale testing, to quantify potential benefits and assess the risk of undesirable impacts. A secure assessment of the full impact of geo-engineering solutions requires a

comprehensive Earth System Model. Such models (which must include for example the land surface, atmospheric chemistry) are still in their infancy but are in active development within NERC (in collaboration with other bodies such as the UKMO). Currently such models do not adequately represent regional climate and its variability. High resolution regional models will be needed to complement field trials, to verify that intended effects did not arise for other reasons. It is a priority research area to improve and assess these models. But model behaviour can never fully replicate real-world behaviour; at full scale-up, it would be prudent to expect the unexpected. Hence the importance of the third criteria—that the manipulation is controllable, and can be easily stopped if net benefits are not achieved.

4. The final bullet in paragraph 9 provides the overall bottom line: "global planning permission" will undoubtedly be needed for schemes of sufficient scale to be climatically effective. As yet, the ethical and legal frameworks for purposeful climatic manipulation do not exist, and their development is unlikely to be straightforward.

Memorandum 155

Submission from John Gorman, Chartered Engineer

Geoengineering for Zero Sea Level Rise

Summary

1. Sea level will probably rise more quickly and much more than the IPCC estimate of 40 centimetres by 2100.

2. The implications for London are obvious.

3. No reduction in CO_2 emissions can avoid or significantly reduce sea level rise this century.

4. The only way to control sea level rise is screening of solar radiation (geoengineering).

5. There is very little geoengineering research because it is not "politically correct" in the climate academic community.

6. There are very practical well-defined research projects in geoengineering that need funding.

7. If shown to be technically feasible there are very practical proposals for implementation.

1. Sea Level Rise

1.1 In most of the world there is not yet much negative effect of global warming. The danger lies in the Arctic and Antarctic where the temperature rise is about 10 times as great as that at the equator. Currently it is 3 to 4° compared with the global average figure of 0.7° (British Antarctic Survey position statement and IPCC.) The result is very significant summer melting of Greenland and the Antarctic Peninsula (which protrude outside the Arctic and Antarctic Circle respectively.) This summer melting is far greater than has occurred at any time since the end the last ice age. (British Antarctic Survey)

1.2 Common sense and many anecdotal reports suggest that this will eventually result in the loss of much of these two ice sheets. (Not the main body of Antarctica where there is at present no summer melting.) This would result in a sea level rise of about 16 metres. The question is how quickly this could occur. This is obviously difficult to estimate. The predicted sea level rise in the IPCC report from March 2007 is 40 centimetres by 2100. This was widely publicised as was the fact that this figure had been reduced from that in the previous report.

1.3 Where does this figure of 40 centimetres come from?

In a nutshell it is the actual rise in the decade to 2003 multiplied by 10 for the 10 decades to 2100. (Which would give 31 centimetres + 7 so 40 is slightly greater.)

This raises two questions:

(i) The average rise in the previous three decades was 1.4 centimetres per decade. This rose to 3.1 in the decade to 2003. Is there any reason to believe that subsequent decades in the century will stay at four centimetres per decade? Isn't it far more likely that there will be a rapid escalation as temperatures rise?

(ii) These are still small rises resulting from an increase in the same mechanisms, such as surface water runoff in summer, which are occurring today. Can we have any confidence that much more dramatic events will not occur such as rapid glacial acceleration following ice shelf breakaway? These are mentioned in the IPCC report but no allowance is made for them in the "executive summary figure" of 40 centimetres.

1.4 Many such possibilities are considered in the report (chapter five IPCC2007) and the difficulty in prediction is frequently mentioned. This difficulty in prediction is exemplified by the loss of Arctic Sea ice in summer. The IPCC median prediction was only a 22% loss by 2100 in the report published in March 2007. This figure was actually equalled in the summer of 2007! Many are now predicting total loss of Arctic summer sea ice as early as 2013—more than century earlier than the IPCC prediction. This loss of reflectivity (albedo) in the whole of the Arctic Ocean is obviously of enormous importance to the survival of the Greenland ice sheet.

1.5 It seems irresponsible of the IPCC to allow such credence to be given to the figure of 40 centimetres. It would have been far better to say "we cannot predict sea level rise". The New Scientist suggested in the issue of 10 March 2007 that there was political pressure to stop any alarmist comment or figure being included. (See page 9—Copy of leader page.)

1.6 The truth is that, with the summer melting that is occurring in Greenland and the Antarctic Peninsula, and the loss of the Arctic Sea ice we haven't a clue how much or how quickly sea level will rise. If it is a slow and progressive rise, but quicker than we plan or build for, then the problems will always arise with a combination of high tide and exceptional storm as demonstrated in Burma recently. The same combination resulted in the flooding of New Orleans, of the English east coast in 1953 and very nearly of Rotterdam and London only last summer. The flood defences in Rotterdam would have been overwhelmed by another six inches of storm surge.

1.7 When you look at the man-millennia that went into the evaluation of sea level rise worldwide from 1960 to 2003 it seems to be a bad case of "not seeing the wood for the trees" to allow the results to be extrapolated to 2100.

2. London

2.1 It seems unnecessary to point out how susceptible London is to any sea level rise, which is not predicted or which occurs more quickly than new sea defences can be erected.

2.2 Sea level rise could be almost instantaneous. The Nobel laureate economist Thomas Schelling, in his lecture to the World Bank, mentions one particular ice shelf in Western Antarctica but there are many such examples. Because this ice shelf is resting on the bottom of the ocean it will result in sea level rise if it breaks away as is happening to so many bits of ice shelf in both Antarctica and the Arctic.

2.3 In the lecture, Thomas Schelling also points out the danger in looking at the probability of such events. He suggests that the catastrophic nature means that we should prevent them if we possibly can and not apply economic cost benefit analysis.

3. Emissions Reduction

3.1 It is important to realise that no reduction in CO_2 emissions can stop sea level rise. If all CO_2 emissions were stopped today we would still have a global warming problem in 100 and even 500 years (Caldera *et al* Recent paper) and Greenland would almost certainly be green. In fact most economists and those in business and politics see it as obvious that emissions will continue to rise for most of this century. The expected worldwide economic development (plus 500% by 2050—Reith lecture 2007) just can't be stopped.

3.2 Even if a large emissions reduction could be achieved, the CO_2 already in the atmosphere will last more than a century and its net heating effect will persist. Temperatures will therefore continue to rise. This could only be avoided if the CO_2 concentration could be reduced now to pre-industrial levels, which is obviously impossible.

3.3 In addition large-scale removal of CO_2 from the atmosphere cannot help quickly because the technology simply doesn't exist yet.

3.4 If emissions continue to rise, as seems inevitable, the escalating CO_2 concentration will have to be controlled by CO_2 removal and storage (CRS). This massive volume technology will have to be developed but this is not the subject of this paper.

4. Geoengineering

4.1 The only tools that we have available to limit sea level rise come into the category of geoengineering. There are several ideas that could be implemented quickly. Among these is my suggestion of a stratospheric sunscreen created by an aircraft fuel additive. (I now find that this was first suggested by a Russian called Budyeko in 1980) but there are several others including the well researched proposal for Ocean cloud enhancement from Stephen Salter, Professor of Engineering at Edinburgh.

4.2 Almost all of these geoengineering ideas aim at reflecting a proportion of the sunlight hitting the earth. Several ideas, including my own, are specifically aimed at the Arctic in order to stop sea level rise. Most rely on the "experiments" already done by nature in the form of volcanic eruptions. There have been 13 large volcanic eruptions in the last 250 years, which have given us invaluable information on the global cooling that can be achieved.

4.3 None of these ideas are yet sufficiently well researched for immediate implementation but some of the ideas, including my own, could be implemented within one or two years. There are scientific voices claiming catastrophic consequences of such implementation but it is difficult to envisage consequences as catastrophic as allowing significant and unpredictable sea level rise.

4.4 If the possibility of net loss from Arctic and Antarctic ice sheets can be eliminated by local geoengineering, then it should be possible to keep the total rise in sea level to zero.

4.5 About half of the rise in the last decade (about 3 centimetres total) is attributable to ocean expansion on warming and the ocean cloud enhancement proposal from Professor Salter could stop further warming of the sea water if researched, developed and implemented.

5. Politics

5.1 Why aren't we hearing these suggestions from the climate experts who should be putting them forward?

5.2 Any suggestion of geoengineering is very political among climate academics. Roger Pielke, an academic specialising in science policy summed up the situation very well saying:

> "some scientists think that scientists should not discuss the prospects for geoengineering because it will distract from other approaches to dealing with greenhouse gas emissions. Thus, decisions about what research to conduct and what is appropriate to discuss is shaped by the political preferences of scientists. This won't be news to scholars of science in society, but it should be troubling because it is unfortunately characteristic of the climate science community (who)—try to tilt the political playing field by altering what they allow their colleagues to work on or discuss in public. The climate debate has too much of this behavior already."

5.3 Anyone who looks at the debate quickly comes to the same conclusion. Oliver Morton, news editor of Nature, investigated geoengineering last year and wrote "—the climate community views geoengineering with deep suspicion or outright hostility". He also saw that "climate scientists have shown new willingness to study (geoengineering) although many will do so—to show that all such paths are dead-end streets."

5.4 Even the Nobel laureate (for his work on CFCs and the ozone layer) Paul Crutzen couldn't get his geoengineering paper published without the intervention of Ralph Cicerone, the President of the American Academy of Sciences who wrote "many in the climate academic community have opposed the publication of Crutzen's work—for reasons that are not—scientific."

5.5 Against this background there will need to be a strong political will to get proper, fully funded, research and development for several geoengineering schemes. Then there will need to be international political agreement on implementation.

6. Geoengineering Research Projects

6.1 There is a tendency, particularly among climate academics, to speak of geoengineering as a last resort to be used "if disaster strikes". I have to describe this as a completely unrealistic attitude to the problem that is developing in Greenland and western Antarctica. The problem is obvious and won't go away. We should therefore set about correcting it now.

6.2 There are geoengineering schemes, like mirrors in space, which might be interesting in the 22nd century, but at this moment stratospheric aerosols must be top of the list. From the 13 large volcanic eruptions since 1750, particularly from Mount Pinatubo in 1991, we already have masses of experimental data.

6.3 Most of the research and evaluation papers concentrate on the quantities and the atmospheric and climatic effects of stratospheric aerosols. There are various suggestions for distribution but most of these are not detailed. If it could be shown that aircraft fuel additives could distribute aerosols without the need to develop any new equipment this would have enormous advantages in allowing experimental distribution to be done inexpensively and very soon.

6.4 *An Actual Research Project*

6.4.1 I have recently proposed the following research project to Qinetiq (the former Royal Aircraft Establishment) but there is at present no available funding.

6.4.2 Experiments using only static engine test rigs would go a long way to proving the practicality of the system at limited cost. The two chemicals suggested are di-methyl sulphide to produce sulphur dioxide and tetra ethyl silicate to produce silica. (I have already done some preliminary experiments.)

6.4.3 Most of the research on stratospheric aerosols concentrates on sulphur dioxide which produces an aerosol of sulphuric acid droplets. This is because it is sulphur dioxide that is produced from a volcanic eruption and gives us most of the data that we have on the cooling effects. There are various disadvantages to sulphur dioxide in its chemical activity and because of these it is worth investigating the silicon dioxide (silica) alternative. It might have far less chemical effect on the ozone. The particles might be crystalline platelets which would float for much longer in the atmosphere. The particles might be much more reflective requiring far less material to be injected. It might be possible to choose particle size and therefore to select the wavelength of light which is preferentially reflected. (An extra ultraviolet sunscreen!)

6.4.4 If there is reason to believe that the turbine will be affected by the use of tetra ethyl silicate even in small concentrations then it would be nice to investigate the possibilities of injecting the fuel/additive mixture into an afterburner. It would be a pity to give up on the possibilities of silica particles and it is likely that initial atmospheric experiments would be done with military jets. Fighters using afterburners are well-known for using up the maximum amount of fuel in the minimum time and getting to the highest attitude.

6.5 *Other Deserving Projects*

6.5.1 With a developing emergency of the global warming kind it is sensible to develop any feasible project in parallel so that sensible choices can be made at a later stage. One obvious candidate is the well researched proposal by Professor Salter of Edinburgh University to spray sea water into the lower clouds to enhance the reflectivity of ocean clouds and cool the oceans.

6.5.2 This project would be least feasible in the freezing conditions of the Arctic and is therefore particularly compatible with the proposed use of stratospheric aerosols in the Arctic and Antarctic.

7. Implementation

7.1 It does seem sensible to have an application in mind in order to justify the preliminary experiments.

7.2 Even among those proposing stratospheric aerosols there is scepticism as to whether aircraft fuel additives could be a distribution system. The doubts expressed include:

(i) aeroplanes don't fly high enough in the stratosphere;

(ii) aerosols will fall out of the atmosphere too quickly;

(iii) sulphur dioxide, which becomes sulphuric acid, will damage the ozone layer;

(v) acid rain;

(v) ozone layer damage will be particularly high in winter (Recent Simone Tilmes paper);

(vi) aerosols will tend to cause high latitude warming in winter because of reflection of outgoing radiation during the longer nights relative to daytime; and

(vii) damage to the jet engine.

7.3 The most likely first application of a stratospheric aerosol sunscreen is that proposed by Gregory Benfold, a planetary atmospheric scientist at the University of California. The title was "*Saving the Arctic*".

7.4 Combined with the aircraft distribution system, the proposal would be to spread the aerosol by aircraft flying between 40 and 60,000 feet from the time of first Arctic daylight (April approximately) until late July approximately.

7.5 I believe that this would "slip" neatly between the various disadvantages mentioned in the following way:

7.5.1 Doubts 1 and 2. Ideally for very long stratospheric life, aerosols need to be injected at about 80,000 feet. If they are only injected at 50,000 ft. they will fall out of the atmosphere in about three months. (Ken Caldera's lecture available on U tube). In this case that is exactly what we want so that they would fall out by the end of the Arctic summer and would not be present during the winter—solving 6. The aerosols will probably also be more effective, weight for weight, in the Arctic since there is no night during the summer when the night-time blanketing effect has to be subtracted from the daytime screening.

7.5.2 Most of the arguments that aerosols will damage the ozone layer assume that the aerosols are injected high in the stratosphere for long life. In this case most of the injection would not reach the ozone layer. In addition the aerosols would no longer be present in winter when the effect is greatest. (The damage to the ozone layer is not directly caused by the aerosols but by the aerosol droplets or particles forming nuclei on which the remaining CFCs have their chemical effect on the ozone. The level of CFCs in the atmosphere is dropping steadily now that controls are in place.)

7.5.3 The problem of acid rain, 4 above, has always been a bit of a red herring because the quantity of sulphur dioxide needed is only of the order of one per cent of that produced by industrial processes worldwide. It could however be eliminated if the silica particle version was used.

7.6 It seems very likely that implementation of this type would succeed in "saving the Arctic". In particular the target would be to eliminate significant melting of the Greenland ice sheet or sudden loss of parts of it. The same principle could then be applied to Antarctica.

7.7 The target should be zero sea level rise. If this could be achieved the saving in costs of construction, relocating populations and flood disasters would be absolutely enormous.

References have not been included in this paper. Most can be found in my poster/paper for the American Geophysical Union 2007 at http://www.naturaljointmobility.info/agu.htm

September 2008

Memorandum 156

Submission from Professor John Latham[22]

1. Summary

- There exists a clear consensus in the geo-engineering community that although it is strongly hoped that it will never be necessary to deploy any of the climate mitigation, temperature stabilisation schemes on which we are working, it is irresponsible not to examine and test the ones considered to be of significant promise, to the point at which they could be rapidly made operational, if viable.
- A crucial requirement of geo-engineering research is that all significant ramifications associated with the deployment of the techniques be fully examined, especially ones that could have adverse consequences: such as rainfall reduction in agricultural regions where water is already in short supply.
- The geo-engineering idea colleagues and I are investigating is to increase, in a controlled way, the reflectivity for incoming sunlight of low-level, shallow oceanic clouds, thus producing a cooling sufficient to balance global warming.
- This technique, together with assessments of it from modelling and observational work are summarised below. The provisional conclusion—subject to satisfactory resolution of specific problems—is that it could hold the Earth's temperature constant as CO_2 levels continue to rise, for at least several decades.
- Preliminary indications emanating from a state-of-the-art fully-coupled atmosphere/ocean global climate model are that significant restoration of Arctic ice is achievable via our cloud seeding scheme. This model is also being used to assess the ramifications associated with the possible deployment of this technique.
- Hadley Centre scientists have recently assessed some ramifications of cloud albedo enhancement using a somewhat simpler model, but since their levels and areal seeding coverage are significantly different from those we have proposed to utilise, their results cannot be regarded as applicable, with accuracy, to our scheme.
- Modelling is of great importance in quantifying and assessing geo-engineering schemes. However, it would be short-sighted and counter-productive to exclude observational and field studies from a programme of geo-engineering research.

2. Outline of our Global Temperature Stabilisation Scheme[23]

1. Atmospheric clouds exercise a significant influence on climate. They can inhibit the passage through the atmosphere of both incoming, short-wave, solar radiation, some of which is reflected back into space from cloud-tops, and they intercept long-wave radiation flowing outwards from the Earth's surface: a global cooling, and warming respectively. On balance, clouds produce a cooling effect, which we propose (Latham, 1990, 2000: Bower *et al* 2006, Latham *et al* 2008) to accentuate by increasing the reflectivity of the shallow, low-level, marine stratocumulus clouds that cover about a quarter of the oceanic surface. These clouds characteristically reflect between 30% and 70% of the sunlight that falls upon them. They therefore produce significant global cooling. A further 10% increase in reflectivity—which we hope to achieve via cloud seeding—would produce an additional cooling to roughly balance the warming resulting from atmospheric CO_2 doubling.

2. The reflectivity increase would be achieved by seeding these clouds with seawater particles sprayed from unmanned, wind-powered, satellite-guided Flettner-rotor vessels (Salter *et al* 2008) sailing underneath the clouds. These particles would be about one micrometer in diameter at creation and would shrink as about half of them are carried by turbulence up into the clouds, where they act as centres for new droplet formation, thereby increasing the cloud droplet number concentration and thus the cloud reflectivity (and possibly longevity). In this way the clouds would reflect more sunlight back into space, possibly for a longer time, and so planetary cooling occurs.

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[22] John Latham is Emeritus Professor of Physics, University of Manchester, and Senior Research Associate, National Centre for Atmospheric Research (NCAR), Boulder, Colorado.

[23] Please note that in the interests of communicating as clearly as possible with readers who are not climate experts I have tried to write the following notes without using specialised terminology. This introduces a "looseness of expression" which I believe does not destroy the sense of the information I am trying to convey.

3. The physics behind this scheme is that an increase in droplet number concentration (with concomitant reduction in average droplet size) causes the cloud reflectivity to increase because the overall droplet surface area is enhanced. It can also increase cloud longevity (tantamount to increasing cloudiness) because the coalescence of cloud droplets to form drizzle—which often initiates cloud dissipation—is impeded, since the droplets are smaller.

4. Simple calculations indicate that a doubling of the natural droplet concentration in all suitable marine stratiform clouds (which corresponds to a reflectivity increase of about 12%) would - roughly—produce a cooling sufficient to balance the warming associated with CO2 doubling. If the seawater droplets have a diameter of about 0.8 micrometres the global seawater volumetric spray-rate required to produce the required doubling of the droplet number concentration in all suitable clouds is about 30 cubic metres per second, this modest figure resulting from the small size of the seeding particles.

5. Major technological components of our geo-engineering scheme are discussed in detail in Salter *et al*, 2008.

6. Ship-tracks are bright streaks crossing photographs of marine stratocumulus clouds observed from satellites, resulting from the release into the clouds of droplet-forming particles in the exhausts of ships sailing beneath them. They can be adduced as evidence supporting our contention that the seeding of clouds can enhance their reflectivity.

3. Global Climate Modelling Computations

7. The calculations mentioned above were simplistic, and although they were useful in providing first estimates of the viability and requirements of our scheme, a definitive quantitative assessment of it requires high-quality global climate modelling. Two separate models were utilized for this work:

(i) the HadGAM numerical model, which is the atmospheric component of the Hadley Centre Global Model, based on the Meteorological Office Unified Model (UM), version 6.1; and

(ii) a developmental version of the NCAR Community Atmosphere Model (CAM).

8. Both models reveal that the imposed increase in cloud droplet number concentration resulting from seeding causes an overall significant global cooling. The largest effects are apparent in the three regions of persistent marine stratocumulus off the west coasts of Africa and North & South America, which together cover about 3% of the global surface. Lower but appreciable amounts of cooling were found throughout much more extensive regions of the southern oceans. The five-year mean globally averaged cooling resulting from marine low-level cloud seeding, with the cloud droplet number concentration approximately quadrupled, produced a cooling sufficient to balance the warming resulting from a quadrupling of the atmospheric CO_2 concentration in the case of the UK model, and a doubling in the case of the NCAR model. If such levels of cooling could be produced in practice by the proposed cloud seeding technique, the Earth's temperature could be held constant for many decades. It follows that the areal fraction of suitable cloud-cover seeded, in order to maintain global temperature stabilization, could, for much of this period, be appreciably lower than unity, rendering less daunting the practical problem of achieving adequate geographical dispersal of disseminated CCN. Thus there exists, in principle, latitude to:

(a) avoid seeding in regions where deleterious effects (such as rainfall reduction over adjacent land) are predicted; and

(b) seed preferentially in unpolluted regions, where the reflectivity-changes for a fixed increase in droplet number concentration are a maximum.

9. The computations showed strong seasonal variations in the global distribution of cooling, with a maximum in the Southern Hemisphere summer. This finding underlines the desirability of a high degree of mobility in the seawater aerosol dissemination system.

4. Discussion

10. Further work is required on technological issues and the complexities of marine stratocumulus clouds. Most importantly, perhaps, we need to make a detailed assessment of ramifications associated with the possible deployment of our geo-engineering scheme—for which there would be no justification unless these effects were found to be acceptable.

11. Deployment of our scheme would result in global changes in the distributions and magnitudes of ocean currents, temperature, rainfall, etc. Even if it were possible to seed clouds relatively evenly over the Earth's oceans, these effects would not be eliminated. Also, the technique would still alter the land-ocean temperature contrast, since the initial cooling would be only over the oceans. In addition, we would be attempting to neutralise the warming effect of vertically distributed greenhouse gases with a surface-based cooling effect, which could have consequences such as changes in static stability which would need careful evaluation. Thus it is vital to engage in a prior assessment of the ramifications mentioned above, which might

involve currently unforeseen feedback processes. This work requires requires a fully coupled ocean/atmosphere climate system model. Such a model has been utilised over the past few months, at NCAR. Results to date are only provisional, but one feature that seems increasingly to be valid is that seeding of marine stratocumulus clouds with seawater particles can cause significant global cooling, which is a maximum in the Arctic regions, causing significant restoration of ice cover.

12. It follows from the preceding discussion that although two separate sets of global climate computations agree in concluding that this cloud seeding scheme is in principle powerful enough to be important in global temperature stabilization, there are defined gaps in our knowledge which force us to conclude that we cannot state categorically at this stage whether the scheme is capable of producing significant global cooling. However, if resolution of these extant issues makes little change to our modelling results, we may conclude that our scheme could stabilize the Earth's average temperature beyond the point at which the atmospheric CO_2 concentration reached 550 ppm (the CO_2-doubling limit) but probably not beyond the 1,000 ppm value. The amount of time for which the Earth's average temperature could be stabilised depends, of course, on the rate at which the CO_2 concentration increases. Simple calculations show that if it continued to increase at the current level, and if the maximum amount of cooling that the scheme could produce is as predicted by the models, the Earth's average temperature could be held constant for between about 50 and 100 years. At the beginning of this period the required global seawater spray rate—if all suitable clouds were seeded—would be about 0.15 $m^3 s^{-1}$ initially, increasing each year to a final value of approximately 25 $m^3 s^{-1}$.

13. Recent experimental work involving data from the MODIS and CERES satellites led to a study by Quaas and Feichter (2008) of the quantitative viability of our global temperature stabilization technique. They concluded that enhancement (via seeding) of the droplet number concentration in marine boundary-layer clouds to a uniform value of 400 cm_3 over the world oceans (from 60°S-60°N) would produce a global cooling close to that required to balance the warming resulting from CO_2-doubling. They also found that the sensitivity of cloud droplet number concentration to a change in aerosol concentration is virtually always positive, with larger sensitivities over the oceans. These experimental results are clearly supportive of our proposed geo-engineering idea, as is the work of Oreopoulos and Platnick (2008), which also involves MODIS satellite measurements.

14. Further encouraging support for the quantitative validity of our scheme is provided by the field research of Roberts *et al* (2008) in which the enhancement of reflectivity was measured on a cloud-by-cloud basis, and linked to increasing aerosol concentrations by using multiple, autonomous, unmanned aerial vehicles to simultaneously observe the cloud microphysics, vertical aerosol distribution and associated solar radiative fluxes. In the presence of long-range transport of dust and anthropogenic pollution the trade cumuli have higher droplet concentrations, and are on average brighter, the observations indicating a high sensitivity of cooling by trade cumuli to increases in cloud droplet concentrations. The results obtained are in reasonable agreement with our modelling.

15. Our view regarding priorities for work in the near future is that we should focus attention on outstanding unresolved issues (scientific and technological) outlined earlier. The major focus should be on assessment of ramifications associated with the proposed seeding scheme. At the same time we should develop plans for executing a limited-area field experiment in which selected clouds are inoculated with seawater aerosol, and airborne, ship-borne and satellite measurements are made to establish, quantitatively, the concomitant microphysical and radiative differences between seeded and unseeded adjacent clouds: thus, hopefully, to determine whether or not this temperature-stabilization scheme is viable. Such further field observational assessment of our technique is of major importance.

16. A positive feature of our proposed technique is revealed by comparing the power required to produce and disseminate the seawater particles with that associated with the additional reflection of incoming sunlight. A simple calculation shows that the ratio of reflected power to required dissemination power is about 10 million. This extremely high "efficiency" is largely a consequence of the fact that the energy required to increase the seawater droplet surface area by four or five orders of magnitude—from that existing on entry to the clouds to that possessed by the cloud droplets when reflecting sunlight from cloud-top—is provided by nature.

18. Further advantages of this scheme, if satisfactorily deployed, are that:

(i) the amount of cooling could be controlled—by measuring cloud reflectivity from satellites and turning disseminators on or off (or up and down) remotely as required

(ii) if any unforeseen adverse effect occurred, the entire system could be switched off instantaneously, with cloud properties returning to normal within a few days;

(iii) it is relatively benign ecologically, the only raw materials required being wind and seawater; and

(iv) there exists flexibility to choose where local cooling occurs, since not all suitable clouds need be seeded.

This flexibility might help subdue or eliminate adverse ramifications of the deployment of our scheme.

5. References cited in Text

Bower, K N, Choularton, T W, Latham, J, Sahraei, J and Salter, S H 2006 *Computational assessment of a proposed technique for global warming mitigation via albedo-enhancement of marine stratocumulus clouds*. Atmos Res 82, 328–336.

Latham, J 1990 *Control of global warming?* Nature 347, 339–340.

Latham, J 2002 *Amelioration of global warming by controlled enhancement of the albedo and longevity of low-level maritime clouds*. Atmos Sci Lett. 3, 52–58. (doi:10.1006/Asle.2002.0048).

Latham, J, PJ Rasch, CC Chen, L Kettles, A Gadian, A Gettelman, H Morrison, K Bower., 2008. *Global Temperature Stabilization via Controlled Albedo Enhancement of Low-level Maritime Clouds*. Phil Trans Roy Soc A, doi:10.1098/rsta.2008.0137.

Oreopoulos, L and Platnick, S 2008 *Radiative susceptibility of cloudy atmospheres to droplet number perturbations: 2*. Global analysis from MODIS J Geophys Res 113. (doi:10.1029/2007JD009655).

Quaas, J and Feichter, J 2008 *Climate change mitigation by seeding marine boundary layer clouds*. Poster paper presented at the session *Consequences of Geo-engineering and Mitigation as strategies for responding to anthropogenic greenhouse gas emissions* at the EGU General Assembly, Vienna, Austria, 13–18 April 2008.

Roberts, GC, Ramana, MV, Corrigan, C, Kim, D and Ramanathan, V 2008 *Simultaneous observations of aerosol-cloud-albedo interactions with three stacked unmanned aerial vehicles*. Proc Natl Acad Sci USA 105, 7370–7375.

Salter, S, G Sortino and J Latham, (2008). *Sea-going hardware for the cloud albedo method of reversing global warming, Phil Trans R Soc A, doi:10.1098/rsta.2008.0136.*

6. Recommendations

— That in view of the potentially serious ramifications of unbridled climate change, and the increasing urgency of this problem, the UK government should provide adequate funding for the pursuance of research into geo-engineering ideas which hold significant promise of holding the Earth's average temperature constant for some decades, in the face of increasing atmospheric CO_2 concentrations. This would provide time for the development of clean energy sources to replace fossil fuels. It is not suggested that such schemes be deployed, but that the research be pursued to the point at which the technique be deemed to be either unworkable or feasible, in the latter case with all scientific and technological aspects resolved, and all possible ramifications of the adoption of such a scheme identified and quantified. The costs of such a proposition are trivial in comparison with those of the likely damage accompanying unrestrained temperature increase—a view unanimously expressed by the participants in the climate-change workshop, involving economists, scientists and geo-engineers, held at Harvard University in November, 2007.

— That a committee be appointed to oversee the planning of a research programme in geo-engineering, and disbursement of the governmental funding provided for it.

— That though DEFRA and the Hadley Centre would be major contributors to the proposed committee and geo-engineering research, there should be funded contributions also from UK universities and other research institutions.

— That although climate modelling would play a very important role in the programme of work, it should not be the only component of the effort. Observational research is of great importance, as is field research and technological development. Without these latter components a reliable assessment of geo-engineering ideas would not be achievable, in my view.

October 2008

Memorandum 157

Submission from Dr Ken Caldeira, Department of Global Ecology, Carnegie Institution

The Current and Potential Roles of Engineering and Engineers in Geo-engineering Slutions to Climate Change

1. We need a climate engineering research and development plan. The widespread desire for the "good life" afforded by economic growth and development places us increasingly at risk of profound and widespread climate damage. Much of the developing world seeks to emulate the coal-powered development of China and India, while those of us in the developed world seek ways to kick-start our relatively moribund, fossil-fueled economies. We may hope or even expect that we will collectively agree to delay some of this economic growth and development and invest instead in costlier energy systems that don't threaten Earth's climate. Nevertheless, prudence demands that we consider what we might do if cuts in carbon dioxide emissions prove too little or too late to avoid unacceptable climate damage.

2. Only fools find joy in the prospect of climate engineering. It's also foolish to think that risk of significant climate damage can be denied or wished away. Perhaps we can depend on the transcendent human capacity for self-sacrifice when faced with unprecedented, shared, long-term risk, and therefore can depend on future reductions in greenhouse gas emissions. But just in case, we'd better have a plan.

3. Existing studies of climate engineering demonstrate that some geo-engineering schemes may have the potential to diminish climate risk. Research into science, technology, and socio-political systems is needed to determine whether such risk reduction could be realized. If so, research will be needed to develop these risk reduction strategies.

National and International Research Activity, and Research Funding, Related to Geo-engineering, and the Relationship between, and Interface with, this Field and Research Conducted to Reduce Greenhouse Gas Emissions

4. A climate engineering research plan should be built around important questions rather than preconceived answers. It should anticipate and embrace innovation and recognize that a portfolio of divergent but defensible paths is most likely to reveal a successful path forward; we should be wary of assuming that we've already thought of the most promising approaches or the most important unintended consequences.

5. A climate engineering research plan must include both scientific and engineering components.

6. Science is needed to address critical questions, among them: How effective would various climate engineering proposals be at achieving their climate goals? What unintended outcomes might result? How might these unintended outcomes affect both human and natural systems?

7. Engineering is needed both to build deployable systems and to keep the science focused on what's technically feasible.

8. Initially, emphasis should be placed on science over engineering. But if the science continues to indicate that climate engineering has the potential to diminish climate risk, increasing emphasis should be placed on building the systems and field-testing them so they'll be ready as an option.

9. Because there are important societal decisions to be made regarding climate engineering, open public communication is necessary at all stages of research—closed scientific meetings on climate engineering must become a thing of the past.

10. Climate engineering research programs should be internationalized and scientific discussion and results shared openly by all.

11. Climate engineering (ie, geoengineering) research should be centred in the university environment. Initially, until options are better evaluated and clarified, it is better to have many small projects rather than a small number of large projects.

12. Much of the fundamental climate and chemical science associated with geo-engineering (ie, climate engineering) is intertwined with the science of environmental consequences of greenhouse gases. Thus, many of the same institutions and researchers engage in science related to greenhouse gases could be engaged in climate engineering research.

13. Policy related studies (ie, issues of governance, social acceptance, etc) are closely intertwined with policies related to greenhouse gas reduction. Thus, many of the same institutions and researchers engage in policy-related studies related to greenhouse gas emissions reduction could be engaged in policy-relevant human dimensions studies related to climate engineering.

The Provision of University Courses and other forms of Training relevant to Geo-engineering in the UK

14. Climate engineering (ie, geoengineering) research should be centered in the university environment because this way research dollars will provide the maximum educational benefit.

15. Climate engineering research and training involves both the science of global change (ie, atmospheric physics and chemistry, carbon-cycle science, marine sciences) and the engineering of possible deployment systems. Thus, it would make sense to spread research and training funds across a wide array of academic disciplines. Much of the research and training would likely be interdisciplinary in character.

The Status of Geo-engineering Technologies in Government, Industry and Academia

16. Geoengineering technologies are largely in the conceptual stage across all sectors.

Geo-engineering and Engaging Young People in the Engineering Profession

17. Climate engineering represents a new way to attract young people to address our climate challenges.

18. Climate engineering research, in many cases, could be conducted by the same institutions and researchers focusing on approaches to reduce greenhouse gas emissions. This will give students the opportunity to examine and evaluate a broad range of approaches to addressing the climate challenge.

The Role of Engineers in informing Policy-makers and the Public regarding the Potential Costs, Benefits and Research Status of different Geo-engineering Schemes

19. Scientific research and engineering development should be divorced from moral posturing and policy prescription. As scientists and engineers, we can say what is and what can be.

20. Armed with this information, scientists and engineers can join, as citizens, with their fellow citizens and policy makers to discuss what ought to be done.

October 2008

Memorandum 158

Submission from Professor James Griffiths and Professor Iain Stewart

Summary

- Geo-engineering has the potential to help provide solutions to climate change issues through: carbon sequestration; modelling past changes in climate; identifying and exploiting alternative sources of energy; seeking “low carbon” resources; sustainable groundwater; underground construction; reuse of construction materials; reuse of foundations; reducing construction costs; evaluating changes in design life; assessing increased risk from natural hazards; nuclear waste disposal.
- Geo-engineering research tends to lack support as it falls between to the responsibilities of NERC and EPSRC.
- There are relevant university courses but there is a lack of suitably experienced staff in academe.
- “Engineering” continues to have an image problem as the label has been inappropriately applied to non-graduate professions, and is deemed to be a hard subject at secondary school level. This reduces the number of young people wishing to apply for undergraduate programmes in any course labelled “engineering”.
- Even when the top universities produce quality graduates, as engineering cannot compete financially with banking, insurance and the law, the best graduates do not always enter the profession.
- To inform policy makers and the public it will be necessary to make use of scientists and engineers that are working at the interface between geoscience and geotechnical engineering. These scientists/engineers should have experience in communicating difficult concepts to a non-specialist audience.

1. *Current and potential roles of engineering and engineers in geo-engineering in climate change solutions*

1.1 Geo-engineering is taken to include the following disciplines: engineering geology, environmental geology, engineering geomorphology, geotechnical engineering, ground engineering, hydrogeology, natural hazard and risk assessment.

1.2 An excellent source of information on the relationship between all facets of geology and climate changes can be found on the British Geological Survey website:

http://www.bgs.ac.uk/education/climate_change/home.html

The main areas where geo-engineering has a vital role to play are as follows:

1.3 Carbon sequestration (see EU article on subject at : http://www.euractiv.com/en/climate-change/uncertainty-co2-capture-fossil-future/article-172834): identification and quantitative evaluation of potential sites where CO_2 might be buried, and use of deep-drilling engineering technologies developed by the hydrocarbons industry to implement a sequestration programme.

1.4 Modelling past climate change events in the geological record to evaluate potential consequences in the contemporary environment. This partly involves the Deep Sea Ocean Drilling programme that allows long sedimentary records to be compiled particularly from the Holocene. However, it also involves examining the onshore stratigraphic record from more ancient sediments to enable a fuller picture of the way the earth behaves during periods of rapid climate change and what affect these changes had on the fossil record.

1.5 Identification and exploitation of alternative energy sources, notably: geothermal "hot rocks"; wind farms; wave and tidal power; solar energy; nuclear; hydroelectric; and groundwater heat pumps. All these will need to be located at suitable sites that have to be investigated by engineering geologists and the foundations designed by geotechnical engineers.

1.6 Seeking resources that will provide alternative low carbon production energy such as: suitable "hot rocks"; suitable quality hydrocarbons; gas hydrates; uranium (see: http://ec.europa.eu/environment/integration/research/newsalert/pdf/109na4.pdf); etc. Exploration for these resources will involve extensive use of remote sensing, geochemical and geophysical surveys, on-site drilling, assaying the resource, designing and monitoring the extraction, environmental impact, planning the after-use.

1.7 Identifying, developing, maintaining and monitoring effective sources of sustainable groundwater.

1.8 Researching into and supporting increased use of energy efficient underground construction.

1.9 Researching into and supporting the reuse of construction materials to reduce energy use.

1.10 Researching into and supporting the reuse of building foundations to reduce material wastage and energy use.

1.11 Developing more cost-effective means of ground investigation to reduce the costs of construction.

1.12 Researching into the effects climate change will have on a developments design life.

1.13 Providing the basis for anticipating and dealing with changes in potential risks associated with climate change, eg increases in the rate of coastal erosion, increased landslide occurrence, increased incidence of coastal and river flooding, melting of the permafrost, groundwater rise etc.

1.14 If nuclear energy generation is going to increase, then geo-engineering will be critical in ensuring suitable waste disposal sites are located, designed, constructed, and monitored.

2. *Research activity in geo-engineering relating to research into reducing greenhouse gas emissions*

2.1 NERC are the primary research council supporting climate change research. Naturally their main concern is collecting data and monitoring, climate modelling, and assessing the environmental consequences.

2.2 Most climate change research in the field of "geo-engineering" which is supported by NERC is undertaken by the British Geological Survey.

2.3 Griffiths & Culshaw, (2004—DOI: 10.1144/1470-9236/04-056) reviewed the 296 research projects funded by NERC 2001-2004 and found only six lay in the field of engineering geology or hydrogeology, none of which related to geo-engineering and climate change. The same paper established that at that time the EPSRC grant portfolio was worth £1,855 million and £13.7 million was spent on ground engineering research, of which Cambridge received £2.9 million and Imperial College, London, £1.7 million.

2.4 The EPSRC funded projects research website does not identify those specifically related to "climate change". However, there are projects on wind power, waste minimisation etc which will are all relevant to the climate change debate.

2.5 There is a concern that "geo-engineering" falls between the responsibility of two research councils and suffers from a lack of research funding as a result. More joint EPSRC-NERC initiatives would help deal with this problem.

3. *Provision of university courses & training relevant to geo-engineering in the UK*

3.1 There are two excellent sources of information on the provision of relevant university courses: the February 2008 issue of Ground Engineering, ie the special issue on Geoenvironmental Engineering that also lists the relevant UK masters degree courses; and the Geological Society of London website that list all the universities that offer degrees in geoscience in the U.K, and specifically identifies those that are accredited:

http://www.geolsoc.org.uk/gsl/education/highered/page271.html

3.2 Training opportunities can be identified through the relevant professional organisations: British Geotechnical Association (a specialist group of the Institution of Civil Engineers); Geological Society of London; Association of Geotechnical Specialists; Institute of Materials, Minerals and Mining; Chartered Institution of Water and Environmental Management; etc.

4. *Status of geo-engineering technologies in government, industry and academia*

4.1 There is a general issue that as of September 2008 civil engineers, ground engineers, and geologists of all types still appear on the National Shortage Occupations List. This illustrates the skills shortage problem that has to be faced if we are going to review the status of geo-engineers. Until this is overcome there will be limited opportunity for geo-engineering to get beyond just dealing with its mainstream activities (essentially ground engineering). This will essentially put a stop to any development work investigating the applications of geo-engineering technologies in dealing with climate change.

4.2 The Geological Society membership indicates that over 3,000 of its members have an interest in engineering geology; however, less than 1% of these are to be found in academia. Therefore there is little research activity in academia because: there are very few with the relevant interest; and geo-engineering falls in the gap between the Natural Science and the Engineering research councils therefore there are few opportunities to win awards to support research in this area.

4.3 Much of the industrial geo-engineering work lies in the practical aspects of foundation design for alternative energy structures, waste disposal, recycling, regeneration, coastal protection etc. Industry will only really incorporate geo-engineering into the climate change agenda once a clear profit line starts to emerge. The hydrocarbons industry is starting to take this forward with their investment in alternative energy. As yet geo-engineering does not have the same income stream or the public profile as that of the big oil and gas multinational companies.

5. *Geo-engineering and engaging young people in the engineering profession*

5.1 The best source of information on the efforts being made to engage young people in the engineering profession is the Royal Academy of Engineering:

http://www.raeng.org.uk/education/default.htm

5.2 Similar initiatives can be found underway in all the professional bodies, eg:

http://www.ice.org.uk/education/homepage/index.asp

http://www.geolsoc.org.uk/gsl/education

http://www.ciwem.org/education/

http://www.iom3.org/content/education-training

5.3 It is apparent that engineering has an "image" problem which puts off many prospective students. The A/Ls required are in maths and science, deemed by students to be "difficult"; the term "engineer" has been widely appropriated for use by a range of occupations that are not graduate level; and even where there is knowledge of what an engineering graduate does, it is not seen as sufficiently glamorous or well-paid particularly given the length of time needed to reach chartered status.

5.4 Possibly of even greater concern is that the best graduates from the most prestigious engineering courses, and indeed many from geosciences degrees, take up positions with financial services institutions rather than enter the engineering profession. This is because engineering graduates are numerate and literate, and hence make very attractive employees for all parts of the financial services industry and the legal profession. Given that the financial rewards from "The City" are far greater than from an engineering career, this loss of engineering graduates is not surprising, but nonetheless the result is that engineering practice and research is losing its ablest minds.

6. *The role of engineers in informing policy makers and public regarding the potential costs, benefits and research status of different geo-engineering schemes*

6.1 Engineers *per se* are not necessarily the best people to inform policy makers and the public, we need to involve the individuals who are working at the interface between engineering, geology, geomorphology, and environmental science, both from academe and industry.

6.2 We must make better use of scientists and engineers who have experience in communicating difficult concepts to a non-specialist audience.

6.3 We need to develop more specialists in the analysis of environmental economics in order to establish the potential costs and benefits of geo-engineering research and projects.

October 2008

Memorandum 159

Submission from David Hutchinson, Civil Engineer, Network Rail (Channel Tunnel Rail Link) Limited

1. *Summary*

- This submission concentrates on the contribution of geo-engineering to the operation and maintenance of the UK's railway infrastructure.
- It briefly indicates how geo-engineering in the railway industry helps reduce the affect of climate change on the operation of the railway and helps reduce carbon emissions from the railway and from transport in general.

2. *Introduction*

2.1 This document has been drafted for submission to the UK Parliament's Innovation, Universities, Science and Skills Committee for their third case history in their inquiry into engineering. It has been written to supplement the submission by the Ground Forum, but from the viewpoint of a major owner of geo-engineered structures in the UK. However, the opinions expressed in the document are those of the author and not necessarily those of Network Rail Infrastructure Limited, or Network Rail (Channel Tunnel Rail Link) Limited.

2.2 Railways are an efficient and environmentally friendly way of moving people and goods from place to place. A significant portion of the railway infrastructure, by value, and by volume, lies in geo-engineered structures. These include embankments, cuttings, track formation, tunnels, retaining walls, drainage systems, sea defences and the foundations to bridges, viaducts, stations and line side structures.

2.3 The majority of the UK's railway geo-engineered structures were built over 100 years ago, and many of them over 150 year ago, well before the formalisation of the science, some would say art, of soil mechanics and geotechnical engineering. These geo-engineered structures were built to different specifications, using different techniques and in some case different materials, from those that would be used today. These structures are now reaching the end of the 120 year design lives that such structures would nowadays be normally designed for. Yet there is no plan to replace these old geo-engineered structures; they are being worked harder than ever, carrying ever greater numbers of passenger and freight trains. The cost of their replacement would be truly astronomic, and the consequential disruption totally unacceptable to the public. So now more than ever before they need nurturing and maintaining by professional engineers, technicians and construction workers skilled in geotechnical analysis, design and construction techniques, so that they can continue to serve for another 100 years or more.

3. *The current and potential roles of engineering and engineers in geo-engineering solutions to climate change*

3.1 Without an efficient and effective national, and international, railway system the use of fossil fuels in the UK would undoubtedly rise. Electricity, rather than fossil fuel, is used to power the majority of the UK railway systems, whereas all other major transport systems use mostly fossil fuel. Electricity, of course, can and is being generated by renewable energy sources. Geo-engineering skills are essential to the maintenance of the aging infrastructure and to maintaining and enhancing the reliability and hence the attractiveness of the existing railway networks to passengers and freight. In particular geotechnical engineers will be required to find solutions to the deterioration caused by the expected future extremes of weather caused by climate change. These include flooding causing embankment erosion, excessive rainfall leading to landslips, and long periods of dry weather causing soil shrinkage and subsidence. Geo-engineering is also an essential part of the maintenance and repair of more recently built railway infrastructure, for example the remediation of the recent fire damage to the north bore of the Channel Tunnel.

3.2 The construction of new national and international railways will reduce the demand for other forms of travel, including national and international air travel, and hence reduce the production of greenhouse gases. Geotechnical engineers are essential members of the railway design and construction teams and provide geo-engineered solutions to minimise land take, minimise disturbance and adverse environmental impact, minimise the need to move soil and rock during construction works, and to take positive measures to enhance the environment around the new railways, while still providing value for money. The design and construction of the High Speed 1 railway provides an excellent UK case history of the input of geotechnical engineers to the successful completion, on time and on budget, of the first main line railway to be constructed in the UK for over 100 years.

4. *National and international research activity, and research funding, related to geo-engineering, and the relationship between, and interface with, this field and research conducted to reduce greenhouse gas emissions*

4.1 Network Rail is a leader in the rail industry, which uses a wide range of engineering disciplines, just one of which is geo-engineering. The company has limited funds for geo-engineering research activity of its own, but it does actively support a number of academic initiatives by supplying information to outside research organisations and by providing them with access to the railway infrastructure.

4.2 Network Rail is a partner in the BIONICS project at Newcastle University which aims to establish a database of high-quality embankment performance data to enable future research into the interaction of climate, vegetation and engineering on the behaviour of infrastructure earthworks. Network Rail is a stakeholder in the CRANIUM project which is developing new methodologies for analysing uncertainty and making robust risk-based decisions for infrastructure design and management in the face of climate change funded by the Engineering and Physical Sciences Research Council as part of the initiative on building knowledge for a changing climate. Network Rail (CTRL) Ltd, who operate and maintain the High Speed Railway, are collaborating with both Southampton and Birmingham Universities in their research in to track, track ballast and track sub-ballast design using modern geotechnical principles.

4.3 In addition to formal research undertaken to improve the knowledge base in geo-engineering, much is learnt by the observation of the performance of real structures, of which Network Rail is one of the largest owners in the UK. The dissemination of that information to the wider geo-engineering profession helps both academics and practicing professionals to develop ever more efficient geo-engineering solutions. Network Rail geotechnical engineering staff are active contributors to the profession, publishing technical papers to technical conferences and in the technical press, as well as providing news items for technical journals, and speaking at technical conferences and professional meetings.

4.4 Most research in geotechnical engineering, such as that above, is directed to the more efficient use of land or the more efficient use of soil, rock and other geo-engineering materials, including the use of waste materials from the railway and other industries. The smaller the volume of material that needs to be moved around to maintain old railways or to build new railways the smaller the volumes of greenhouse gases created during construction operations. The fewer disruptions to trains caused by failures of geo-engineered infrastructure the more reliable the railways and the more used they will become.

5. *The status of geo-engineering technologies in government, industry and academia*

5.1 Historically in Network Rail geo-engineering has generally been managed by non-specialist civil engineers. Over the last 10 years Network Rail has increasingly realised the need to retain a specialist geotechnical capability within the civil engineering departments of each of its five territories if the railway is to become more reliable, more cost effective to run and more attractive to its customers. The status of the geotechnical engineering departments within Network Rail is on a par with those for structures (bridges) and for buildings (such as stations), and civil engineering is on a par with the other engineering disciplines such as signalling, track, electrical power supply.

6. *Geo-engineering and engaging young people in the engineering profession*

6.1 Network Rail recruits engineering graduates from a range of disciplines into the railway industry. Network Rail runs civil engineering training schemes which leads to chartered membership of the Institution of Civil Engineers, which is the natural "home profession" for many geo-engineers. Once chartered, a graduate would be encouraged to consider specialising in geotechnical engineering, as one of a range of special or general disciplines within the civil engineering profession.

7. *The role of engineers in informing policy-makers and the public regarding the potential costs, benefits and research status of different geo-engineering schemes*

7.1 For Network Rail the Office of Rail Regulation (ORR), and its board appointed by the Secretary of State, is the key organisation that it must inform regarding the way that Network Rail manages the railway network and the way in which it meets the needs of its users. The ORR makes recommendations to the government for funding for railway maintenance and for enhancements promoted by Network Rail. Geotechnical engineers are actively engaged in those areas of the proposed schemes which require their expertise.

October 2008

Memorandum 160

Submission from the Engineering Professors' Council

SUMMARY

- The Engineering Professors' Council represents the interests of engineering in higher education. It has over 1,600 members in virtually all of the UK universities that teach engineering. They are all either professors or Heads of departments.
- It has as its mission the promotion of excellence in engineering higher education teaching and research.
- It includes academics with interest in teaching and research in geo engineering.
- This evidence refers to the geo engineering in the construction, extractive and environmental (including water resources) industries. It focuses on teaching and research undertaken at universities.
- The recommendations are to:
  - Recognise the contribution that geo engineers will make to the impact of climate change on the built environment, and to developing innovative solutions to make use of the ground for CO2 storage and as source of energy.
  - Ensure that there is adequate research funding into geo engineering related challenges such as those associated with the effects of extreme events such as subsidence damage due to ground movements, failures of natural and made slopes, and changes to the ground water regime; the impact of rising ground water levels on subsurface structures such as tunnels, basements and structural foundations; and the impact of rising sea levels on flood and sea defences.
  - Ensure that there is adequate funding for specialist advanced programmes to combat the skills shortages and gaps in geo engineering to ensure that the government, which is a major beneficiary of much of geo engineering work because it is related to the infrastructure that underpins the economy, provides core funding for education it ensures that innovative solutions are developed and exploited for the benefit of the public sector and that knowledge can be exported.

1. *Introduction*

1.1 Geo engineering has various meanings that includes the large scale engineering options which aim to remove CO_2 directly from the air, for example, through ocean fertilisation, the use of the ground as a means of storing CO_2, the abstraction of fossil fuels, the use of ground as a construction material and the use of groundwater as a resource.

1.2 This evidence for the case study into geo engineering refers to engineering that is concerned with the impacts of climate change on the ground in the construction, extractive and environmental (including water resources) industries. It focuses on teaching and research undertaken at universities.

2. *The current and potential roles of engineering and engineers in geo-engineering solutions to climate change*

2.1 Geo engineers are professional engineers who are concerned with the impacts of climate change on the ground in their work in the construction, extractive and environmental (including water resources) industries. These include the effects of extreme events such as subsidence damage due to ground movements, failures of natural and made slopes, and changes to the ground water regime; the impact of rising ground water levels on subsurface structures such as tunnels, basements and structural foundations; and the impact of rising sea levels on flood and sea defences.

2.2 Geo engineers will be engaged in adapting existing geo structures such as foundations, tunnels, retaining walls and slopes to the impact of rising ground water levels and extreme events; applying mitigation measures to reduce or eliminate the impact of these effects; and developing innovative solutions to ground related problems associated with the built and natural environment.

2.3 They will also be involved in producing innovative uses of the ground as a source of energy, a means of carbon capture and storage, and assisting in bridging the gap between the current fossil fuel economy and the future hydrogen economy.

2.4 Note that geo engineers, according to the Home Office UK Border Agency (2008) [1], are responsible for:

- Design, supervision and interpretation of ground investigations.
- Mineral exploration and extraction.
- Design and supervision of construction of geotechnical structures including foundations, slopes, excavations, tunnels, and retaining walls.

- Design of ground improvement schemes.
- Monitoring the performance of geotechnical structures.
- Regenerating brownfield sites including identification of contamination and recommending, designing and supervising appropriate treatment.
- Regeneration to identify contamination and recommend, design and supervise appropriate treatment.
- Contamination studies that involve solid, liquid and hazardous waste including identification, disposal, treatment and reuse.
- Landfill design.
- Underground storage of hazardous materials including nuclear waste and carbon dioxide.
- Development of geothermal energy systems.
- Stability of mineral workings including underground and open cast mines.
- Investigation of subsidence and recommending and designing mitigation measures.
- Coastal and river stability.
- Properties of the groundwater including its chemical properties and pattern of flow.
- Causes and effects of ground water pollution.
- Causes and effects of construction processes on the ground water.
- Investigating of the impact of changes to groundwater flow due to the construction of the reservoir.
- Studies of the geological structures in the vicinity of the reservoir leading to the appropriate location of the dam and the scope of the design of the foundation of the dam.

3. *National and international research activity, and research funding, related to geo-engineering, and the relationship between, and interface with, this field and research conducted to reduce greenhouse gas emissions*

3.1 There are a number of consortia funded by Research Councils, Government Departments and industry that bring together geo engineers working in universities, research and development institutions, and industry to create multidisciplinary teams to investigate the effects of climate change on the ground and means of reducing greenhouse gases. These include:

- The Tyndall Centre [2] which is the national UK centre for trans-disciplinary research on climate change which brings together scientists, economists, engineers and social scientists to develop sustainable responses to climate change. Research themes that involve geo engineers include examining ways to adapt to unavoidable climate change and providing the basis for flexible adaptation to, and efficient mitigation of changing environmental conditions around coastlines.
- CLIFFS [3] is an EPSRC-funded network based at Loughborough University that brings together academics, research and development agencies, stakeholders, consultants and climate specialists to improve forecasting of slope instability in the context of progressive climate change.
- EPSRC have created a £3.2 million portfolio of collaborative research projects, Building Knowledge for a Changing Climate [4], to investigate the impacts of climate change on the built environment, transport and utilities. Research projects cover areas ranging from risk management to the impact of climate change on energy supplies, land use and historic buildings. The major ground engineering project in this portfolio is the BIONICS [5] (Biological and Engineering Impacts of Climate Change on Slopes) project at Newcastle University which is a unique facility consisting of a full-scale, instrumented soil embankment, planted with a variety of flora with controlled heating and rainfall at its surface. This replicates road and rail embankments found throughout the UK.
- The Scottish Centre for Carbon Storage [6] is a centre of excellence for research and development in carbon capture and storage looking to containment solutions to complement emissions reduction strategies.
- The UKCCSC [7] is a consortium of engineering, technological, natural, environmental, social and economic scientists from the British Geological Survey and universities that are investigating the reduction of UK CO2 emissions by decoupling economic growth from energy use and pollution; rapidly expanding the UK research capacity in carbon capture and storage, assisting in enabling the continued use of the UK's coal reserves; investigating fossil fuel gasification as a bridge to the hydrogen economy; assisting in bridging the gap between the present day fossil fuel economy and the future hydrogen economy; and making an overall assessment of lifecycle costs and emissions of fossil fuel supply options.

3.2 These collaborative projects are mainly about the consequences of climate change on the environment. There is little research into mitigation and adaption especially in the construction industry.

3.3 The UK is the only developed country in the world that does not have a dedicated construction research and development funding stream [8]. Therefore there is not a dedicated stream related to the impact of climate change on construction and the reduction of greenhouse gases within that sector. Further geo engineers within the construction industry operate within a framework of Building Regulations, codes and standards. These ensure that their work meets minimum standards and follows best practice. There is no longer a mechanism that directly supports the development of this framework which includes a framework to deal with the impacts of climate change and the reduction of greenhouse gases.

3.4 This was not always the case. The Government co-funded the Construction Research and Innovation Programme for about £23 million per annum until 2002 for materials testing, development of codes and standards, general guidance, network groups, work underpinning changes to the Building Regulations, and the development of sustainability assessment tools.

3.5 The current annual public funding of research for the construction industry is less than £10 million [8] (Select Committee for Construction Matters, 2008). Additional annual funds include:

— £32 million for academic-led research from Engineering and Physical Sciences Research Council;
— £5 million for research underpinning the Building Regulations from Department for Communities and Local Government;
— £8 million towards asset management issues from the Highways Agency;
— £4 million into flood management from the Environment Agency;
— £4.5 million from the Carbon Trust; and
— Funds available through European Research Framework Programmes.

3.6 This £63 million of government funding for the whole of the construction industry compares unfavourably with the £206 million in France, and £750 million in Japan.

3.7 The lack of government funding means that there is no longer sufficient monitoring of the performance of new geo products and processes to understand their behaviour, there is little funding to share best practice especially from overseas and there is a limited engagement in the development of European standards. The National Platform for the Built Environment was launched in 2005 to mirror the European Platform but without adequate seed funding. These examples demonstrate the impact the lack of core funding can have on a sector.

3.8 Research into geo engineering in the construction sector has to compete for the limited funds for that sector. Hence research into adaption and mitigation in the geo engineering sector is limited.

3.9 We recommend that:

3.9.1 The government creates a dedicated funding stream for construction related research that includes research into developing innovative solutions to ground related issues arising from climate change and provides data to enhance the framework for the mitigation of the impact of climate change on geo engineering structures.

4. *The provision of university courses and other forms of training relevant to geo-engineering in the UK*

4.1 Geo engineers provide professional services within the construction, extractive and environmental industries. In order to act as professional engineers they have to complete a degree programme. These degree programmes can be accredited by one of the professional institutions that represent the interests of the members (eg ICE, CIWEM, Geol Soc, IMMM). Hence geo engineers can be chartered engineers, chartered geologists or chartered environmental scientists.

4.2 Geo engineering covers a variety of careers [1]:

— A geoenvironmental engineer is someone who deals with environmental aspects of the ground.
— A geotechnical engineer is someone who deals with engineering the ground in the construction industry.
— A geological advisor is someone who deals with geological aspects of the ground.
— A geological analyst—a term used to describe a geoscientist who specialises in geological aspects.
— A geologist/hydrogeologist describe anyone working in the field of geology or hydrogeology.
— A geology/reservoir engineer is someone who specialises in geological aspects of reservoir engineering.
— A geophysical specialist is someone who specialises in the use of geophysics as an exploration tool especially in mineral exploration.
— A geoscientist is someone who is involved in analysing the chemical aspects of the ground.

— An engineering geologist is someone who deals with engineering the ground who has specialist geological knowledge.

— And a contaminated land specialist is someone who deals with environmental aspects of contaminated ground.

4.3 Thus there are a number of pathways to becoming a professional geo engineer but in the majority of cases it starts with a bachelor degree in civil engineering, mining engineering, highway engineering, geology, engineering geology, earth sciences, environmental sciences, physics or maths. There are two universities offering dedicated programmes in engineering geology or applied geology. There are 73 HEIs offering accredited undergraduate programmes in civil engineering which will include the core subject of geotechnical engineering. There are 39 universities offering undergraduate courses in geosciences including geology of which 21 are accredited by Geological Society.

4.4 Geo engineering is a specialist area, an area that deals with uncertainty. The ground is spatially variable both in type and properties which means that geo engineers have to have underlying knowledge in a range of disciplines in order to tackle the challenges created by construction activity, climate change, mineral extraction, and ground water regimes. This specialist knowledge is either developed in advance courses in higher education or in work based education.

4.5 Thus most geo engineers have to extend their education to complete either an MEng (in civil engineering) or an MSc/PhD in soil mechanics, rock mechanics, geotechnical engineering, engineering geology, geophysics, hydrogeology, or other ground related discipline.

4.6 A key concern of the industry is the decline in the number of specialist advanced programmes, a decline in the number of places on these advanced programmes and the lack of funding for these programmes. For example, EPSRC has recently announced that it will no longer fund traditional MSc programmes. This has led to a skills gap which is has been made worse by the skills shortage. Hence the inclusion of geo engineers on the Home Office Key Worker List [1].

4.7 This skills issue is a particular problem in the construction industry. The Select Committee on Construction Matters in its 2007–08 [8] report states that the high level of fragmentation and reliance on sub-contracting, combined with the project-based and itinerant nature of most work, the low profit margins and cyclical demand, create a strong disincentive for firms to invest in people. It is clear, however, that the professional services sector makes a significant contribution to the industry which produces some 70% of the manufactured wealth of the UK, and is responsible for some £3.5 billion worth of exports per annum. Hence there is a strong business case for investment in skills. Geo engineering represents about 13% of all the professional engineering services in the construction industry [9].

4.8 We recommend that:

4.8.1 The government produce adequate funding for specialist advanced programmes in geo engineering that meet the challenges of the geo engineering industries. This will help resolve the skills gap and skills shortages. The government is a major beneficiary of much of geo engineering work therefore by providing core funding for education it ensures that innovative solutions are developed and exploited for the benefit of the public sector and that knowledge can be exported.

5. *The status of geo-engineering technologies in government, industry and academia*

5.1 Geo engineers have to deal with a complex particulate material that has the largest range of properties of any material. Geo failures can be catastrophic (eg landslides, earthquakes) affecting communities and the built environment. Geo materials are essential to the built environment and a prime source of energy. There have been significant developments in predicting the behaviour of ground through the development of constitutive models based on quality tests and field observations, and the application of those models in sophisticated programmes. Much of this has developed in research institutions and universities with government funding. Indeed public sector funding of geo engineering research has been essential to develop the underlying science which is iterative by nature.

5.2 There is a critical need, especially with the impact of climate change, to monitor the performance of geotechnical structures given that knowledge is needed to develop codes and standards and improve our understanding of the behaviour of these structures.

5.3 Industry has led the way in developing innovative processes in dealing with geo materials whether it be improved methods of extracting energy *in situ* from fossil fuels, developing more efficient methods of extracting fossil fuels, making use of the ground as a source of energy, improvements in construction processes and more effective and efficient geo structures.

5.4 We recommend that:

5.4.1 The government provides adequate research funding to continue the successful development of innovate solutions to ground related problems. This is especially important as solutions will be needed to adapt existing geo engineering structures to mitigate the effects of climate change.

6. *Geo-engineering and engaging young people in the engineering profession*

6.1 Engineers and scientists working in geo engineering are engaged in promoting geo engineering through company schemes, articles in NCE Insite magazine, RAEng Ambassador Scheme, Professional Institutions' career events, EPSRC Public Understanding Projects, and ConstructionSkills Constructionarium.

7. *The role of engineers in informing policy-makers and the public regarding the potential costs, benefits and research status of different geo-engineering schemes*

7.1 All structures are built on, in or with ground: the largest structures in the world involve the ground (eg dams, surface and subsurface mines); road and rail networks rely on earth structures (eg embankments, tunnels, cuttings) to function; communication, energy and water networks are constructed underground; and the major building materials of concrete, steel and bricks evolve from the ground. All geo engineering activity impacts in some way on ground water; and climate change will have an impact on the ground water. All primary resources and fossil fuels are derived from the ground.

7.2 Geo engineers make a significant contribution to the construction industry which contributes 8.7% (2006) of the UK economy's gross value-added (GVA) which, in 2006, was worth over £100 billion [8]. This is more than twice the GVA produced by the energy, automotive and aerospace sectors combined. It generates some £10 billion of exports each year which includes some £3.8 million from the professional services.

7.3 The construction industry is a "manufacturing" industry in that it designs, builds and maintains a product (eg bridges, tall buildings). However, its products cannot be exported (its skills and knowledge in design and construction can), all of its products contain an element of originality especially in the area of geo engineering. These products create the built environment which represents some 70% of UK manufactured wealth.

7.4 Fossil fuels account for some 90% of the UK's energy supply (UK Energy Sector Indicators, 2007) [10]. It is expected that geo engineers will assist in the continued use of the UK's coal reserves; investigate fossil fuel gasification as a bridge to the hydrogen economy; assist in bridging the gap between the present day fossil fuel economy and the future hydrogen economy; and make an overall assessment of lifecycle costs and emissions of fossil fuel supply options.

7.5 Therefore it is expected that geo engineers would be represented in a number of government departments and be part of the decision making process. This is not the case.

7.6 We recommend that:

7.7 The government appoints engineers with practical experience to advise departments on all geo engineering related matters. This includes the development of policy and the implementation of that policy.

8. *Conclusions*

8.1 The EPC welcomes the Select Committee's Inquiry and considers both that it is timely and that it deals with issues of high importance for the future of the UK. As a body representing the interests of practitioners in Higher Education including those that undertake research and teaching into geo engineering, we would like to make the following RECOMMENDATIONS and thus urge the Government to:

8.1.1 Recognise the contribution that geo engineers will make to the impact of climate change on the built environment, and to developing innovative solutions to make use of the ground for CO2 storage and as source of energy.

8.1.2 Ensure that there is adequate research funding into geo engineering related challenges.

8.1.3 Ensure that there is adequate funding for specialist advanced programmes to combat the skills shortages and gaps in geo engineering.

8.2 We would be delighted to meet the Select Committee and discuss the issues involved at greater length.

9. *References*

1 Skilled Shortage Sensible: The recommended shortage occupation lists for the UK and Scotland Migration; Migration Advisory Committee, September 2008, UK Border Agency, Home Office

2 Tyndall Centre (HQ), Zuckerman Institute for Connective Environmental Research, School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ, UK

3 Climate Impact Forecasting for Slopes; http://cliffs.lboro.ac.uk/

4 Buildings: Building knowledge for a changing climate; http://www.ukcip.org.uk/

5 BIONICS http://www.ncl.ac.uk/bionics/

6 Scottish Centre for Carbon Storage http://www.geos.ed.ac.uk/sccs

7 UK Carbon Capture and Storage Consortium http://www.geos.ed.ac.uk/ccs/UKCCSC

8 House of Commons Business and Enterprise Committee: Construction matters, Ninth Report of Session 2007–08, Volume I

9 Survey of UK Construction Professional Services 2005/06; Construction Industry Council (CIC)

10 UK energy sector indicators 2007 http://www.berr.gov.uk/energy/statistics/publications/indicators/page39558.html

October 2008

Memorandum 161

Submission from the Institution of Mechanical Engineers

The Institution of Mechanical Engineers (IMechE) is a professional body representing 80,000 professional engineers, working in all sectors of industry. The following evidence is in submission to the Innovation, Universities and Skills Select Committee geo-engineering engineering case study. The evidence is structured in response to some, but not all, of the case study's terms of reference.

1. *The current and potential roles of engineering and engineers in geo-engineering solutions to climate change*

1.1. As greenhouse gas emissions continue to rise and deforestation shows no sign of halting, geo-engineering is emerging as a potential third branch of humankinds' response to climate change. Alongside the more common mitigation and adaptation approaches, geo-engineering has the potential to avert the effects of climate change.

1.2. However, geo-engineering is an area of activity that has to-date received little serious attention from the engineering profession. Typically, the majority of the concepts, ideas and schemes thus far suggested have been proposed by the scientific community; professional engineers have rarely engaged in assessment of their engineering feasibility. In the Institution's view this has largely been due to the international political community's focus on finding ways to reduce the amount of carbon dioxide emitted.

1.3. As a discipline, geo-engineering is still very much in its infancy. Much of the theory behind geo-engineering is based on the principles of mechanical engineering; professional engineers are critical to the conversion of geo-engineering concepts and ideas into practical working devices and machines. Reflecting this possibility, the Institution has recently begun to address the subject area. Initially this will be aimed at raising awareness within the profession of the potential future engagement of mechanical engineers in geo-engineering. It is anticipated that the Institution will increase its activities in this area in the coming years and that the emphasis will shift with time to the dissemination of technical knowledge and best practice.

2. *The provision of university courses and other forms of training relevant to geo-engineering in the UK*

2.1. We are unaware of any specific geo-engineering courses in the UK.

3. *Geo-engineering and engaging young people in the engineering profession*

3.1. One of IMechE's key objectives is to inspire and nurture the next generation of professionally qualified engineers. To this end, in common with other engineering institutions, we organise a number of outreach activities across the country that use practical and technical based approaches to stimulate a continued interest in engineering. Indeed, we find many young engineers are motivated to address contemporary environmental challenges, particularly in the areas of global warming and sustainability. Geo-engineering solutions are one such challenge that therefore offers an opportunity to engage young people in the profession.

3.2. In recognition of the potential of geo-engineering to inspire young engineers, the Institution has been working with its Young Members Executive Board to develop an international competition based on teams of young engineers making initial technical assessments of the feasibility and sustainability of potential geo-engineering solutions. The competition will be open to a wide range of young engineers and take place from November '08 to March '09. It will culminate in a public final to be held at IMechE headquarters in London. Outcomes from the competition are intended to catalyse debate around geo-engineering solutions to global warming.

4. *The role of engineers in informing policy-makers and the public regarding the potential costs, benefits and research status of different geo-engineering schemes*

4. Professional engineers are critical to the conversion of geo-engineering concepts and ideas into practical working devices and machines. Proposed schemes will require initial assessment of their technical feasibility from the engineering perspective. Some may require the development of new innovative techniques both for their manufacture and operation. In the process of making these initial assessments it will be necessary for engineers to report on the availability of the required techniques, materials, manufacturing and construction processes as well as identify the risks associated with manufacture, installation, operation, maintenance and decommissioning, together with the costs and benefits. Whereas some information may be commercially sensitive, the engineering profession will need to inform policy-makers and the public of the potential costs, benefits and research status of geoengineering schemes.

October 2008

Memorandum 162

Submission from the Engineering Group of the Geological Society of London

Engineering Geology

"*Engineering Geology is the science devoted to the investigation, study and solution of the engineering and environmental problems which may arise as the result of the interaction between geology and the works and activities of man as well as to the prediction and of the development of measures for prevention or remediation of geological hazards.*" (IAEG statutes, 1992).

Summary

- An understanding of the ground is fundamental to nearly all engineering projects and to ensuring safety against natural geohazards (landslides, karst collapse, subsidence and heave).
- Engineering Geologists are at the forefront of understanding the "ground model" and hence the assessment of a range of activities that impact on, or are affected by, climate change.
- A reliable ground model is needed for projects for the use of renewable energy including wave, tide and wind, for landfill sites, carbon storage schemes and nuclear power stations and for assessing the risk from geohazards.
- The ground models is a key element in remediation of contaminated land and the use of brownfield sites.
- Engineering Geologists are prominent in optimising use of natural resources and maximising the use of alternative materials, including reuse of "waste products", for example as fill for embankments (road, rail and flood defences) and aggregates for concrete.
- Engineering Geology is experiencing a severe skills shortage which is due to a combination of shortage of students and closure of geology departments and MSc courses, largely as result of due removal of government funding.

The Engineering Group of the Geological Society of London (EGGS)

1. The Engineering Group is a specialist group of the Geological Society, founded in 1807. Since its formation in 1964 the Group has been the main focus in the UK for geologists concerned with the study and practice of geology within the engineering industry. The Group's currently has some 2,500 members, more than a quarter of the Society's membership.

2. The Group is the UK Chapter of the International Association of Engineering Geology (IAEG) and represents the Geological Society on the Ground Forum and The Hazards Forum. It is member of the Geotechnical Training Co-ordination Committee and has firm links with a number of associated organisations.

The Role of the Engineering Geologist

3. The role of the Engineering Geologist is broadly the establishment of the ground model and the prediction of the changes that will affect the model as a result of proposed man made activities or likely natural occurrences. Engineering Geologists commonly carry out desk studies, devise and supervise ground investigations, interpret the results, write reports detailing the existing ground and groundwater conditions,

produce designs and advise during the life of the project. These projects include construction on a green or brownfield site, landfill, offshore works, remediation of contaminated land, or stability of existing or proposed man-made or natural slopes.

I. *The current and potential roles of engineering geologists in geo-engineering solutions to climate change*

4. Virtually all construction or engineering impacts on the earth in some way. The behaviour of the ground is therefore fundamental to most, if not all, engineering endeavours. Unlike man-made materials soils and rocks vary in the their physical and chemical properties in both time and space, as a result of their intrinsic nature (constituent particles and mode of formation) and their long history of chemical and physical change. The effects of the proposed man-induced changes must be superimposed on this already complex model.

5. Engineering Geology involves the investigation of ground conditions based on knowledge of the geological setting, the land use history, inspection of the ground surface for signs and effects of geological, geomorphological or anthropomorphic activity. An intrusive investigation is then required to confirm and refine the model and to obtain design parameters. If these investigations are appropriately conceived and managed then this will reduce the risk of unforeseen ground conditions and enhance the sustainability, reduce waste and CO_2 emissions and be protected from the effects of climate change.

Future Structural Stability

6. The Engineering Geologist identifies natural and man-made geohazards such as landslides, karstic ground and subsidence and hence, assesses the effects of potential climate changes on the behaviour of the ground. This knowledge is used to inform planners, developers and the public and to advise on mitigation and avoidance measures. For example, high rainfall increases the risk of landslides, embankment failures, erosion, heave in clays and ground collapse due to sink holes and caves which can lead to destruction and death. Lower rainfall and higher temperatures causes ground shrinkage due to drying of clay while increased abstraction of ground water in times of drought may cause ground lowering, resulting in subsidence and hence damage to buildings and infrastructure. Construction materials must remain stable throughout the life of the project.

7. Specific activities associated with climate change that require Engineering Geology input include:

- Assessment and repair of rail, road and marine infrastructure
- Design, maintenance and enlarging (raising) of flood relief structures
- Coastal management
- Design and monitoring of slope stability to reduce landslide risk
- Site assessments and design for new reservoirs and dams and continued efficiency and safety of existing structures

Efficient Use of Natural Resources including Land

8. The Engineering Geologist is at the forefront of the use of materials in construction such as:

- Identification and characterisation of natural resources and planning their exploitation
- Identification of suitable local resources to reduce haulage
- Optimising earthworks design, including reinforced earth and ground improvement to reduce the volume of imported materials
- Use of alternative materials such as crushed glass, shredded tyres, pulverised fuel ash (PFA), furnace bottom waste, tyre bales, crushed concrete, construction waste and spoil from quarries and mines
- Reuse of old foundations
- Carbon storage and sequestration
- Assessment of the carbon footprint

9. The Engineering Geologist is a key professional in the rehabilitation of brownfield sites, thereby reducing the need for the use of greenfield sites. Key activities include:

- Land quality assessment by desk study, walk over and investigation.
- Establishing a ground model and identifying pollutants, linkages and receptors for predicting the risks arising from contamination.

— Assessing the risk of groundwater becoming contaminated and spreading contamination
— Producing options for remediation or containment and appropriate design and implementation

Renewable and Alternative Energy Sources

10. Site assessment, investigation and design for:

— Foundations and earthworks for wind turbines, tidal, wave, hydro and other alternative sources of energy, including site characterisation for nuclear power stations.
— Investigation for shallow and deep ground source heat pumps
— Development of deep seated "hot rocks" geothermal energy sources
— Design and management of landfill sites including methane collection as a source of energy.

II. *National and international research activity, and research funding relating to geo-engineering, and the relationship between, and interface with, this field and research conducted to reduce greenhouse gas emissions*

11. The research work that that formed the basis for the discipline of Engineering Geology was largely carried out in the 1960s to the 1990s at universities and government funded research establishments such as the British Geological Survey (BGS), CIRIA, the Building Research Establishment (BRE) and the Transport Research Laboratory (TRL then the TRRL). The UK was at the forefront of Engineering Geology and the MSc courses at Imperial College and the universities of Leeds, Durham and Newcastle attracted students from all over the world. Undergraduate options were offered at some universities and the then Portsmouth Polytechnic (now the University of Portsmouth) introduced the first (and only) undergraduate Engineering Geology course. Pioneering research was done into the behaviour of soils and rocks and of methods of testing. Literature from that time forms the basis for the industry to this day, including the publications of the aforementioned institutions and of the Geological Society (Engineering Group Special Publications and the Quarterly Journal of Engineering Geology and Hydrogeology (QJEGH)).

12. The situation is somewhat different today. Geotechnical work at the BRE has ceased while TRL and BGS operate largely as commercial consultancies with research in a more minor role where external funding is available. Research at universities is mainly for PhD programmes and on a very much smaller scale. There have been developments in investigative techniques but few recent advances in the understanding of the behaviour of soil and rocks.

III. *The provision of university courses and other forms of training relevant to geo-engineering in the UK*

13. The traditional route for training Engineering Geologists is a three year undergraduate degree in Geology and an MSc in Engineering Geology, soil mechanics or rock mechanics. Today both three year and four year degrees are available for geologists but, with the exception of the undergraduate programmes at the University of Portsmouth, Engineering Geologists still require an MSc. A PhD is not necessary to practice Engineering Geology but in some circumstances can be an advantage.

14. The Geological Society is licensed to confer the titles of Chartered Geologist (CGeol), Chartered Scientist and EurGeol. With suitable support and training a graduate in geology can attain chartered status within about five years. It is intended that CGeol should be the professional standard.

15. The Engineering Group provides a training guide for graduates in progressing to chartered status and for their continuing professional development thereafter. The Geological Society endorses selected CPD (Continuing Professional Development) courses.

16. The Engineering Group publishes the Quarterly Journal (QJEGH) and a range of "Special Publications". The Group runs working parties whose reports have formed a valuable range of publications on subjects such as weathering, clay minerals, and aggregates.

17. In recent years there has been a reduction in the number of MSc courses for Engineering Geologists and those remaining are under threat because of a shortage of students and of funded places. At the same time industry is experiencing a severe shortage of experienced professionals. Engineering Geologists are have been on the Government Shortage Occupation List for work permit purposes since 2005.

18. The industry has had to provide training for those recruited with less than the full range of skills required, and for further development of existing staff. Short courses are run by employers and by universities and commercial organisations. Industry has found that even well qualified graduates can lack basic skills in numeracy, problem solving, report writing and understanding of fundamental principles that were once taken as read. Within their training budgets companies also provide courses in health and safety, quality assurance and environmental management some many also support research and students at universities.

IV. *The status of geo-engineering technologies in government, industry and academia*

Professional Status

19. In common with other ground specialists, Engineering Geologists are active in the earliest stages of a project, far removed from prestigious opening ceremonies and their endeavours are buried and forgotten—provided they perform adequately. There have been many unsung Engineering Geologists on projects such as the Channel Tunnel, Jubilee Line Extension, the Greenwich Peninsula and the 2012 Olympic site.

20. Ground engineers suffer from a long standing difficulty in persuading clients and others within the engineering profession of the need for comprehensive and robust ground investigation. If anything this situation is worsening with more "fast track" projects putting further pressure on the investigations which are relatively time consuming.

21. It seems that Engineering Geology is still not well understood even within the construction industry. Furthermore, the importance of ground engineering is questioned despite the fact that the majority of construction claims are ground related ("unforeseen conditions"). The potential for appropriate geological assessment to save time and money is overlooked. This is perhaps reflected in the removal of government funding from degree courses particularly the vital MSc courses.

22. Foundation and slope designs are not regulated in the UK—except in Scotland where structural engineers are required to sign-off building designs, including the foundations, for which they almost certainly lack the expertise. The Engineering Group is contributing to the formation of a register of geological and engineering professions who are competent to advise on ground engineering. Support of government agencies such as the HA and EA in specifying membership of the register for certain roles will be critical to the success of the register and the support of infrastructure owners such as local authorities, Network Rail, London Underground, BAA and ABP will also be invaluable.

23. There has been a steady decrease in the number of MSc courses in Engineering Geology in the UK. A number of geology departments have closed and in some universities Engineering Geology is taught in geography, civil engineering or other departments, removing it from its principles in pure geology.

24. The industry faces a skills shortfall, especially in the mid-career range, but increasingly affected by the reducing number of students. The situation is likely to worsen in the next 10 years as senior professionals retire because a reduced number of graduates entered the profession during the recession years of the 1980s when opportunities were limited. In addition, a demographic downturn in 18 year olds is due in 2010–11. The result is a need to recruit Engineering Geologists from overseas. Although this need is likely to continue for the foreseeable future, it can only be seen as a short term fix. Recruitment is currently being affected by a shortage of applied geologists in countries such as Australia and New Zealand which encourages their nationals to stay at home, or return home, and has seen companies from these countries recruiting from the UK.

Status of Technology and Practice

25. Engineering Geology practice has seen a number of technological advances in recent years including:

- improved field and laboratory testing procedures, for example in data loggers and the transfer of digital data
- development of more mobile and flexible drilling equipment, primarily driven by the rail industry
- development of insitu testing such as Cone Penetrometer Testing, for example the piezo-, seismic- and contamination detection cones
- downhole logging tools and other geophysical techniques
- developments in instrumentation and remote data retrieval
- electronic data bases and GIS for data storage, manipulation, interpretation and presentation
- increased use quality drilling techniques, such as triple tube core barrels advanced bits and polymer mud;
- use of geo-textiles, marginal materials and recycled or 'waste' materials
- the use of satellite and land based remote sensing imagery, notably for asset management

26. Areas in which Government can assist:

- Planning would be improved if Planning and Policy Guidance (PPG) was applied by equally by all local authorities to avoid inappropriate development which is prone to climate change-related geohazards such as flooding, landslides, subsidence and collapse (in karstic areas)
- Resolution of the uncertainties surrounding Soil Guideline Values for contaminants, which are hampering progress in the industry

— The autonomy of Area Planning Officers and Environment Agency Officers results in inconsistencies that cannot be referred to a central authority.

— Area Planning Officers and Environment Agency Officers commonly refuse to provide clear requirements at the early stages of projects which results in wasted time and effort.

— The industry as well as the nation would benefit from a mandatory requirement for an adequate site investigation as part of applications for detailed planning approval.

— Support for the proposed Register of Ground Engineering Professionals to ensure that ground engineering is carried out by those with appropriate qualifications and experience.

V. *Geo-engineering and engaging young people in the engineering geology profession*

27. The Schools Outreach sub-committee of the Engineering Group is developing a series of presentations which tie into the current Welsh Joint Education Committee (WJEC) and Oxford Cambridge and RSA Examinations (OCR) curricula for A and A2 level geology courses. These presentations are aimed at presenting applied geoscience as an attractive higher education opportunity and an exciting career prospect. The presentations are based on four key themes, slope stability, transport, water and mining and energy resources. Each theme is supported and illustrated by case studies.

28. This programme will be extended to GCSE level to reach students aged 14 to 19 years. The sub-committee is planning to recruit young Engineering Geologists to make these presentations in schools, adding case studies based on their own academic and industrial experience as their career develops.

29. One of the Group's members had recently published articles about her work experiences in two magazines aimed at school children, NCEinsite and Rockwatch.

30. In its work to promote Geology, Engineering Geology and Applied Geoscience as educational and career opportunities the Engineering Group is seeking to cooperate with other organisations including: BGS, Earth Science Education Unit, Earth Science Teachers' Association, Institute of Materials Minerals and Mining, OCR, Science and Engineering Ambassadors Scheme (SETNET) branch of ICE Ambassadors in Schools, The Geologist's Association, WJEC and the Young Geoscientists Group of the Geological Society

VI. *The role of engineering geologists in informing policy-makers and the public regarding the potential costs, benefits and research status of different geo-engineering schemes*

31. The Geological Society speaks for the geological profession on appropriate issues such as geothermal energy. The Engineering Group is represented on the Ground Forum which informs policy makers on geo-engineering issues through the Construction Industry Council (CIC) and government via the Parliamentary and Scientific Committee and responses to consultation documents.

32. Despite increasing awareness of the need to do so, the construction industry probably still fails to advertise its successes outside its own media. Little is made of the significant achievement of projects such as the Channel Tunnel while rare "failures", such as the excessive movement of the Millennium Bridge, are widely publicised, as are the activities of those opposed to new schemes. High profile projects such as the 2012 Olympic development, Crossrail, the Thames Tideway Tunnel and the Severn Barrage provide opportunities to promote the industry's role in regeneration, energy efficiency and the strategy for dealing with climate change.

September 2008

Memorandum 163

Submission from the Royal Society

1. Geoengineering of the climate covers a wide range of schemes and technologies. At present there is no single definition that is universally accepted, although it typically refers to any large scale intervention or manipulation of the earth's climate system. Schemes can be categorised in two forms:

2. Blocking or filtering sunlight. For example, through dispersing sulphates in the atmosphere, cloud seeding, or space-based mirrors.

3. Removal of CO_2 from the atmosphere. For example by promoting algae blooms to increase oceanic carbon uptake (by fertilisation with iron or urea, or through tubes circulating deep ocean water); capturing of CO_2 directly from the air or at the point of emission (as in carbon capture and storage); promoting carbon sequestration by terrestrial biological processes such as forestation, avoided deforestation and changes in agricultural practices.

4. Apart from point source carbon capture and storage, forestation and agriculture projects, most of the schemes are still conceptual and need considerable research and development to understand the effectiveness of these various technologies as well as the feasibility. It remains unknown whether any of these proposed schemes will ever offer any viable solution to climate change. Research will also be needed to understand and evaluate the potential wider environmental and social impacts of these technologies and the risk of unintended consequences. The diversity of issues and schemes will mean a wide range of expertise including scientists, engineers, social scientists and economists, across a number of disciplines, will be required.

5. Potential options for large scale engineering of the climate are slowly gaining prominence, both in the media and in parts of Government. The motivation for developing these schemes is driven by concerns about the continuing rise in atmospheric concentrations of greenhouse gases and the inadequate global response to cutting emissions. Furthermore, commercial interests are promoting some of these projects, driven by the potential to develop credits in a carbon market.

6. At this stage, with such a wide range of potential technologies and options, many of which are only concepts, too little is known to be prescriptive about the role of engineering in the development of geoengineering. This lack of knowledge about the potential of the various schemes means it is too early to make any assumptions about how they will interact with other responses to climate change.

7. Regulation will be needed for each of these various technologies and, more immediately, of the research needed to develop them. Decisions on research and development must be informed by the best available science and engineering to minimise the risks of unwanted or unintended environmental and social impacts. Uncertainties about the potential for these impacts have already led some international bodies, such as the Convention on Biological Diversity, to raise concerns about the development of geoengineering technologies.

8. In response to this lack of reliable information on the topic, the Royal Society will be launching a major study of large scale climate engineering in October/November 2008. The working group, which will include scientists and engineers, will investigate the potential, feasibility and drawbacks of suggested geoengineering techniques. Consideration will also be given to the kind of regulatory framework that will be needed for the development of these technologies.

October 2008

Memorandum 164

Submission from Defra

This submission addresses the following topic within the Committee's terms of reference for their Geo-engineering case study: *The current and potential roles of engineering and engineers in geo-engineering solutions to climate change*

SUMMARY

- There has been relatively little research so far into the feasibility and effects of geo-engineering approaches for mitigating climate change and there are wide-ranging concerns about their implementation. Despite this, many parties consider that further research into the feasibility of geo-engineering options is warranted, as they might provide a way of "buying time" to reduce greenhouse-gas emissions if those reductions were not being achieved quickly enough to avoid dangerous climate change.
- Defra has recently undertaken a preliminary assessment, informed by a poll of UK experts, of a number of high-profile geo-engineering options that have been proposed for mitigating climate change. The options were categorised under either (a) alteration of the Earth's radiation balance, or (b) removal and storage of atmospheric carbon dioxide (CO_2).
- Defra concludes that there are large uncertainties regarding the effectiveness, impacts, technical feasibility, cost and risks of all the geo-engineering schemes considered and that it is premature to draw firm conclusions on the feasibility of implementing any of them.
- Although the priorities for tackling climate change should continue to be overwhelmingly focussed on emissions abatement and adaptation to unavoidable change already underway, we consider some further research into the feasibility of using geo-engineering options could be merited. If research goes ahead, we have identified a number of desk, field, laboratory and climate model-based studies as priorities for the research community to consider.
- We also make some preliminary conclusions about individual schemes:
  - "Air capture" schemes potentially have fewer detrimental side effects than other options, but their effectiveness in net CO_2 capture is still uncertain.

- Injection of aerosols into the stratosphere or troposphere, surface albedo modification, ocean iron fertilisation and "air capture" schemes have the advantage that they could be implemented gradually and altered relatively easily.
- Options involving space shades/mirrors (high risk and an unlikely prospect in the near term) or injection of aerosols into the stratosphere or troposphere have the disadvantage that rapid climate change could result if they were stopped abruptly.
- Ocean pipes and cultivation of marine algae were considered to have limited feasibility.
- Schemes that change the Earth's radiation balance have the disadvantage that they do not counter ocean acidification or other negative effects of increasing CO_2 concentrations.
- The climate system and ecological impacts of most, if not all of these schemes, are currently highly uncertain and as such they would be associated with high environmental risks.

Introduction

1. Geo-engineering, defined here as intentional large-scale manipulation of the global environment, has been suggested as a means of mitigating the effects of anthropogenic greenhouse-gas emissions on climate, without necessarily reducing emissions. The topic is currently attracting significant interest. However, to date there has been relatively little research into the feasibility and effects of such large-scale manipulations, and there are wide-ranging concerns about their implementation.

2. This submission is informed by a Defra assessment paper on a number of high-profile geo-engineering options for mitigating climate change. The paper was prepared after polling a range of UK experts for their views and comments, and has been shared with the Royal Society.

Background

3. Defra has not, so far, undertaken any research into geo-engineering; its limited assessments of the topic have been informed by:

- the IPCC's Fourth Assessment Report (AR4), published in November 2007, which concluded that geo-engineering options are largely unproven and potentially high risk;
- Defra-funded science undertaken at the Met Office Hadley Centre; and
- informal comment from the U.K. climate science community.

4. Potential concerns about the implementation of geo-engineering schemes include:

- our incomplete understanding of the Earth system means it is impossible to understand fully the potential impacts of any geo-engineering scheme;
- geo-engineering schemes based on changing the Earth's radiation balance do not counter the other negative effects of increasing CO_2 concentrations, such as ocean acidification (which could have significant detrimental effects, including threats to marine productivity and biodiversity);
- many geo-engineering schemes, if implemented, would need constant maintenance to retain their effect, which could be extremely expensive and/or impractical; and, in the event of funding for maintenance ceasing to be available, the environmental implications could increase significantly;
- consideration of geo-engineering options could divert funding, public attention, and specialist engineering expertise away from other policies and projects, including those aimed at reducing greenhouse-gas emissions;
- gaining public acceptance and international agreement on geo-engineering schemes could be difficult; and
- in some cases, it is unclear how funding for schemes could be generated, particularly where there are significant uncertainties around the extent of the mitigation effect or of other environmental consequences, or where it is unclear how the developer of a technology would be able to reap an economic benefit.

5. Despite these concerns, many parties feel that further research into the feasibility—in relation to the effectiveness, impacts, technical feasibility, cost and risks—of geo-engineering options is warranted because these options could offer a means of "buying time" to reduce greenhouse-gas emissions if those reductions were not being achieved quickly enough to avoid dangerous climate change. It is also worth noting that some geo-engineering schemes could have beneficial side effects such as increases in agricultural and forest productivity due to CO_2 fertilisation (in the case of schemes that do not reduce atmospheric CO_2 concentrations) and/or increases in diffuse radiation (in the case of schemes that modify the properties of the atmosphere).

Geo-engineering options

6. The following geo-engineering schemes, grouped into two categories, were considered in the Defra assessment paper:

Alteration of the Earth's radiation balance

- Space shades or mirrors positioned in space between the Earth and the Sun to reduce the amount of sunlight that reaches the Earth;
- Aerosol[24] injection into either the stratosphere (upper atmosphere, where aerosols have a cooling effect by backscattering solar radiation) or troposphere (lower atmosphere, 0–15 km, where aerosols can increase cloud albedo[25]); and
- Changes in the land/ocean surface to modify the albedo of natural or artificial surfaces.

Removal and storage of atmospheric CO_2

Involves capturing CO_2 from the atmosphere through:

- Ocean fertilisation to increase phytoplankton growth and associated carbon "removal" eg by adding iron or by "pumping" ocean water to near the surface using pipes;
- "Air capture" schemes such as "synthetic trees", which can chemically capture and remove CO_2 from the atmosphere;
- Electrochemically-induced increases in ocean alkalinity; and
- Marine-algae cultivation.

7. "Carbon Capture and Storage" options or schemes that aim to increase the length of time that carbon stored in non-atmospheric reservoirs is isolated from the atmosphere (such as the addition of "biochar" to soils or the disposal of agricultural crop waste in the ocean), were not included, because these are not routinely considered to be "geo-engineering" approaches.

Main findings

8. The Defra assessment paper concentrates on science and technological issues. Whilst the paper recognises that socio-political and economic issues may be crucial for delivery of geo-engineering options and identifies a number of these related issues, it does not consider them formally.

9. Defra concludes that there are large uncertainties regarding the effectiveness, impacts, technical feasibility, cost and risks of all the geo-engineering options schemes it considered; and that it is premature at this stage to draw firm conclusions on the feasibility of implementing the schemes discussed. However, the following preliminary conclusions, in relation to scientific and technological aspects of individual schemes, can be drawn:

- options involving space shades/mirrors (particularly those that involve significant engineering in space) are unlikely to be available in the near future and (as they stand at present) would be high-risk compared to other options because they would be difficult to modify or remove;
- ocean pipes are probably not a feasible geo-engineering option because they are unlikely to remove significant quantities of CO_2 from the atmosphere (and could result in CO_2 release);
- cultivation and storage of marine algae is unlikely to be a feasible option for mitigating climate change on a large scale due to practical difficulties associated with storing algal biomass, but it might be possible to combine small-scale storage operations with other processes, such as biofuel production;
- options involving space shades/mirrors and injection of aerosols into the stratosphere or troposphere have the disadvantage that rapid climate change could result if they were stopped abruptly (either due to failure or policy decisions);
- injection of aerosols into the stratosphere or troposphere, surface albedo modification, ocean iron fertilisation and "air capture" schemes have the advantage that they could be implemented gradually and modified or stopped relatively easily; and
- "air capture" schemes potentially have fewer detrimental side effects than other options, but their effectiveness in terms of net CO_2 sequestration/release remains uncertain.

10. The challenge of significantly reducing greenhouse-gas emissions is great and the risks associated with failing to do so are high. There is therefore an argument for carrying out further research to assess the feasibility of using geo-engineering options to "buy time" to reduce greenhouse-gas emissions in case the global community cannot reduce emissions quickly enough to avoid dangerous climate change; although,

[24] Sub-microscopic particles.
[25] Proportion of sunlight reflected.

given the significant doubts over feasibility, it is essential not to rely on the availability of geo-engineering options. Research into the scientific, technological, economic, and socio-political aspects of geo-engineering options would be necessary to bring deployment closer to reality. A number of desk, field, laboratory and climate model-based studies are identified as priorities for the research community to consider:

— Field-based studies to explore the effects (desired and undesired) of (i) changing surface albedo and (ii) spraying seawater into the troposphere.

— Model- and laboratory-based studies to understand the atmospheric chemistry (particularly ozone) involved in injecting sulphate aerosols into the stratosphere.

— Climate model-based studies to explore the effects of (i) changing surface albedo, (ii) spraying seawater into the troposphere, and (iii) injecting sulphate aerosols into the stratosphere. A particular priority in this regard could be to use more "realistic" scenarios (such as simulating aerosol injection using fully-coupled General Circulation Models that include atmospheric chemistry, rather than using "solar dimming" to represent the effects of aerosols). Simulations could also explore the effects of different options for applying the schemes, such as Arctic vs tropical and pulsed vs continuous injection of sulphate aerosols into the stratosphere.

— Climate model-based studies to determine the optimal "mix" of geo-engineering schemes (ie the combination that maximises desirable effects and minimises detrimental effects).

— The use of observational data to validate climate model results (for example, the use of satellite data to validate simulations of changes in surface albedo).

— Research into the net effect on atmospheric CO_2 concentrations of schemes that require significant amounts of energy to implement⁄particularly (i) electrochemically increasing the alkalinity of the ocean, and (ii) "air capture" schemes such as "synthetic trees".

— Research to assess the technical and economic feasibility of options, particularly where the science is relatively well-understood (such as changes in surface albedo).

— Research into the socio-political feasibility of options, particularly for schemes that involve modification of privately-owned property (such as increasing the albedo of urban surfaces) and schemes that would probably require universal political agreement to implement (such as space shades/mirrors and injecting sulphate aerosols into the stratosphere).

Other Considerations

11. Defra recognises that socio-political and economic, as well as scientific and technological, issues will need to be considered when assessing the feasibility of geo-engineering options; for example:

— There should be a measurable benefit that unambiguously outweighs the impacts arising from the full lifetime energy costs, carbon emissions and other adverse consequences involved in establishing, maintaining and decommissioning the relevant technologies.

— The magnitude of the manipulation must be controllable, and it must be easy to "switch off" the effect (in the event of unforeseen consequences).

— There must be very wide public acceptance and international agreement on the acceptability of geo-engineering schemes. The following political issues must be addressed if geo-engineering is to be carried out on a globally-significant scale:

(i) There needs to be high public trust in both the science/technology and the competence of the implementing bodies (private sector, national governments or international agencies), which may be difficult to achieve. It is, therefore, important that the factors that influence public understanding, risk perception and acceptance of such options are understood and taken into account before attempting to implement them.

(ii) Geo-engineering actions by one country must not be regarded as an infringement or incursion on the territory of another (although it is worth noting that greenhouse-gas emissions have such effects). This may be particularly relevant to atmospheric manipulations, which affect national airspace and need to be large-scale to have significant effects.

(iii) Political commitment needs to be sustained over the period for which geo-engineering is required.

(iv) Even if there is international acceptance that a net global benefit will result, it must be recognised that disadvantages may occur for some countries. Multi-billion dollar compensation could be involved between winners and losers (for example, the latter suffering floods or droughts potentially attributable to geo-engineering). The ethical and legal frameworks for such arrangements do not yet exist, and are unlikely to be straightforward. (It is worth noting, however, that this concern is unlikely to be significant for geo-engineering options that significantly reduce CO_2 concentrations and thus directly reduce the impacts of greenhouse-gas emissions.)

— The way in which the cost of the scheme would be met must be considered (particularly as the benefits would ideally be shared by all).

— If CO_2 reductions obtained through geo-engineering schemes were to be traded as carbon credits in carbon trading schemes, the principles and practices for verifying the value of such credits must be agreed between the scientific, commercial, and regulatory communities; and we would need to avoid situations where climate benefits were rewarded whilst any adverse environmental effects (such as biodiversity impacts), which might not be experienced by the developer or deployer of the technology, were not paid for.

— Considerable resources would probably need to be expended to offset even a small fraction of predicted climate change. While this benefit could complement other measures, the possibility that geo-engineering options could divert attention and resources away from more fundamental solutions to global warming (ie emissions reductions and avoiding deforestation) must be considered.

CONCLUSIONS

12. It is clear that, given the significant uncertainties surrounding geo-engineering options, research funding has a high probability of not leading to the development of useable technologies. Any public support for geo-engineering research should therefore be understood in the context of the wider effort to tackle climate change, the priorities for which should continue to be overwhelmingly focussed on emissions abatement and adaptation to unavoidable change already underway. Defra currently has no plans for significant research funding on geo-engineering; however, if other parties, countries and institutions wished to develop a shared approach, Defra would be interested in sharing expertise, and in helping to develop an initial detailed scoping study.

13. The Committee asked some specific questions on the role of engineering and engineers in geo-engineering, and on the relationship with research conducted on the reduction of greenhouse gas emissions. It is clear that the profession is vital to tackling the problem of climate change, and that success will depend in large part on society's ability to develop and deploy innovative solutions. Climate change mitigation and adaptation should therefore form a significant focus for the engineering profession, and for university courses and other training for the profession; and that climate change policy in the UK needs engineers. However, Defra considers that geo-engineering should not be considered a priority for the engineering profession's contribution to tackling climate change, compared with the overwhelming need to develop and deploy methods for the abatement of greenhouse-gas emissions and the need to adapt to the levels of climate change to which the world is already committed.

September 2008

Memorandum 165

Submission from Greenpeace

Greenpeace is a campaigning organization which has as its main objective the protection of the natural environment. Greenpeace has offices in 40 countries, 2.8 million supporters worldwide and around 150,000 in the UK. It is independent of governments and businesses, being funded entirely by individual subscriptions.

Greenpeace was one of the first organizations to campaign for action to be taken to halt anthropogenic climate change. It has built up considerable expertise and has access to independent expertise on the links between energy use and climate change. The expertise includes scientific knowledge, economics and analysis of state subsidy, as well as understanding of how the development of traditional approaches to energy can have detrimental effects on the development of new, cleaner technology to combat climate change.

It is widely recognised that climate change is the gravest threat presently faced by humanity. The most important greenhouse gas in terms of anthropogenic radiative forcing is carbon dioxide. The 4th Assessment Report from the IPCC[26] presented the firmest evidence yet that the threat of severe climate change impacts means the economies of the developed world must be decarbonised within such a rapid timeframe that radical action is necessary. We have less than a decade in which to slow, stop and reverse the trend of rising greenhouse gas emissions if we are to avoid the worst impacts of climate change.

An average rise in global temperature of 2°C above pre-industrial temperatures is widely regarded as the limit beyond which irreversible climate change impacts will occur. Global greenhouse gas emissions, primarily carbon dioxide, have already generated a rise of 0.7°C and the inbuilt lag in the earth's atmospheric

[26] Intergovernmental Panel on Climate Change (IPCC) (2007), Fourth Assessment Report: *Climate Change 2007: Synthesis Report—Summary for Policymakers.* http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf

system means we are already committed to a further rise of approximately 0.7°C. It is therefore clear that the window of opportunity to limit global temperature rise below 2°C is closing swiftly. The very latest evidence from the UK Met Office's Hadley Centre confirms the necessity to act very swiftly to cut emissions.[27]

The context is clearly that global emissions need to be on a downward path before a further decade has passed—developed country emissions need to be declining immediately. Yet in UK CO_2 emissions have barely gone down the past decade. This is despite obvious technical and policy measures that could deliver energy and carbon saving including better management of heat, product standards on appliances and vehicles, better support to renewable energy technologies, proactive policy to deal with the poor thermal quality of the UK building stock etc. Much or all of this critique could be applied to EU and North America. In other words, the most effective ways of dealing with climate change are not being adopted owing to a lack of political will and commitment to tackling the greatest long-term threat to humanity.

It is also clear that action is being impeded by vested interests including the industries that profit from the *status quo*. This has been most visible in the case of Exxon,[28] vehicles,[29] energy intensive industries[30]—other examples of effective industry lobby to avoid environmental protection are from chemicals regulation.[31] Even this month challenges to weaken rules on the EU Emissions Trading Scheme—the preferred low-cost compliance option which is the cornerstone of EU Emissions reduction plans—came from governments representing coal based industry.[32] The reason for this political activity by companies is straightforward—it prevents change that would otherwise undermine their commercial position. Time, money, effort and innovation which could be dedicated to solving the climate crisis are instead dedicated to its maintenance.

Thus the concept of "geo-engineering" enters a highly charged political and economic context where change on climate policy grounds will create winners and losers. At a societal level we have a "moral hazard"[33] in that the promise of geo-engineering, however speculative, reinforces behaviour that makes its need more likely. The wider point is not the pros and cons of particular technologies, but that the scientific community is becoming so scared of our collective inability to tackle climate emissions that such outlandish schemes are being considered for serious study. We already have the technology and know-how to make dramatic cuts in global emissions—but it's not happening, and those closest to the climate science are coming near to pressing the panic button. A focus on tinkering with our entire planetary system is not a dynamic new technological and scientific frontier, but an expression of political despair.

Consequently, Greenpeace believes that there need to be very strict conditions attached to research into any potential candidates for geo-engineering. Specifically:

1. All propositions for geo-engineering research must be evaluated using strict and precautionary sets of rules, including scientific, legal and policy components, developed and overseen by international cross-disciplinary advisory committees set up under UN auspices. Scientific expertise needs to include ecology, engineering and life cycle analysis. Political components need to have at the very least regional and stakeholder representation. Legal compliance with international agreements would be a necessity.

2. There need to be pre-set criteria for environmental and social acceptability.

3. Actual geo-engineering should be prohibited except for research agreed through the international governance arrangements. No payments should be considered through, eg CDM, before sign off by these committees.

Criteria in (2) need to recognize that not every proposition is necessarily environmentally damaging, but there are features of the risks associated with their implementation.

1. Ideas which remove CO_2 and other gases from the atmosphere by physical means are less interventionist that those which use existing ecosystems, and deliver more effective change than those which try to "reflect" heat. In addition to climate change, CO_2 also causes ocean acidification which will potentially have serious impacts on the marine ecosystems and on coastal communities. Ocean fertilization as a mitigation strategy, whether with iron or other nutrients, could exacerbate this problem, damage marine ecosystems and even result in increased emissions of other, biogenic greenhouse gases. A Note published on iron fertilization published last year by the Greenpeace International Science Laboratory is submitted as an appendix.

2. Large scale intervention in natural ecosystems is generally perturbing systems that we do not understand with the potential for widespread, unpredictable and long-lasting adverse consequences. It should be subject to the precautionary principle.

3. There needs to be a thorough understanding of the life-cycle impacts of any propositions.

[27] Vicky Pope, Hadley Centre, Met Office "Degrees of Caution", *Guardian,* 1 October 2008 http://www.guardian.co.uk/environment/2008/oct/01/climatechange.carbonemissions
[28] http://www.exxposeexxon.com/
[29] http://www.euractiv.com/en/transport/meps-side-carmakers-co2-cuts/article-175032
[30] http://www.euractiv.com/29/images/Turmes%20European%20Spring%20Council%202008-Background_tcm29-170918.doc
[31] http://www.greenpeace.org/raw/content/international/press/reports/toxic-lobby-how-the-chemical.pdf
[32] http://euobserver.com/9/26901
[33] http://en.wikipedia.org/wiki/Moral_hazard

This approach and criteria are suggested because of the context in which geo-engineering ideas are being raised. It is a much better option for society as a whole to use existing technology and policy to reduce emissions rather than attempt the potentially dangerous approaches that geo-engineering propositions represent. Public money and policy focus is better spent on this than on speculative and potentially risky geo-engineering ideas.

November 2008

Memorandum 166

Submission from Professor Klaus S Lackner, Columbia University

Stabilizing the concentration of carbon dioxide in the atmosphere requires dramatic reductions in worldwide emissions. At the same time, a growing world population striving for a higher standard of living will demand more energy, which today is the major source of carbon dioxide emissions. Stabilization under a scenario of economic growth can only be achieved through a transition to a carbon neutral energy infrastructure. Worldwide emission reductions by roughly a factor of three, which is required to even approach a stabilization regime, simply cannot be achieved by efficiency improvement and lowered consumption.

Thus, much effort must focus on replacing fossil fuels, and on developing means of capturing carbon dioxide and storing it safely and permanently. The demand for storage could reach between ten and a hundred billion tons of carbon dioxide annually. This should be compared to the present fossil fuel related carbon dioxide emissions of twenty five billion tons of carbon dioxide per year, or several thousand billion tons over the course of a century. Surely the storage of such vast quantities, comparable in size to the amount of water in Lake Michigan, represents a form of geo-engineering.

About half of all carbon dioxide emissions are from small and distributed sources where collection at the point of emission would be difficult. We argue that the easiest way of compensating for these emissions is to capture an equal amount of carbon dioxide directly from the air. In the press, this approach has also been called geo-engineering because it actively manages the global anthropogenic carbon cycle. However, it should also be seen as the logical extension of capture at the point of combustion. Here we want to contrast such carbon cycle management with albedo engineering efforts that try to counter greenhouse warming with active efforts of cooling the planet.

The problem of fossil fuels is the mobilization of carbon. Climate change is only one of several consequences. At present the public focus may be exclusively on global warming, but as the global mobile carbon pool increases other impacts like ocean acidification will become more pressing. Any effort that allows the unfettered rise in atmospheric carbon dioxide concentrations in the end is doomed to fail. The simple and direct solution to climate change and other consequences of carbon dioxide release is to prevent the run-away buildup of mobile carbon, ie, the buildup of carbon dioxide in the atmosphere. Carbon dioxide capture and storage, at the power plant and directly from the air, either avoid emissions or compensate for emissions that have already happened, or are about to happen in the near future. By contrast, albedo engineering, through sulfates, through cloud generation, through space based solar reflectors only cure a symptom. While they can slow down warming, they do not address the root cause, which is a continuously growing mobile carbon pool that threatens to destabilize the world's ecosystems through warming, through changes in the hydrological cycle, through eutrophication of eco-systems and through acidification of natural water bodies. Albedo engineering will not stop us from breaching 1000 ppm of carbon dioxide in the atmosphere within the next hundred years; carbon dioxide capture and storage will.

Carbon dioxide capture and storage requires three important technologies: the capture of carbon dioxide at large sources like power plants, steel plants and cement plants; the capture of carbon dioxide from the air; and the safe and permanent disposal of carbon dioxide in geological formations or other permanent sinks. Capture at central sources is certainly feasible. It has been demonstrated and once it has been made mandatory, its cost will come down through practice and learning.

Storage of carbon dioxide in geological formations is already feasible. In addition to this well understood technology, there are a number of options with more permanence, larger capacity, and easier accounting. Usually these methods suffer from a higher price. As an example I point to the formation of mineral carbonates, which I have championed for nearly 15 years. Taken together all these methods leave no doubt in my mind that the world can store all the carbon dioxide mankind could ever produce, as long as there is the political will to do so. Cost will come down and capacity for storage is virtually unlimited.

Finally, I have been involved for the last nine years in an effort to develop the means of capturing carbon dioxide directly from the air. Some refer to this effort as the creation of synthetic trees. Just like a tractor is more powerful than a horse when it comes to plowing a field, these synthetic trees are about a thousand times faster in collecting carbon dioxide from the wind passing over them than their natural counterparts. Thanks to work I have been involved in with a small company, this technology is now ready to move toward the first air capture parks. As Altamont Pass in California provided a first demonstration of serious wind energy, I believe an air capture park for carbon dioxide could demonstrate to the world that this technology offers real promise. Air capture would become the carbon dioxide collector of last resort, in that it would collect all carbon dioxide which is not amenable to capture at the point of emission. This includes but is not limited to the carbon dioxide from air plane engines, from the tail pipes of cars, and potentially the carbon dioxide from old power plants unsuitable for cost effective retrofits. We believe that air capture could compete with power plant retrofits and could collect the carbon dioxide from a litre of gasoline at a price that is dwarfed by gasoline taxes. We expect to move rapidly from an initial price of 20 pence a litre to ultimately less than three pence a litre.

Ultimately, carbon dioxide capture and storage makes it possible to put a price on carbon at the source. What needs to be controlled is the mobilization of carbon, which happens the moment carbon is extracted from the ground. For national or regional implementation one should also charge for imports of raw carbon. A cap and trade system, or a carbon tax that acts on the extraction of carbon and on imports of carbon fuels is far simpler than current cap and trade devices, as the number of companies that need to be controlled is greatly reduced, and their carbon production is already carefully monitored. Moreover, such a carbon trading scheme would affect all industries equally and not distinguish between large and small emitters, between mobile or stationary sources. Ultimately carbon extraction must be matched by carbon dioxide capture and storage. For every ton of carbon pulled from the ground, another ton of carbon must be taken out of the mobile carbon pool. A coal, gas or oil company would have to create or purchase certificates of sequestration that cancel out the mobilization of fresh carbon. Obviously there is a transition time in which mobilization and sequestration cannot be fully matched, but at the end of this transition the economy becomes carbon neutral.

It is thus possible to achieve a worldwide transition from a fossil fuel economy that smothers the world in excess mobile carbon to one that is carbon stabilized. Air capture could play a crucial role as it can compensate for emissions from the transportation sector. Air capture can also remove excess carbon that has already accumulated in the environment. It separates sources and sinks in time and space. Very importantly, air capture makes it possible for the transportation sector to keep relying on efficient liquid hydrocarbon fuels. These fuels could be produced from fossil energy resources like oil, gas or coal, but even if these fuels were made synthetically with input of renewable energy, the carbon dioxide emissions from a vehicle would still have to be recaptured as otherwise they would still accumulate in the atmosphere. In all cases, air capture technology can truly close to the anthropogenic carbon cycle. It is an enabling technology that, if successfully demonstrated, removes the largest obstacle on the path toward sustainable energy supplies.

November 2008

Memorandum 167

Submission from Professor Steve Rayner[34]

Engineering Inquiry

(Geoengineering Case Study)

1. The politics of geoengineering is complex.

2. It can be understood within the broader discourse about climate change in which two parallel agendas co-exist.

3. One is the utilitarian agenda focused specifically on efficiently preventing increased damage to human and natural systems from anthropogenic climate change.

4. The other is an egalitarian agenda for which the threats posed by disruption of the existing climate represent a natural sanction against otherwise boundless consumerism and industrial development.

5. These two goals converge in the conventional emissions mitigation agenda. However, for those whose primary motivation is social reform and behavioural change, both adaptation and geoengineering are viewed as a moral hazard that threatens to weaken the political consensus behind greenhouse gas emissions reductions achieved by behavioural change.

6. In the case of adaptation, this has led to more than a decade of delay in the world coming to grips with the challenges and, as a result, very large numbers of poor people living in marginal conditions, mostly in the less-developed world, are in greater danger from climate impacts than would otherwise have been the case.

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[34] James Martin Professor of Science and Civilization, University of Oxford; Honorary Professor of Climate Change and Society, University of Copenhagen; Member of the Royal Commission on Environmental Pollution.

7. Climate change is par excellence a field in which political disagreements have continually found their expression in surrogate disputes about science. Therefore it is imperative to understand, especially in these early stages of the geoengineering discourse, where both systems uncertainty and decision stakes are high, that the positions taken by scientists and policy analysts (including me. inextricably interweave political as well as technical judgements.

8. This is the case with respect for positions either "for" or "against" geoengineering in principle as well as for or against specific options.

9. For example, NASA's Jim Hansen recently dismissed air capture technology on the basis that it would be unacceptably expensive at $20 trillion per 50ppm of carbon removed from the atmosphere. Roger Pielke Jr of the University of Colorado points out that this translates into a carbon price of $190/ton or $52/ton CO, which by 2030 would amount to about 1.5% cumulative global GDP. This places it at the low end of the 1–5% of GDP that the Stern Report regards as a reasonable cost for society to pay for conventional mitigation, of which Hansen is a longstanding advocate. Clearly the argument here is not really about costs.

10. There are at least three distinctive viewpoints on climate geoengineering in general.

11. One view sees geoengineering as offering potentially cheap solutions to climate change which also have the added advantage that many options could be implemented unilaterally by countries, or even wealthy individuals, thus circumventing the delays in achieving atmospheric carbon stabilization that result from trying to achieve a universal intergovernmental consensus on mitigation and/or waiting for the emergence of an effective and efficient carbon market.

12. A second view regards geoengineering options as potentially dangerous manipulation of earth systems, relying on the kind of technological hubris that got us into the current predicament. The potential for unilateral action that exists with geoengineering is seen as a threat to global solidarity rather than an advantage. In turn, this leads to calls for international regulation to limit even field scale experiments with such technologies. The moral hazard argument against geoengineering is also emphasized in this view.

13. The third position calls for research and development of geoengineering, not for immediate implementation but as insurance against failure to meet atmospheric stabilization goals or the eventuality that we have underestimated the sensitivity of the climate system and urgent further action proves necessary.

14. In the interests of full disclosure, the third is probably closest to my own view, although I prefer an analogy to the value of options rather than an insurance metaphor.

15. I am also aware that this view tends to overlook the possibility that at least some options may offer the possibility of stabilizing atmospheric carbon concentrations at lower costs than conventional mitigation, in which case one has to wonder why they should only be implemented in extremis. From the standpoint of carbon removal, there seems to be no reason to regard mechanical trees as inferior to biological ones. In fact their ability to achieve long term sequestration may even be much better.

16. A finer grained approach becomes necessary as soon as we move from discussing geoengineering in the abstract and begin to focus on particular technology options. The various options have quite different characteristics and raise distinctive challenges for sound governance. Each may have quite different institutional prerequisites and socio-political, economic, and legal implications.

17. In a short discussion it is not possible to delve into the diverse policy-relevant features of all of the options in detail, but it may be helpful to characterise some broad brush differences.

18. Defra, in its submission to the committee follows the common convention that distinguishes two kinds of geoengineering technologies based on whether they aim to remove and sequester carbon from the atmosphere or to alter the earth's radiative balance by reflecting energy from the before it hits the atmosphere, in the stratosphere or on the earth's surface. For example, iron fertilization of the ocean is one way to achieve carbon removal while injecting sulphate aerosols into the stratosphere seeks to increase the reflectivity of the upper atmosphere.

19. This is one useful dimension. However, another axis along which such technologies can be differentiated is according to whether they seek to achieve either of these goals by tuning or tinkering with ecosystems on one hand, or the development and application of hard engineering technologies, ie, nifty gadgets, on the other. Air capture, sometimes referred to as "mechanical trees" shares with iron fertilization the objective of carbon removal, while orbiting sunlight deflectors, such as space mirrors, represent a hard engineering approach to changing the earth's radiative balance.

20. Combining these ways of looking at geoengineering yields the fourfold typology in figure 1.

21. Ecosystem tinkering, either for carbon removal or changing radiative balance, promises to be cheap and relatively simple to implement. This could make them attractive to nations, or even wealthy individuals, who become impatient with internationally coordinated efforts to achieve conventional mitigation. Companies have already been formed with a view to implementing this technology.

22. However, unilateral action would not be universally welcomed as it would raise issues about sovereignty and national hegemony in international relations.

23. There are also concerns that ecosystems tinkering will have unwelcome unanticipated side effects. At least some instances of this kind of approach could raise issues of international law. For example, iron fertilization could be interpreted as a violation of the London Dumping Convention and/or the Biodiversity Convention

24. The costs of hard engineering approaches range from figures which are potentially competitive with those of conventional mitigation, as in the case of air capture, to quite costly options such as space deflectors which would require launch and heavy lifting capacity to put equipment into orbit and maintain it there.

25. Air capture could be pursued by private companies, provided that a price is established for carbon through either cap-and-trade or a carbon tax. However, it seems likely that heavy engineering in space would be implemented by nation states possessing the necessary technology and financial resources. There are no obviously viable mechanisms for relating measures designed to increase radiative balance to a carbon price.

26. Increasing radiative reflectivity, whether through ecosystems tinkering or hard engineering, is subject to a hazard not present with carbon removal, which is that cessation of the intervention, either through technical failure or change of political commitment would almost certainly result in a very sudden temperature spike due to the high concentration of carbon dioxide that would have accumulated in the atmosphere but without affecting the temperature while the intervention was in progress.

27. Some commentators see this as a potential advantage in that it could discourage parties to such an intervention from defecting. Others worry more about the power that the threat of defection might give to certain parties.

28. Concerns have also been raised about the possible military misuse of hard-engineered capabilities to alter radiative balance. Could space mirrors be used for aggressive purposes?

29. All of the options identified would raise potential issues of public acceptability. One design for mechanical trees involves building structures over 30 metres high for filtering carbon from the air, thus raising issues analogous to the public acceptability of wind farms. On the other hand, these could be located far from populations, close to carbon sequestration sites, such as spent oil and gas wells, offering advantages over carbon capture at the point of electrical generation. The public is likely to be concerned about the potential unintended environmental impacts of any ecosystems tinkering approach.

30. The central problem is that while we can identify potential issues with all types of geoengineering, we can only resolve those through research, development, and demonstration. The key issue is how to move forward with appropriate safeguards.

31. There have been calls for a moratorium on geoengineering, and even on geoengineering research, such as recent moves in Europe to ban field trials with iron fertilization except in coastal waters (of which there is no clear legal definition and where in any case it will not work. .

32. As American political scientist David Victor points out, a moratorium on geoengineering is likely to deter only those countries, firms, and individuals who would be most likely to develop the technology in a socially responsible fashion while encouraging potentially dangerous experimentation by less-responsible parties.

33. He suggests encouraging an international consortium designed to explore the safest and most effective options while also socializing a community of responsible geoengineers along the lines of other international scientific collaborations that have had potentially hazardous side effects, such as CERN and the Human Genome Project.

34. Given that we do not yet know the shape of geoengineering options, it is difficult for social scientists to make specific recommendations for its effective governance. It is almost certainly too early to propose any kind of international treaty or protocol for research and development in the field.

35. However, given past experience with novel technologies that either tinker with open biological systems (think GM crops here) or large scale engineered systems (think nuclear energy), it would be prudent to involve social scientists closely in the research and development process to reflect in real time on the institutional implications of any options under consideration.

36. Ultimately, geoengineering research is an issue of risk management. Therefore the classic considerations of TLC—trust, liability, and consent—will likely shape the outcome. Who can be trusted to manage geoengineering research and implementation? What will be the mechanisms for making good in the event of unintended adverse consequences? And what mechanisms of consultation and consent will be used to shape any programme.

Figure 1

FOUR APPROACHES TO CLIMATE GEOENGINEERING

	Carbon removal	Alter radiative balance
Ecosystem tinkering	Iron fertilization of oceans	Stratospheric sulphate aerosols
Hard engineering	Mechanical air capture	Space deflectors

October 2008

Memorandum 168

Supplementary evidence from the Met Office following the oral evidence session on 10 November 2008

FOLLOW-UP NOTE TO IUSS COMMITTEE CASE STUDY ON GEOENGINEERING: FUNDING OF MET OFFICE CLIMATE CHANGE RESEARCH

During its oral evidence session of 10 November 2008, the Committee asked how much funding for climate change science is provided by the commercial sector.

Funding for the underpinning climate change research, carried out by the Met Office Hadley Centre, comes from programmes of work funded largely by Government customers. The total current direct funding for the Hadley Centre in 2008–09 is £21.7 million, broken down as follows:

Integrated climate programme—jointly funded by DEFRA and MoD	£18.4 million
Defra Intergovernmental Panel on Climate Change (in final year of existing contract)	£0.3 million
European Union Funding	£1.2 million
Other (mainly UK and overseas Govt depts)	£1.8 million

The Met Office is a trading fund owned by the MoD and is required to maximise the return to the taxpayer by drawing in profitable revenue from sources not directly funded by the Exchequer.

Climate change may have significant impacts on businesses and the Met Office offers a range of commercial services designed to advise what these impacts are and how best our customers can mitigate the risks and maximise the opportunities presented.

December 2008

Monday 17 November 2008

Members present:

Mr Phil Willis, in the Chair

Dr Ian Gibson
Dr Brian Iddon
Mr Gordon Marsden

Witnesses: **Dr Phil Williamson,** Research Councils UK; **Professor Nick Jenkins,** Royal Academy of Engineering, **Dr Tim Fox,** Institution of Mechanical Engineers; and **Professor Steve Rayner,** University of Oxford, gave evidence.

Q1 Chairman: Could I welcome our first panel of witnesses to the Innovation, Universities, Science and Skills Sub-Committee looking at geo-engineering, two oral sessions looking at an emerging discipline of geo-engineering. Welcome, Dr Tim Fox, from the Institution of Mechanical Engineers, welcome Tim, Professor Steve Rayner from the Said Business School at the University of Oxford, welcome to you again, Dr Phil Williamson from NERC, on behalf of RCUK, welcome to you, Phil, and last but by no means least an old friend of the Committee and a past adviser, Professor Nick Jenkins from Cardiff University, who is here on behalf of the Royal Academy of Engineering, but hopefully on his own account as well. This is a very interesting short inquiry, gentlemen, which the Sub-Committee is looking at in terms of geo-engineering. I wonder if I could start with you, Professor Rayner, to ask you if you could in a nutshell define geo-engineering for us and see if your colleagues agree?
Professor Rayner: I am not sure, actually, that I am the best qualified to define the field since I am actually a social scientist rather than an engineer, but I take it basically to encompass a very wide range of technological options which could be brought in to being to counter either the processes or the effects of climate change, largely either by changing the radiative balance of the atmosphere or alternatively by extracting carbon from the atmosphere. That is a fairly conventional distinction, I think. I would like to lay across that a different distinction, which is between what I would describe as interventions which are designed to tune or tinker with eco-systems and interventions which are actually hard engineering interventions. If you actually lay that distinction across the former distinction, you actually end up with four quite distinctive types of geo-engineering options with very different characteristics, I think, and certainly very different implications for management and governance and public acceptability.

Q2 Chairman: Professor Jenkins, you are an engineer so perhaps you would either agree or disagree with that?
Professor Jenkins: I am happy to agree with that definition, which as I understand it accords with the terms of reference of the Royal Society's inquiry.
Dr Williamson: Agreement there.
Dr Fox: Yes, I agree with that.

Q3 Chairman: All right. So we have now got a definition. Professor Jenkins, last week when we had two experts from the States giving evidence before us they made a very clear distinction between indirect carbon sequestration, which they did not regard as geo-engineering, and those aspects of other things which you are actually doing to manipulate, if you like, the earth's eco-system, or in fact been able to put in safeguarding elements. Do you agree with that sort of rough definition?
Professor Jenkins: No, I come back to Professor Rayner's view, if I interpret that correctly, these are elements of a two dimensional matrix with both reducing solar radiation and indirect carbon sequestration but through these two routes, one of engineering and the other manipulating the eco-systems. I would have thought that where one is in the subject at the moment, to maintain that breadth would be helpful.

Q4 Chairman: Any disagreement with that on the panel?
Professor Rayner: Not in the least, and actually I would caution against narrowing it because I think we are quite accustomed to climate change being a field in which political battles get fought out through scientific surrogates, and I am afraid that there are very strong partisan views within various parts of the scientific and engineering community as to which of these kinds of options they favour and which they hold in disfavour. So I think it is actually very important to keep a broad view of the range.
Dr Fox: At the holistic overview level, I think I would certainly agree with that for the Institution of Mechanical Engineers. Carbon sequestration, in the sense of removing from power stations the source of emissions and finding a storage for those, could in some definitions be regarded as a mitigation approach and a mitigation strategy, but if you step back and look at the overall definition of geo-engineering then carbon sequestration from power stations could be regarded as a geo-engineering approach.
Professor Rayner: Although I think we are talking here about actual carbon removal and sequestration by air capture, are we not?

Q5 Chairman: Yes, indirectly in that sense. Dr Williamson?
Dr Williamson: The other area of potential sort of overlap or confusion is in re-forestation and change in agricultural policy,[1] and whether or not that is global in its implications. I think the "geo" of geo-engineering has to be a global approach and to a certain extent it relates back to the governments and who takes the action, whether or not one is removing a pollution at source or trying to come afterwards and then trying to put things right afterwards. On the whole, the geo-engineering is something afterwards, saying, "Here is a problem. What are we going to do with it?" rather than stopping the problem in the first place.
Chairman: Okay, that is a fairly broad definition there. I will come on to Ian Gibson.

Q6 Dr Gibson: What about public finance? Is there much public finance going into this area, geo-engineering?
Dr Williamson: Very little directly from the research councils but, as from the RCUK submission, there is a lot of relevant research which is funded by EPSRC and NERC in terms of the fundamental knowledge which is necessary, and very, very roughly a figure of £50 million per annum is in the category of geo-engineering relevant, but in terms of absolutely directly saying, "This is money to support geo-engineering research," up until now I do not think we have actually funded any research grants or studentships, but the EPSRC has put aside £3 million for next year's spend on a "geo-engineering ideas factory", which is an exercise to encourage proposals in the area initially of an inter-disciplinary nature and so although it is EPSRC funded, other environmental and social science work would be considered, and that is for next year.

Q7 Dr Gibson: When is that meeting taking place?
Dr Williamson: I do not think the dates have been decided, but provisionally autumn 2009.

Q8 Dr Gibson: Do you think that is a long time in the future?
Dr Williamson: Not that long in the sense that then it could take the benefit of the Royal Society study, which will be reporting next summer, and also for these meetings they have a sift through expressions of interest beforehand and at that meeting they then make the decisions of what is to be funded, so there is not another year before the results.

Q9 Dr Gibson: You are an old hand. Do you think the money is going to be around then, in 2009? Do you think you should be pressurising them now to get the money now? Research councils have got a kind of reputation for moving things about a bit.
Dr Williamson: I think this is pretty firm. It may be that there might be the possibility of more funding coming in from other sources to supplement that.

[1] *Note from the witness*: "For example, biofuels, carbon sequestration in soil and other land-use changes affecting albedo or the global carbon cycle".

Q10 Dr Iddon: We have had some pretty whacky ideas like trillions of mirrors in the sky, sun shades to protect the polar caps, you name it, artificial trees—CO2 in, oxygen out—spraying salt into the atmosphere, and today more realistic things like carbon capture and storage. What are the top priorities for the researchers in this area? What are we concentrating on? If funding is going in, where will it go in?
Dr Fox: From an engineering perspective, we really do need to try to filter out these potential approaches and to look at those which have a real practical potential to be applied. What really needs to be done is to create a listing, a ranking if you like, of the risks associated with the projects and the possibilities of the project's benefits and for engineering teams to look at these and to assess the feasibility of these, the practicality of these, the costs and risks associated with implementation and deployment to enable usto make those initial assessments and recommendations as to which solutions might offer potential should geo-engineering be regarded as a route which we need to go down. There has been little, if none, engineering assessment of these solutions.

Q11 Chairman: When will that be done, Tim, do you think?
Dr Fox: We really need the scientific community initially to sort out an order of merit, if you like, for these solutions so that the engineering community and the engineering profession can pick those up and look at them. So a first step from the scientific community is to really come forward with the solutions which are really viable from a scientific potential point of view and with regard to an understanding of any unforeseen consequences or risks associated with those. We, within the Institution of Mechanical Engineers, are already beginning to try to make some initial assessments of the feasibility of some of these systems through our young membership by organising a competition and engaging our young membership in looking at these, but we really need some guidance from the scientific community as to which ones offer the most scientific potential for us to do a really detailed professional feasibility assessment.
Professor Rayner: Could I suggest that the assessment of feasibility needs to be extended to consider the socioeconomic, legal and institution implications as well. For example, ecosystem tinkering or tuning approaches, such as iron fertilization and stratospheric sulphate aerosols, are probably quite inexpensive. In fact, it has been suggested that these are possibly within the price range of some well-intended individuals of great wealth. As somebody has described, the possibility of a Greenfinger rather than Goldfinger being behind such intervention.

Q12 Dr Gibson: You are not talking about Sir Richard Branson, are you?
Professor Rayner: On the other hand, they are ones which from the public's point of view would be likely to raise significant issues of concern about the

unwanted environmental side-effects, and there is a point of view which says that tinkering with the ecosystem is the problem and further tinkering is not the solution. I am not saying that I agree with that, I am just trying to put forward what some of the considerations are. On the other hand, the space mirrors technologies that we have talked about will probably be very expensive and could probably only be implemented by nation states with access to the necessary heavy lift and launch technology. Mechanical air capture—there seems to be disagreement about the relative costs of that. We can also think about financing. To push Ian's question a bit further beyond the research stage, both iron fertilization of oceans and mechanical air capture—in other words going down the carbon removal dimension—are things which could conceivably be funded within a carbon pricing framework, whether you favour a carbon tax or cap and trade to drive the price. It is very difficult to see how that mechanism could be used to fund measures to alter the radiative balance. There are all kinds of institutional, economic and potential legal implications. There are concerns that iron fertilization might violate treaties like the London Dumping Convention or the Convention on Biodiversity. So there is a lot of socioeconomic, legal, and institutional factors which need to be considered right up front alongside the technical dimensions of feasibility.

Q13 Chairman: That is precisely the basis of my next question, Professor Rayner. These are global problems and I admit they require global solutions, but do we have the global legislation in place to prevent somebody causing a major economic disaster of the kind you have alluded to? Should the legislation come first, before we start tinkering with these?
Professor Rayner: It is very difficult to have the legislation come first because we still have so much indeterminacy about what the actual shape of the technologies will be. It is quite foreseeable that we could design legislation with one set of technologies in mind and find that we accidentally preclude ourselves from developing other alternatives which we might want to pursue.

Q14 Chairman: We are not putting any resources into this area. We have heard from Research Councils UK that they are going to have an ideas factory in 2009, which might in fact bring something forward. All our witnesses last week said it was only private finance that was actually funding their research. If we are not putting anything in and people like the UK Government are not putting anything in, we are not going to have anything on which to base decisions, are we?
Professor Rayner: I think certainly there needs to be a significant investment in the R&D necessary to characterise the technologies, both from their technical dimensions and also the social –

Q15 Chairman: Do you all support that view?
Dr Fox: Yes.
Professor Rayner: But I think we need to go forward with that characterisation in a way which does not put too many constraints on the R&D process. For example, it has been suggested in Europe already that there be a moratorium on field tests with iron fertilization outside of coastal waters. Unfortunately, as I understand it, iron fertilisation is not supposed to work in coastal waters and there is not a good legal definition of what constitutes coastal waters anyway. As David Victor, an American political scientist, has pointed out, a moratorium in this area is likely to penalise those nations, companies and individuals who proceed in a socially responsible manner whilst allowing those who are less inclined to be socially responsible to go ahead unrestricted. So a moratorium would not be the answer.
Chairman: Okay, I think you have rightly raised that incredibly important issue, which goes alongside the R&D. I will bring Ian back in specifically on the R&D.

Q16 Dr Gibson: Is this all joined up between different councils and different individuals? I know you as a man who is very concerned about the socioeconomics and they kind of bring you in too late I often think. Are you involved in it right at the beginning? Would it not be better to have a sort of general research grouping to handle all questions at once, including R&D?
Professor Rayner: I would certainly like to see a lot more engagement through the Economic and Social Research Council in funding for social science work in this area. It would be carried out in close collaboration with engineering –

Q17 Dr Gibson: Let us be clear, is there any or is there a lot?
Professor Rayner: At the moment, to my knowledge there is certainly no dedicated funding for geo-engineering from the social science standpoint.

Q18 Dr Gibson: So what is your biggest fear of what might happen? Nanotechnology, GM, it all comes in, the new technology, and there has been very little development of the socioeconomic ideals, the social settings, the moralities, the ethics, whatever these words all are. What have we learnt from those episodes?
Professor Rayner: Unfortunately, I think we are still in the mode of reinventing the wheel each time a novel technological field comes into view.

Q19 Dr Gibson: Why is that? I am going to probe you a bit. You are a bright guy. Why does that happen? Why do they ignore us?
Professor Rayner: I think there is a lot of reasons. One is that the actual technical fields shift and so there is not much social learning between, say, GM technology and nanotechnology, although from the social science standpoint you would say a lot of the issues are actually very similar in both cases. So we tend to define things by their technology rather than

by the kinds of management and governance challenges which they present. So we need a different cut into the projects.

Q20 Dr Gibson: Why is that? Why does that happen? Is that because scientists are arrogant swine and they do not care about the social implications?
Professor Rayner: No, not in the least, and I would say engineers least of all. Although they would probably not necessarily be complimented by my saying so, I regard the best of engineers as being good social scientists, because they have to be, because they have to think of the whole system rather than a narrow technical framing. I think it is largely to do with institutional issues as to how we organise the funding of research, how we organise the scientific research enterprise, how we organise our professional and scientific organisations and professional associations. I think these ways of organising, which we have evolved for perfectly good reasons historically, do not necessarily serve us as well as they might do in confronting these new technologies.
Dr Fox: This is an interesting direction we are heading in with this. Engineering is very much involved today with sustainable approaches and looking at sustainability issues, which do have to bring in the ethics and the social sciences. I wonder, looking at the institutional model here, whether there is potentially a model there for bringing together the multi-disciplinary nature of the geo-engineering project through such an organisation similar to the Tyndall Centre, which has a number of strands of activity going on which are both social science orientated and hard science, if you like, using that term in its colloquial form, and technical and engineering issues. These are all brought together within the framework of the Tyndall Centre and from the Institution's point of view we wonder whether there is an opportunity to add geo-engineering onto the work which the Tyndall Centre is already doing on mitigation and adaptation, to ensure that we do not lose that learning which has already taken place with regard to the social science aspects of mitigation and adaptation.

Q21 Dr Gibson: Have you ever suggested this before to anybody?
Dr Fox: No, this is the first opportunity I have had to bring that forward as a possibility.

Q22 Chairman: Could we get some comments from you, Phil, on that?
Dr Williamson: As far as I am aware, the research councils are not exactly overwhelmed with proposals for geo-engineering, so to a certain extent they react and develop and test ideas which come forward and unless there is a very strong policy driver—and clearly the engineering principle has got to be sound, but the problem with the spread of ideas is that they go in all sorts of different directions and they have not satisfactorily yet passed the first hurdle of even the theoretical analysis: is this viable from an engineering point of view? is it viable from an environmental point of view? and then is it acceptable for governance issues? Although one has got to consider those as a package you have got to have ticks in all those boxes.

Q23 Chairman: I thought you were involved with blue skies research at the Research Council. Should you not be promoting some of these things and actually saying, "These are the great challenges"?
Dr Williamson: The blue skies research is finding out how the system works. For example how clouds form, how the ocean works, how the system interacts and that then gives, from the NERC side of things, the response to an engineering manipulation. The blue skies part of engineering is a little bit different because then it is sort of saying, "What could we do?" But the proposals have got to come into the funding system in the first place.

Q24 Dr Gibson: Suppose the Tyndall Centre idea caught fire. Who would implement it? Who would make it happen?
Dr Fox: I think government policy through the Research Council would have to drive the initial seed development of that. One thing I would like to bring to the table from the engineering industry's point of view is that if industry, the commercial sector of the engineering industry, sees that government policy is moving research spend and research initiatives into the geo-engineering area and looking at the feasibility of some of these geo-engineering systems, then commercial companies in their own research and development departments will start to invest sums of money in doing their own initial assessments and blue skies research activities to try and second-guess the market opportunities which might arise out of the policy which is being pursued. If I might offer an example of this, the aerospace industry has for many years been continuing studies on second generation supersonic aircraft on the basis that that might become a transport policy of government at some stage in the future. So companies do not want to fall behind in the development of their tools and capabilities and it really needs a small investment essentially on the part of government to engender some momentum into bringing geo-engineering into the policy framework as a potential direction, and that momentum will carry forward into industrial engineering activities at the commercial level to prepare for that potential market.

Q25 Dr Gibson: We are meeting two ministers and Bob Watson next after you guys. What would your question be to make this happen, because they are government in that sense? What would you say to them, "Pull your finger out"?
Dr Fox: Yes, speaking colloquially. The Institution of Mechanical Engineers supports investment in research and development at the feasibility level of geo-engineering approaches. There are two reasons for that, if I might bring those forward. The first reason is that we need to prepare our technical community to potentially deploy these systems, but secondly, as a country, as a nation we need to be technically informed to participate in any international discussions or bilateral national

discussions, or indeed discussions with individual private entrepreneurs who want to bring geo-engineering solutions forward to shape the very legislative framework which Professor Rayner has been describing.

Q26 Dr Gibson: Have the venture capitalists talked to you yet?
Dr Fox: No, they have not, but of course there is great potential for some organisation such as Richard Branson's Virgin carbon challenge to potentially take a geo-engineering approach on board. The difficulty is that as a nation we potentially would be uninformed in the discussion and the debate around that solution or approach if we have not done some initial feasibility and research work at the engineering technical level.

Q27 Dr Gibson: Could you do this without venture capitalists? I say that because I have just had a meeting with them, and by God they know what they are doing—so they say!
Dr Fox: There are two different technical dimensions of geo-engineering, one which is indirect carbon sequestration and the other which is essentially tinkering with natural systems. The carbon-based approach has the potential to be of interest to venture capitalists because there is potentially a carbon market in which they can operate. The other approach, which is a little bit more globally esoteric in a sense, has less opportunity, I think, for a commercial venture capitalist intervention.
Professor Rayner: I just want to say that there are at least two firms which have been looking at iron fertilization, one of which has already gone bust, Planktos. The problem is that venture capitalists usually look for a return on around about a three-year timeframe of investment. We are looking here at technologies that are not really going to be available to produce those kinds of returns, so there certainly is a very important role for government, public support, to look into the feasibility of the technologies.

Q28 Dr Iddon: Richard Branson, as we have just heard, has thrown down the gauntlet with the Virgin Earth Challenge, a prize of US$25 million there for the grabbing from some keen entrepreneur. What difference has throwing that gauntlet down made? That challenge was made in February 2007 and we are well over a year on, nearly two years on now.
Professor Rayner: The problem is, that does not fund research. That is the prize at the end, so you have got to have sufficient capital to invest up front before you are even in the running for the prize.

Q29 Dr Iddon: I understand that, but has just throwing the gauntlet down produced a set of ripples?
Professor Jenkins: It seems to me that the position we are in is still very opaque. We have a very wide range of technical options, which then have very far-reaching economic and social consequences and I think the challenge of, for example, the EPSRC sandpit which is coming up is with their limited funding to get an appropriate spread so that we can actually move towards—I will not use the word "ranking" but at least some form of assessment of these options. I personally am rather nervous of ranking technologies at this early stage. I think some are clearly in the potentially interesting area and some are in the longer term area, but to expect a ranking to come out I think is too optimistic.

Q30 Dr Iddon: But that is not an answer to the question. The question was, has Richard Branson made any difference to this field?
Professor Jenkins: No, I do not believe it has made any difference at the moment because of this uncertainty in the technological and other areas.

Q31 Dr Iddon: Can we generally agree that?
Dr Williamson: I think he has made a difference in that he has brought the topic of geo-engineering into the public arena more and it has been reported in the press and there is generally more awareness of it. It is embedded in the consciousness a little bit more.
Dr Fox: I think the difficulty with the Branson challenge is that there is a need in there to show that the implementation will not have any unforeseen side-effects or consequences and that is a rather difficult challenge to meet with regard to the climate science involved in getting to that answer without that specialist knowledge.

Q32 Dr Iddon: Okay. This is one for you, Professor Jenkins. I am going to give you a quote from the Institution of Mechanical Engineers. They, in their submission to us, said: "geo-engineering is an area of activity that has to date received little serious attention from the engineering profession". That was a quote in the submission made by Dr Fox's organisation. You seem to be a bit more open than that in your attitude to geo-engineering in that the Royal Academy of Engineering seems to think there should be funding in this area now?
Professor Jenkins: Yes, I think in terms of research funding and to try to get a better understanding of the area and its consequences there is little doubt that that would be very desirable. I do not think that conflicts particularly with the idea that commercial, industrial and engineering organisations have not been active in this area because it is such an early stage for them.

Q33 Dr Iddon: Yet, Dr Fox, the Institution of Mechanical Engineers chose this topic, geo-engineering, to try and excite young engineers in a competition. Will the young engineers who take part in that competition, if they have not already done so—and if they have, did they do this—consider the social and ethical issues surrounding these technologies as well as the "Can we do it?" attitude?
Dr Fox: Yes. Within the framework of the competition, which is indeed underway as we speak, we have a clause in the rules of the competition for the participants that they must consider some of the ethical and moral issues as part of their wider look at the sustainability issues associated with the particular technology they are bringing forward.

The competition is very much geared around the engineering feasibility, that is the prime role of the competition, and it is looking to engage and excite young graduates in thinking about this potential field of mechanical engineering application which they may get involved in at some time in their professional careers, so to begin to take on board the thought processes associated with getting involved in delivering those solutions.

Q34 Dr Iddon: I am going to ask our other guests this afternoon whether young people in general are aware of geo-engineering. I am a scientist, but I must confess that when we began this inquiry I was not aware of all these potential new technologies. I was aware of carbon capture storage, of course, at the hard end of the thing but not the H.G. Wells stuff. I was not aware of that. Do you think your young engineers are aware in general of what is going on in this field?
Professor Jenkins: I think the short answer is, no.

Q35 Dr Iddon: How are you making them aware, Professor Jenkins? Is this one of your aims, to make them aware?
Professor Jenkins: Yes. If I understand the area well, the first initiative was the seminar in Cambridge in 2004. There have been two or three more seminars. This area in the general academic community has not received a high profile so far. I am absolutely open to the idea that it ought to. I think meshing, if you like, the hard engineering questions with these wider societal questions certainly for post-graduate students is entirely desirable and appropriate, so I would absolutely support that. I would absolutely support further seminars, further summer schools, as a way of disseminating these ideas.
Dr Fox: The competition has indeed engendered a lot of enthusiasm and excitement amongst our young members and they are engaging very actively with it. It is in line with our other activities in the educational outreach programmes, which use climate change and sustainability as a vehicle for engaging young people in thinking about engineering as a possible career and a possible professional option. Indeed, we have found that engaging schoolchildren as young as 12 or 13 in thinking about climate change related issues and how engineering can be used to solve those is very, very enthusiastically received by the young people. This year we have some 3,000 children involved in thinking about climate change adaptation in a competition we are running with secondary schools.

Q36 Chairman: Tim, it was interesting that you could not name a single university which actually has a geo-engineering curriculum. There is not one which actually put these things together.
Dr Fox: Yes, I can answer that. Geo-engineering, from an engineering perspective, will rely largely on the existing theories, existing concepts and existing skills which we teach within our mechanical engineering and civil and other engineering disciplines, chemical engineering disciplines. The geo-engineering is an application of the engineering knowledge in the same way that renewable energy systems are an application of mechanical engineering science and other engineering sciences. You do not have to study renewable energy per se to be an engineer in that sector. It is the same with geo-engineering. There will be some specialist areas that we will need to do work on, for example materials potentially that can cope with the chemistry involved, maybe some special development of mooring systems. There will be niche technologies in very much the same way as when the UK went into the North Sea, but fundamentally the underpinning engineering is something that all our undergraduates in all our engineering courses will learn as part of their existing curriculum.
Professor Rayner: Tim, I think with respect, though, your answer sheds some light on Ian Gibson's question earlier as to why we do not seem to get social learning going from these cases of the introduction of one new technology field to another.

Q37 Chairman: This is the point I was going to make to you, Phil, that one of the issues which has come through this inquiry and the main engineering inquiry time after time is that the engineering seems to be still stuck in silos and its ability to be able to connect those silos up and to move forward seems to be holding back engineering. Is that a fair comment?
Dr Williamson: There are courses in environmental engineering, and carbon capture and storage in its sort of technological sense has brought those fields together, and with environmental science courses then there are the applications being considered. It has not come fully together because the ideas are not that well developed.

Q38 Chairman: Going back to Dr Iddon's comment about whacky ideas, I do not know how we expose young engineers to these whacky ideas and let them engage with them, because that surely is something which would excite more people to come into engineering.
Dr Williamson: If they read Scientific American, New Scientist and Nature the ideas are there. They have just got to find out a little bit about them, but it is in the papers and it is pretty general public knowledge. For the last 20 years people have been talking about adding iron to the ocean.
Dr Fox: Two very quick answers. The ethics and the wider social context are very much embedded in a lot of university engineering courses now under the sustainability agenda, which is very much involved in the geo-engineering application agenda. In relation to exciting young people, I think it is very much the responsibility of the professional bodies, such as our learned society the Institution of Mechanical Engineers, and indeed the Royal Academy of Engineering and the other institutions, to pursue outreach programmes such as the ones we have done on our Cooling the Planet competition into universities and we find that the undergraduates and postgraduates are very excited about getting involved.

Q39 Dr Gibson: Steve Rayner, what are the potential moral dilemmas in this area, just briefly?

Professor Rayner: I think first of all I would caution against reducing all of the institutional dimensions in relation to these technologies to moral dilemmas. Some of them are about economics, some are about politics, international relations, governance and management, and I am afraid there is a tendency towards what we in the social sciences call "ELSIfication". What we do is we take a scientific area, whether it is biotechnology or engineering, and we have the ethical, legal and social implications box and we stick everything in there and it tends to have a very strong ethical component and is not really looking so much at the practical governance issues and certain broader issues of public acceptability, which may not be ethically related but may relate to a whole range of other dimensions. I think, though, with respect to these particular sets of technologies there are at least three positions which one can discern. There is one which I call the utilitarian position, which sees the inexpensive options of iron fertilization or stratospheric sulphate aerosols, as being something which could be readily pursued in a practical way. If the world cannot get its act together to do coordinated mitigation through conventional means then countries could act alone. That is seen as an advantage from that position. But then there is another position, which actually is scared witless about the prospect of countries acting alone because of the concerns about the unanticipated side-effects and also this issue I mentioned earlier, that some people view technology as the source of the problem and they are therefore very suspicious of the idea that technology should also be providing the solution. As I say, I do not happen to agree with that point of view, but it is well-known. Then I think there is a third position, which is the one I guess I am broadly sympathetic to, which is that the development of these kinds of technologies are an option which we cannot afford not to develop, although we may not want to necessarily move to implementation. There is a tendency to accept them as a last resort. I do wonder, though, why we say "accept as a last resort" because, after all, if mechanical trees do turn out to be good at sucking carbon out of the atmosphere and can do so as cheaply as biological trees, why would we restrict ourselves to implementing them as a last resort unless we have some kind of ethical notion that somehow nature knows better than we do? So there are at least three different, what you might call ethical positions within which this debate is going to play out.

Q40 Dr Gibson: Suppose Paul Baker of the *Daily Mail* and Prince Charles get together and start talking about this arena of endeavour and just reflect it the way they want to because it is a new, dangerous technology, how will you persuade the public that it is a bona fide pursuit, an investment?

Professor Rayner: I think that is why one has to be developing the institutional apparatus for managing and governing these technologies alongside developing the technologies themselves, and I think it has to be done—and at this point I can only offer generalisations—in a way which engenders public trust, which demonstrates that there are appropriate mechanisms for dealing with liability, in other words for putting things right if they go wrong, and finally for ensuring that there is actually some notion of consent on the part of populations for the implementations of technologies, what I call the TLC factors.

Q41 Dr Gibson: Yes. So how are you going to stop these mad scientists just going ahead and throwing things up in space and ionization, et cetera? You are interested in public dialogue. You want to get the message over to people. You have not published this, have you?

Professor Rayner: With respect, I think that is, to a significant degree, your job. It is a question of what kind of a legislative framework, what kinds of rules under which you want to fund the research and development necessary to bring these technologies to a level of maturity where they can at least be sensibly characterised.

Q42 Dr Gibson: Yes, but we are waiting for you to give us the arguments. You, the bright chaps, have got time, you know.

Professor Rayner: The arguments are fairly simple, I think, which is that if we take the warning of scientists seriously and we are looking to stabilise the atmosphere, say at around 550 parts per million, by the middle of the century given current progress with conventional mitigation we are in grave danger of falling very far short of that goal. Therefore, we may at some point in the future find it necessary to avail ourselves of the option of geo-engineering solutions. There is also the danger, of course, that we might even meet the goals—we might even meet a more ambitious goal of 450 parts per million—and then discover that the climate sensitivity is much greater than we have anticipated. Once again, if at that stage we start from scratch and say we are going to develop these technological options from point zero, we are going to miss the boat. So I think there is a very strong argument here which can be made across all three of the positions I outlined, that there is at least an option value in developing and characterising technologies.

Dr Gibson: That is the same argument as nuclear power stations in the eighties.

Q43 Dr Iddon: What do you say to Greenpeace, who say, "We are trying to get people to alter their societal behaviour and to stop producing carbon dioxide," and you guys are telling the general public out there that there is an escape route? Will that not stop people from altering their behaviour?

Professor Rayner: This is the concern that there is a moral hazard involved in developing alternatives, but I would say that we have heard that argument for the best part of two decades with respect to adaptation to climate change, that if we actually start to take adaptation seriously and look at it and analyse it seriously, then we are encouraging people to believe that it is okay to carry on emitting greenhouse gases—I used to live in the southern United States and it is a bit like talking to Southern Baptists about sex education in schools, you know, you do not want to do it because you will encourage the kids to behave badly. So it is the same moral argument. I would argue that we have now reached the stage where the taboo on discussing adaptation has been lifted, but we have lost 10 to 15 years' worth of progress, which is going to condemn tens of thousands at least, if not millions, of poor people in vulnerable situations in developing countries to a very uncomfortable time, to put it modestly. I think we have seen that that moral hazard argument really just is not one which we can afford to give in to with respect to adaptation and we should not give in to it in respect of developing geo-engineering options.

Chairman: I think on that sobering note we will finish this first session. Can I thank very much indeed Dr Tim Fox, Professor Steve Rayner, Dr Phil Williamson and Professor Nick Jenkins. We would have liked to have extended this considerably, but thank you all very, very much indeed.

Witnesses: **Rt Hon Lord Drayson,** a Member of the House of Lords, Minister of State, Department for Innovation, Universities and Skills; **Joan Ruddock,** a Member of the House, Parliamentary Under-Secretary of State, Department of Energy and Climate Change; and **Professor Bob Watson,** Chief Scientific Adviser, Department for Environment, Food and Rural Affairs, gave evidence.

Chairman: Welcome to our second panel for the afternoon in the IUSS Sub-Committee's work on geo-engineering. Welcome very much indeed, Joan Ruddock MP, the Parliamentary Under-Secretary of State at the new Department of DECC, Professor Bob Watson, the Chief Scientific Adviser at Defra, and Lord Drayson, the Minister of State for Science and Innovation. Welcome to all of you and thank you very much indeed for joining us today. I am going to immediately start by asking Ian Gibson to begin the session.

Q44 Dr Gibson: The Tyndall Centre, which I am sure you have heard often, has suggested that the Government has been in a state of, in their words, "blissful ignorance" when it comes to geo-engineering. Do you agree with that?
Professor Watson: No!

Q45 Dr Gibson: Why not?
Professor Watson: The issues of geo-engineering have been around for a long while. As the previous panel said, iron fertilization has been discussed on and off for at least 20 years. The volcanoes give us a natural experiment in putting aerosols into the stratosphere, so we know effectively what the implications of stratospheric aerosols can be. So I think on the issue of geo-engineering, certainly when I chaired IPCC for the 2001 report we were talking about it from 1997 through to 2001, so I am not at all convinced we are in a state of blissful ignorance.

Q46 Dr Gibson: Right, but what are you doing to fathom the geo-engineering research which comes along? How are you keeping in touch with it in your busy life?
Professor Watson: I think it is a question of whether that is the highest priority at the moment, given scarce resources versus actually putting investment into current technologies and pre-commercial technologies such as carbon capture and storage, IGCC, future generation biofuels. So I would argue at the moment that one of the key issues, which we are doing, is looking to see what the implications through theoretical modelling would be of adding tropospherical aerosols, stratospherical aerosols, particles in outer space, et cetera. So at the moment Defra is clearly not putting any funding into any of the engineering aspects but we have clearly been, as the paper we submitted to you shows, looking to see what the current thinking is of the academic community, what the potential implications are, positive and negative, of different approaches.

Q47 Dr Gibson: Have we got a hope in hell with geo-engineering, do you think, giving us something interesting? Do you believe that at this stage?
Professor Watson: I think it is still worth doing some exploratory theoretical thinking. I think the issue of the artificial trees has positive elements. I do not see that that has negative implications, although you still have to store the carbon dioxide afterwards, so there are some issues of storage. If we go to some of the other areas, on paper there are potential offsets, whether it is tropospheric or stratospheric aerosols, but I would argue the number one priority at the moment is to actually implement a low carbon economy in both the production and use of energy and that would be the number one priority. For example, carbon capture and storage is a crucial technology on which at the moment the rhetoric is way ahead in the world at large of actual implementation. While there is no single bullet technology to move to a low carbon economy, without carbon capture and storage we will never achieve a low carbon economy if the US, India and China continue to use their fossil fuels, given they are so cheap, to produce electricity.

Q48 Chairman: So why are we procrastinating? Why did we fail to deliver on the Peterhead project? This is probably to Lord Drayson rather than yourself, but you must have a view?
Professor Watson: The European Union is talking seriously about trying to do a dozen or so carbon capture and storage pilot studies, which I believe is what we need. I would argue we need somewhere between 10 and 20 pilot studies, both pre and post-combustion, in different types of storage facilities. So I think now is the time to move aggressively forward. It needs international cooperation. I would argue it goes even beyond the EU, it should bring in

the US and Japan, but clearly this is something which I think has to be moved quickly. I would call it an Apollo-type programme where you do not do one, learn from it, do a second, learn from it and do a third. We need to go in parallel and try multiple approaches simultaneously.
Lord Drayson: I think that is a very fair comparison and I think it nicely puts into context the real difference in the risk and benefit balance of something such as carbon captured storage against projects which we would consider under geo-engineering. I would say in the case of carbon capture and storage you have got an absolutely pressing need you have got a certain amount of time for that technology to be delivered. In concert with the changes which need to take place in terms of the switch at coal-fired power stations you have also got really quite a significant commercial opportunity. If the UK could convert successful research into this area into a commercially successful sector, it would have global export potential, particularly within China because of the number of coal and oil-fired power stations. If you compare that with geo-engineering, where some of the projects which are being postulated provide real questions of the downside risk, for example upsetting the radiation balance of the planet, incredible estimates of costs, for example, in terms of the reflective shields, as the Professor says, therefore the right thing to be doing is to be spending small to moderate amounts of money in the geo-engineering field, concentrating on the use of computer models, looking in a focused way at projects which have a sort of greater sense of feasibility, for example the artificial trees project, but at the same time really looking harder at how we can accelerate projects which have a real need now in addressing the challenge of climate change, and I think the example of carbon capture and storage is absolutely fair.

Q49 Dr Gibson: What is the role of DIUS in this then?
Lord Drayson: DIUS's role is to make sure that there is a clear link-up between the decisions which are taken under the Haldane Principle by the research councils identifying which projects are supported within research within a strategic focus set by the Government in terms of addressing key challenges which our society faces, an example of that being climate change, clearly, and to make sure that the link-up between the strategic objective at the top and the research input which is being taken at the very early stage gets pulled through into the creation, where we can, through the use of government procurement, through the use of the support for innovative new hi-tech industry, such that as we do the research to find solutions to these problems it does lead, we would hope, to the development of a strong sector around that. I think we really need to be, as we are, putting a lot of effort through the Technology Strategy Board to make sure there is think linkage between government policy, research input and the creation of next generation industry.
Joan Ruddock: Chairman, could I just add something to what has been said? First of all, in relation to Dr Gibson's first question about whether we were completely unaware—which is not his own criticism, I know, he was reporting a criticism, but of course there was an internal paper produced by what was then Defra, which was the result of a lot of discussions which had taken place between the chief scientist and UK experts on the very issue of geo-engineering and it was looking at options for mitigating climate change, so very obviously we have, as a department (Defra and now DECC), taken an interest in this subject and indeed Professor Watson has been a leading light in that. There is a difference between taking an interest in a subject and then concluding that this interest leads you into direct action within the Department. The interest is there, the understanding is there and we are not in any sense unaware, but we have concluded things which do not lead us to a great deal of direct activity, and you may want to come on to that.

Q50 Chairman: We just wanted to ask you that very specific question because we are a little confused now as to where your responsibilities and the new Department for Energy and Climate Change start and where Lord Drayson's responsibilities in DIUS finish, because he has quite rightly claimed in terms of climate change that there is a major responsibility for DIUS. What is it within this particular field of geo-engineering that you are going to deliver? Where do you see your responsibilities?
Joan Ruddock: The question is, are we going to deliver anything? We would have to be convinced that geo-engineering offered us a major lever to tackle and to mitigate greenhouse gases.

Q51 Chairman: Can I just start with the question which Professor Watson left us with, this vision of carbon sequestration? He made a very, very powerful case, I think, about European cooperation. He included Japan and the United States in that and I think we, as a Committee, particularly those of us who did an inquiry into this for a number of years, would totally agree with him. Do you regard carbon sequestration as geo-engineering, in which case why are you not fully supporting that?
Joan Ruddock: Let us make it absolutely clear that we believe carbon capture and storage is going to be a major way forward in terms of mitigating CO2 emissions, so that is very, very clear. That has been the position of Defra and BERR, DECC now, for a very considerable period of time.

Q52 Chairman: Is that geo-engineering?
Professor Watson: I would argue no.

Q53 Chairman: I want to know what the Minister feels within her Department. You are not the Chief Scientific Adviser for DECC yet, are you? Or are you?
Joan Ruddock: But he will do!

Q54 Chairman: He will do? I see. This is moonlighting!

Joan Ruddock: I think whether somebody such as Professor Watson would advise us to consider it geo-engineering or not is not a central issue. I think we are already committed to this concept. We believe that it is the way forward. We understand that China and India in particular, but many other countries as well, will continue burning fossil fuels for decades to come and if they are to do that we have to find some way of capturing those emissions and sequestrating those emissions. So that is absolutely clear, that we believe this is a way forward and we have cooperated in a project with China, we are cooperating with one of the leading lights within the EU and keeping it as part of the 2020 package, and we also of course have our own competition which we are still pursuing.

Q55 Chairman: Can we just put to one side carbon capture and storage? The rest of it you are actually disregarding? You say that that is not of any significance to your Department?
Joan Ruddock: No, I am not saying it is of no significance to the Department. I said it was not leading to immediate action.

Q56 Chairman: And you are not going to do anything about it?
Joan Ruddock: We will have, at the very least, a watching brief. Also, there is work which is going on with the Hadley Centre. There is work which is worth doing, we believe, which is at the level of desk studies, at the level of modelling, and we are more than happy to contribute to that and indeed if there were other partners who seek to go forward then we will be more than prepared to consider whether we should partner with them, but as for the Department, let us make it absolutely clear there are no plans for us to fund research in this field.
Chairman: That is absolutely clear.

Q57 Dr Gibson: Bob Watson, can I ask you, how would you get your advice, what is crap and what is good in this field and what is going somewhere and what is not? How does that come to you?
Professor Watson: Basically the same way as when I chaired the IPCC, and that is bringing together a broad range of experts to assess both theoretically what is possible and the experiments which have already been performed—and there has been a significant number of experiments on iron fertilization. As I have already said, nature itself almost does the experiment, in some respects, partially for us on stratospheric aerosols, so I would bring experts together, some of whom are very positive on some of these approaches, some who are sceptical, and actually access the evidence, just like we did at IPCC. What we did on our short desk study paper was that a couple of consultants put it together, but then we sent it probably to about 40 or 50 people to peer review it. As we know, the Royal Society is looking at this particular issue and it would not be surprising to me if the National Academy of Sciences in the US also looked at it, but what would be, in my opinion, quite worthwhile would indeed be a more in depth analysis by the IPCC or a combination of all the major academies of the world, the US with, I would say, the UK, also with China, India and Brazil. So it would indeed be an assessment which had a process which had buy-in from the international science community and the international policy community.

Q58 Dr Gibson: I would like to ask all of you a question about the initiatives which are going on in this field. Have you seen new initiatives that are necessary to drive it faster or get new ideas in there by combining people together, international cooperation, things like that, new ideas coming through, or are you just going to let it tick over?
Lord Drayson: I think the worldwide recognition of the accelerating effects of climate change are leading to a really quite significant development in the whole area of interest of development of the science in this field. I think it is important for us, therefore, in the role of DIUS, with responsibility for the prioritisation of research, to make sure that we continue to invest, although in a modest way, in blue skies research even for the most challenging areas of climate change. Some of the projects which are being postulated under geo-engineering do strike one as in the realms of science fiction with enormous budgets associated with them, the idea of massive shields to reflect the sun's light. However, with the development of computer models, modelling such projects, looking at the possible effects of aerosols, these are things which it is right for us to fund small amounts of money because groups, as you say, Dr Gibson, are developing an interest in this area and it may be that something comes out of this which may be of use. Also, scientists are postulating that there may be some really quite significantly nasty effects which come out of the effects of climate change which can create positive feedback, accelerating the rate of climate change, for example the release of methane from the melting ice, which would suggest that the value of an emergency-type solution in extremis and our views about the relative risk/benefit of such a technology may change in the future. Therefore, I think the balance we are striking at the moment is the right balance. We need to be moderate, keeping a careful eye on this area. It is an area which is developing and something may come out of this, but we must not allow the priority which needs to be taken on the urgent implementation of energy saving or action against climate change, apart from geo-engineering, to be detracted from.

Q59 Dr Gibson: International development. Bob Watson has mentioned the United States academies, and so on. Are there joint papers in this field from different countries? Is the work jointly funded, or is this very much a British effort?
Lord Drayson: This, in common with most areas of science, is an area of international collaboration.

Q60 Dr Gibson: Does that happen for the DECC too, your department, Joan? Does it interact with other departments across the world?
Joan Ruddock: Absolutely. We, as DECC, obviously are involved in major discussions with the IPCC on a sort of constant basis with the UNFCCC as well,

because all our work on climate change is clearly currently aimed in the international sphere at getting an agreement at Copenhagen. So there are constant discussions and one of the concerns we have about geo-engineering is that those countries which are not so keen on getting a global agreement in which every country has to make its own efforts in relation to climate change, people who do not want to enter into agreements which mean they have to reduce their emissions, might see this as a means of doing nothing and being able to say, "Science will provide. There will be a way out. If we were just to look in this direction, then ultimately something will come up." Our concern is that although we do not want to dismiss this work, we do not want to be unaware of it, it could be used politically in that way, which would be extremely unfortunate because what we know about engineering is that engineering can provide us with well-tried and trusted solutions to reduce CO2 emissions from a huge range of activities and it is those existing engineering solutions that we seek to promote in the international arena and where we seek, of course, to get technology transfer to those countries which at the moment do not have that opportunity for themselves. So it could be a means of deflecting engineers from the very best work which can be done to help the world community to get such a deal.

Q61 Chairman: Thank you very much indeed. Could I just briefly ask you, Joan, before I bring in Gordon Marsden, whether in fact in your short time within the new ministry there has been or are plans to have meetings of your Department with DIUS and with Defra, because you all seem to play a key role within this space? Is that work going on?
Lord Drayson: Absolutely, Chairman.
Joan Ruddock: Yes.
Lord Drayson: In fact it is, in part, the purpose and role of the new Committee for Science Innovation, which I will be chairing, to make sure that departmental coordination for tackling these major challenges such as climate change are better coordinated.

Q62 Chairman: Is this issue of geo-engineering likely to be on your agenda?
Lord Drayson: Certainly the issue of climate change and energy is on the agenda. I would think within that carbon capture and storage is a very important theme, and within that I would say the one geo-engineering area which looks to have more relevance and does not cause the international treaty problems which we have mentioned is this area of artificial trees.

Q63 Mr Marsden: I would like to ask one or two questions about the implication of this particular branch of geo-engineering for potential future skills provision in universities and elsewhere. I wonder if I could start by asking you, Lord Drayson, because I know that in September DIUS contacted the Engineering Subject Centre to get a summary of the current and proposed provision of university courses relevant to geo-engineering and that was to look at issues such as delivering modules, research interests, demand for subject development. We understand that DIUS originally asked for that information to be provided by the beginning of October and I would be interested to know what the initial finding from that has been.
Lord Drayson: Our position is that we do not see that there is a need for us to specifically support the skills for geo-engineering because the feedback we have had and the conclusions we have come to are that the skills required for geo-engineering are common to many of the other areas of science related to climate change, for which those skills within all of the branches of engineering are going to be required. So our focus is really to concentrate on developing the skills base within engineering per se to make sure that the provision of courses for those branches of engineering relevant to the aspects of research and provision of solutions and infrastructure for addressing climate change are properly addressed. That is part of the wider government agenda in terms of encouraging an increase in the development of, firstly, pupils studying those subjects at school and the proportion of students going on to study those subjects at university. In all of those areas we are seeing an uptake, so our policies are working. We just need to see them working more quickly and with greater effect.

Q64 Mr Marsden: I understand the point you are making about the link between specific branches of engineering and general awareness and general provision, and of course that was an issue which we discussed previously in the inquiry in relation to nuclear engineering. Given this is a cutting edge area, and obviously you cannot be prescriptive and would not want to be, but do you have any concerns about the current status of what students in universities or schools may or may not be being taught about geo-engineering?
Lord Drayson: I would say that my concern is more that within this country we do not have enough scientists, we do not have enough engineers, period, and therefore what we need to be doing is addressing those issues with real vigour, which is what we are doing. Our analysis of this sub-field of climate change engineering and the particular focus which you are asking me about around geo-engineering is that we have not found that there are any particularly specialist skills for engineers and scientists which are not common to other areas more generally, for which we need to make specific provision. We clearly need to monitor that, but we have not concluded that as yet.

Q65 Mr Marsden: Professor Watson, if I can just turn to you, in your position as Chief Scientific Advisor at Defra you are, presumably, continually on the look out for areas of interesting promising research which may then have the sorts of broader implications we are talking about. What analysis or what reports have you given to Defra so far as to the potential implications of geo-engineering for university and school provision?

Professor Watson: I would actually agree with Lord Drayson. I do not see there are any special skills needed for the types of geo-engineering we are talking about, whether it is iron fertilization, adding tropospheric aerosols, stratospheric aerosols, et cetera. So as we noted earlier, Defra did indeed commission a paper which we then had peer reviewed on the various types of geo-engineering. We did not in that paper look at the skill set needed. We purely looked to see what were the approaches which could be taken, what were the potential benefits, what were the potential negative effects, basically, environmental, and social. We did not do a good cost estimate either. So we raised the issue and six months ago we actually sent our paper to the Royal Society suggesting they might want a more in-depth study, which they are now actually doing. We did not look at the skill set, but as Lord Drayson said, I actually do not see that there will be special skills needed at this moment for these types of projects.

Q66 Mr Marsden: Just a final question, if I may. I understand the way in which you have laid that out, but are you aware of how that approach which you have outlined and Lord Drayson has touched upon compares with the approaches in governments elsewhere—and I am thinking of particularly the evidence session we ad the other week from a couple of distinguished scientists from the United States—for a comparison between the way in which the US, Germany or France may be dealing with these issues?

Professor Watson: To be honest, I am not up to date with what the US is or is not doing on this. I know what they are doing in general on climate research. I used to be in the White House and I oversaw their programme of basically a couple of billion dollars a year. I have not stayed in touch with what the US is currently doing on geo-engineering though.

Chairman: Thank you very much.

Q67 Dr Iddon: Lord Drayson I think I should address the first question to. The Tyndall Centre believes that we should be seriously looking at geo-engineering projects, admittedly as an emergency policy option, in other words plan B, and they come under criticism then from the green organisations, particularly Greenpeace, who believe that would be an admission by Government that they supported geo-engineering of this kind, that mitigation of and adaptation to climate change had actually failed, and Joan Ruddock referred to the political sensitivities. Is it these political sensitivities, under pressure from the green organisations, which are preventing us from investing in any, in this country, geo-engineering research?

Lord Drayson: No, I really do not believe so. I think it is right for people to raise concerns as to where the priorities lie and I think they are right to say that the priority needs to be in addressing those aspects of science which can most have the impact in terms of the risk/benefit equation and make the most sense, but I do not subscribe to the view that you should on purpose put all your eggs in one basket to make sure that you look after that one basket really carefully. I think that is not how sensible science policy should be implemented. I think it is right for us to have a watching brief, as we have described, on these areas of geo-engineering. I think they could rightly be described as an emergency plan B. That does not mean that we should not absolutely put full effort into focusing our investments on plan A. But one never knows. That is the value of pure research and that is why it is right for us to be putting a moderate amount of money into this area, to be focusing on aspects such as modelling where we can learn an awful lot without having to invest too much.

Joan Ruddock: I think there is another aspect to plan B and it is this: if we want the whole of the world community to come together, as we do, to both mitigate climate change and adapt to the climate change which is inevitable then we have to engage and get a huge political consensus behind this, and that is what all our efforts are going towards. We also have to in certain ways produce vast sums of money, which I will not even begin to go into. If plan A has failed, if all that has failed, then there is very little reason to imagine plan B could succeed because most of the sorts of geo-engineering solutions which are being proposed would require international agreement. They could not be done in one country without consequent effects in other countries. Perhaps the simple chemical trees might be in that category, but most of the others we require international agreement. The sums of money which would be required are colossal. So if we have entirely failed to bring the world community together to do the rather simpler things which we already understand very well and we could not get political consensus around them, then it seems to me rather unlikely that plan B offers you the "Get out of jail" card. I think that is a narrow dimension which has not been well explored, perhaps, on geo-engineering solutions, just what an international effort would be required to make the majority of these potential plans come into being.

Q68 Chairman: They are global issues and I suppose that leads me to my next question, which is, is geo-engineering high up on the agenda for world discussions or do we never discuss it at international conferences between politicians?

Joan Ruddock: I am not aware that I am so new in this job that my testimony should not be taken, perhaps, too seriously. I am not aware of politicians discussing these matters at length, although I do know that there have been many meetings at which there have been scientific discussions, working groups, groups of officials, and I, in my limited experience, have heard that such discussions have dealt with ocean seeding for example, for fertilization, which I know has certainly been on the international agenda, but the extent to which politicians have been involved I suspect is limited. I also think that given the absolute necessity to come to some global agreement on climate change, that is probably correct, that scientists should probably not be looking to what I regard as being somewhere down the list of priorities and potentially the plan B,

because we need all our energies directed at the plan A, but perhaps Professor Watson will have more knowledge than I do and can tell you rather more.
Professor Watson: I have not taken part in the recent negotiations but when I was the chair of the IPCC, so until six years ago, most of the negotiators looked to the IPCC not only to say what was the state of knowledge with respect to climate change, what the impacts could be, but they would also look to the IPCC to talk about mitigation approaches and the economic cost. The IPCC, in the fourth assessment report, basically said that the geo-engineering options put forward to date remain largely speculative with little known about their effectiveness and cost, with the risk of unknown side-effects. They looked at ocean fertilization, they looked at reflectors in outer space between the earth and the sun, they looked at reflecting aerosols in the atmosphere, and changing the albedo of clouds, et cetera. They did not, by the look of it, look at artificial trees, but they looked at most of it and clearly with that relatively negative report and at the same time, their statement that we do have cost-effective technologies in both production and use of energy to try to get on a pathway to 450, 500 parts per million and the need, which they analysed in great length, of what technologies could you bring to the marketplace within, say, the next decade (i.e. carbon capture and storage, future generation biofuels), so with that sort of statement by the IPCC it is not likely it would have been a major discussion point by the politicians of the world. They will have put their effort, in my opinion where they should, on how to transform to a low carbon economy.
Joan Ruddock: I have been passed a note, so if you like I can tell you that apparently there have been no discussions in the UNFCCC on geo-engineering, for the record.

Q69 Chairman: That is very helpful. Thank you very much. There is little commercial activity in this area at the moment, but four companies the Committee is aware of Planktos, a Californian company, has actually gone under, but Climos is still in existence in California, Atmocean in Sante Fe, also in the United States, and a company in Australia called Ocean Nourishment Corporation appears to be active in this area, all operating in a marine sense. If there were companies like that about to spin out in Britain, I guess the question is, would we (i.e. the Government) support them because I know that Linda Gilroy, who is the Member of Parliament for Plymouth and is aware of the marine scientists efforts to use algae to accelerate the carbon cycle in the sea and they would very much, I think, like to break out as a spin-off company in the not too distant future. Would the Government support any companies which want to spin out in that way?
Lord Drayson: Yes, particularly because Plymouth in that region has shown a really excellent track record both in the area of marine research but also the way in which a cluster of marine research-related spin outs and commercial enterprises have been developed. We also recognise that there is overlap between different types of marine research with this area. So although we would not see at the moment that the commercial opportunity for geo-engineering projects is well-established, we do see that there would be a sound commercial business plan based around a general research area, which would include geo-engineering as part of a number of different areas within marine science. Providing that was done in an area where you had the benefits of the cluster effect, good intellectual property and a sound infrastructure to support it, then we would be supportive of such a development.

Q70 Chairman: Thank you very much. Could I stay with you, Lord Drayson? In terms of the research community, we did have a very interesting session last week. I think my colleague, Brian Iddon, made the point earlier this afternoon that I think for all of us this was an area we had not really engaged with before. I think we say that quite openly and honestly, but we were quite excited last week on hearing particularly from the United States but also from our own scientists here in the UK, very, very committed scientists who were looking at geo-engineering not as a bridging technology but also as a genuine technology aimed to deal with this whole issue of climate change. I wonder what relationship you have as the Science Minister with this emerging scientific community, who do feel a little beleaguered and not listened to. What is your pathway to be able to discuss with them some of these ideas so that they do not feel they are just banging their heads against a brick wall or an artificial tree?
Lord Drayson: I would encourage them to make full use of the Government's existing programmes in the area of climate change.

Q71 Chairman: But how do they do that?
Lord Drayson: They can firstly make themselves known to the Technology Strategy Board, which is a key mechanism the Government has implemented to allow an independent assessment to be made of the technology investment priorities. Within that, climate change is a key challenge which the Government has identified. I would encourage them to not see their area defined as geo-engineering but to define themselves more broadly within that space and I would recommend that the Technology Strategy Board will be the first port of call for them.

Q72 Chairman: Okay. In its submission DIUS report that sulphate aerosols have a residence in the atmosphere for around about five years and yet Defra had a similar report based on Nobel Laureate Professor Crutzen's work, which says that they stay in the atmosphere for one to two years. Why do we get such differences of opinion?
Professor Watson: It simply depends at what altitude and at what latitude you actually inject the aerosols. When Mount Pinatubo exploded it put the sulphate aerosols into the lower stratosphere and it had what we call a half residence time of about one

and a half to two years. If you could inject them much higher, they would indeed stay in the atmosphere longer. So it really depends where you inject them, both in altitude and in latitude because there is only a few parts of the world where you get an exchange of air across what we call a tropopause.

Q73 Chairman: If I can come back again then particularly to you, Lord Drayson, and also to you, Joan, how do your departments intend to really spread this message about geo-engineering, albeit that it is on the periphery of your main policy areas? How do we get particularly young people, young scientists, to engage with research groups? We heard last week that there is not a single grant which is coming directly from the research councils for a particular project in terms of geo-engineering. How do we get tomorrow's scientists, tomorrow's young engineers to actually engage with this if in fact there is no research funding coming through at all either from the Department or indeed from the research councils?
Lord Drayson: Chairman, I think this speaks really directly to the point I made just a moment ago about the importance of the way in which scientists in this field and people looking to commercial the science define the field they are in, because within the area of climate change we are currently spending within the NERC £66 million on fundamental research, so it would very much depend upon the specifics of the type of research, so that is research into the effects of climate change. In terms of total research investment by the research councils in the area of energy it is approximately £300 million. So there is investment at the moment going into the areas of which you could possibly argue that some of these geo-engineering projects would fall. I think that decision relating to the balance of investment within the particular areas of science is rightly not a decision which is made by politicians under the Haldane Principle. We see that these decisions about which projects are supported is left through the peer review process into the research councils and that is, of course, the way it should be.

Q74 Chairman: Do you share that view, Joan?
Joan Ruddock: Yes. I have nothing to add directly to that. I do not think it would be the job of my Department to be trying to enthuse young people about a particular branch of science or engineering. What I do think is the job of my Department is to engage our population at large in working with us, working with industry, working right across the piece to tackle climate change because we know that 40% of the emissions that concern us come from the individual actions of human beings directly in their own lives. We can influence them and so we want young people to understand that that is the case and that there are things they can do. It is my belief—and I hope this will prove to be right—that the great challenge of climate change and the degree of interest young people have shown in climate change and the fact that it is their lives which will be constantly threatened by climate change will actually, I hope, lead to all of young people to want to be scientists, to want to be engineers and to see that they can not only change things in their own lives but they could actually do something which could make a very big difference. So I think it can be a source of inspiration for young people. We certainly have climate change champions who are drawn from young people in competition around the whole country and in the work they do and the work which is done in the eco schools, for example, people become very innovative, they become very interested in science as a result of joining this popular movement of people who want to address climate change. So I think tangentially we come at this, but of course we would not be promoting a particular branch of science to young people as a department.
Chairman: Okay. On that note could we thank you very much indeed, Joan Ruddock, Professor Bob Watson and Lord Drayson. Thank you very much indeed for your evidence this afternoon.

Oral evidence

Taken before the Innovation, Universities, Science and Skills Committee

on Wednesday 19 November 2008

Members present

Mr Phil Willis, in the Chair

Mr Tim Boswell	Dr Brian Iddon
Mr Ian Cawsey	Ian Stewart

Witnesses: **Professor David Fisk**, Imperial College London; **Professor Michael Kelly**, Chief Scientific Adviser, Department for Communities and Local Government; and **Professor Wendy Hall**, Member, Council for Science and Technology, gave evidence

Q1 Chairman: I welcome our first panel of witnesses this morning to our inquiry on engineering in government, part of a major piece of work which the Committee is doing looking at engineering. We welcome in particular Professor David Fisk, a former departmental Chief Scientist, Professor Michael Kelly, the Chief Scientific Adviser in the Department for Communities and Local Government and Professor Wendy Hall, a member of the Council for Science and Technology and a professor of computer science at the University of Southampton. Could I start with you, Professor Kelly? We have Chief Scientific Advisers, of which you are one, within government departments, and certainly David King was very keen on promoting that and John Beddington is equally very keen on that, but we do not have Engineering Advisers. When we talk about STEM subjects, science is very much to the fore of it and engineering is slipped over very quickly. Why is that?

Professor Kelly: I think that is probably historical. I want to correct you, though; there are a number of Chief Scientific Advisers now who are engineers.

Q2 Chairman: Now, but they are called Scientific Advisers and not Chief Engineering Advisers.

Professor Kelly: That is correct, but I happen to have had a first degree in maths and physics and became an engineer while working in industry, so I feel quite passionate about engineering with all the passion of a convert. I think you are quite right. As I said last time I was here, my distinction between science and engineering is that scientists know and engineers do. There is a certain element about scaling up and, as my colleague David Fisk mentioned, making professional judgments about the feasibility of aspects of projects which I think are integral to an engineering training and which may not necessarily come through the regular scientific route.

Q3 Chairman: Given the massive infrastructure projects which are being procured by government, surely having professional engineers very much at the heart of those projects would be something which we ought to be promoting?

Professor Kelly: I totally agree with you, sir.

Professor Fisk: Chairman, I think in a way it is a failure of the internal audit processes on those projects. In very many cases the real catastrophe is a back room failure; it is people not recognising the symptoms, not doing the right processes, not having enough background. If you look very often at the audit, the audit is largely about whether contracts are delivered on time and indicators which are not full measures of the project process. I fully support the idea. It just seems to me that somewhere you need the pressure in the system to ask: how does a department assess different proposals for a project? In the Ministry of Defence there has always been an internal challenge function that has been there for years trying to check and steel up the way the process works. My main point is that one needs to find the pressure to make sure that it happens.

Q4 Chairman: Are we barking up the wrong tree as a committee by thinking that there should be a separate engineering discipline as opposed to a scientific discipline, or in fact, as some claim, are they are just two sides of the same coin?

Professor Hall: I do not think you are barking up the wrong tree. I would like to say it a bit more strongly than my colleagues here: I believe that the Government does not engage engineers and engineering practices enough in its processes. David King and John Beddington both use science to mean science and engineering but to me—and you will understand this—it is very like when people say, “Well, ‘he’ means he and she” but when people say “he” they mean he, particularly “he’s” when they say “he”. When scientists say “science” they mean science. I believe quite strongly that engineering needs to be pulled out. In “The Council for Science and Technology”, “Technology” adds a bit of development and implementation and practical things but I would much rather it had “Engineering” in the title as well. There are a number of engineers on CST and we have a very good say in what CST does, and we produce some good engineering-based reports. I do not think Government engages engineers early enough in the procurement processes. I think they should be there from day one on these large-scale projects and identified as such.

Q5 Chairman: So you distinguish between scientific advice and engineering advice?
Professor Hall: Yes, I do.

Q6 Chairman: Professor Fisk, would you distinguish between those two, engineering advice and scientific advice?
Professor Fisk: Chairman, I think I have a very good precedent. When Michael Faraday explored the problem of exploding dust in coal mines, he cracked the science and then, in his final report on these tragic events, gave his view of how much fresh air needed to be supplied in order to stop this happening, and then very bluntly says he does not have an idea how on earth how he would get that amount of fresh air down into the mine. "This has to be left", he said, "to men who are practical". In the Victorian times there was a very clear division in people's minds between the practice and knowledge of things and actually getting them set up.

Q7 Chairman: You would have a clear distinction between scientific advice and engineering advice. Would you, Professor Kelly?
Professor Kelly: Certainly in some subjects and last time I was here you asked me whether I could give you confidence about the engineering integrity of the Olympic legacy. I took that as a mission sense. Of course what has happened is that the people inside the Department who look after the London Olympics, but the first thing they have done is retain a group, a company, as independent consultants for them. I always feel that that is second best to having somebody inside the tent who will argue the case with the passion of being the ultimate owner or having ultimate responsibility for a big project.

Q8 Chairman: On the clear question as to whether this Committee should recommend that there is a Chief Engineering Adviser in each department alongside a Chief Scientific Adviser, what would your answer be?
Professor Kelly: My answer would be: yes, for the vast majority of departments.

Q9 Chairman: Would that be same for you Professor Fisk?
Professor Fisk: I do not find it a very thrilling question, to be honest.

Q10 Chairman: I am very sorry about that. I will try my best later on.
Professor Fisk: That is because most of the errors in engineering are not occurring at the level at which the Chief Engineer would see things. In fact, Chief Scientists tend to see things quite late, unless it is a very big, very high profile Secretary of State issue. The problem in many departments is what is going on in the engine rooms when quite small but very important parts of White Papers are being discussed in committees and so on. It is probably more important that the Chief Scientist is assured that there are people who know their engineering in the department than having to read every one of the engineering papers. Probably in some departments they would just be overwhelmed.

Q11 Chairman: To that specific question, yes or no, Professor Hall? Should we have a Chief Engineer alongside a Chief Scientific Adviser in most departments?
Professor Hall: Yes.

Q12 Chairman: Could I move on from that and ask, and you seemed to hint at this earlier and certainly Professor Fisk also hinted at it: are engineers, be it in terms of a consultative group, consulted at the policy formulation stage in government, do you think, or is it when we are executing the policy?
Professor Hall: I think it is too late in the process and this is the problem. I disagree slightly with Professor Fisk.

Q13 Chairman: Disagree seriously as he insulted me earlier!
Professor Hall: I believe that just as Chief Scientific Advisers set best practice for science policy in a department, you need the engineering expertise to set best practice for engineering policy. Obviously, if we had a Chief Engineering Adviser, he or she is not going to look at every report. You have to lead from the top on the best practice for doing that. There are not enough engineers in the Civil Service anyway; the Civil Service should be recruiting more engineers at every level. We should not just be talking about at the top level; we should be recruiting at every level.
Chairman: I think the whole panel agrees with that.

Q14 Dr Iddon: My first question was going to be: what role do Chief Scientific Advisers play in enabling Government to make full use of engineering expertise? Professor Fisk has already indicated that certainly at the lower tiers of the Civil Service engineering expertise is not trickling down, even if the CSA is an engineer. How can we alter that? What mechanisms do we need to put in place? Perhaps we should start with Michael Kelly.
Professor Kelly: One of the submissions that came in reported to the level of just what I call GCSE level science that general civil servants have. Most people would be ashamed if they could not read a series of basic economic tables or understand certain aspects of statistics but none of them would be ashamed if they admitted they did not know the Second Law of Thermodynamics. Look at the National School of Government and see to what extent civil servants are exposed to some of what is basically GCSE science. The other day when I had somebody from another department in wanting to reduce the energy consumption in a house by 5, I said, "Let us take your shower. Do you want to have a shower for one-fifth of the time or do you want to raise the water temperature by one-fifth, so that you have the same time but a colder than blood temperature shower? Those are the only alternative you have". That is zero order physics upon which a lot of dreams came cascading down. I think there is a huge problem there. Even in our own department when it was a

matter of setting up a climate change group, we had to have two economists and a statistician; that was the starting point of a problem which is essentially about climate change in buildings. If they had said, "Let us get a buildings engineer and a couple of people to support that", I would have said that was the appropriate way to start.

Q15 Dr Iddon: Let me get this quite clear. The Chief Scientific Adviser should ensure that when serious policies are being considered right down to the lower tiers of the Civil Service, if the expertise is not there, it should be brought in? That is what you are saying?
Professor Kelly: Yes.

Q16 Dr Iddon: Does anyone have a different view or do we all agree on that? Moving to the next question: can any of you give any examples of where the advice of engineers in departments or that brought in externally has been used successfully in policy making and, on the reverse side of that coin, can you give any examples of failures in policy making due to a lack of engineering expertise?
Professor Kelly: Can I answer the first part of that? If you take the work that the Climate Change Committee is doing, I certainly saw some figures a year ago which I thought were out by a factor of 5 on the impact of certain aspects of measures on buildings. I queried these. They had come from another department. As a result, that work has been done again and the results are much closer to that which I had expected. The net result of that is that the group concerned with the papers and the announcements that are coming out soon have asked me, and I arranged for both the Royal Academy of Engineering and a group of consulting building engineers at the Bartlett School, to review the material. They both came back with critiques, but these were not critiques saying "this is out of the order" but "you might want to tweak this or tweak that", or that they thought there was a slightly different way. Basically what came back was to say that these people are now on the right track. I can do that with my networks, and have done it on a number of other occasions. Another issue is coming out on multi-foil insulation where through my networks I could get two experts who have not become involved in the legalities of a particular claim that is being made about their effectiveness. I was able to do that and I find that is one of the important roles that I have that I can pick up the phone.

Q17 Dr Iddon: If I can just pick up the first one, I think you are referring to your experience with carbon efficiency in buildings and there was this team meeting to bring in new regulations presumably. Had you been told that that team was meeting or did you stumble over that committee?
Professor Kelly: There are a lot of meetings. I only work three days a week, so that lots of things happen without me. I have commitments in my other job which do not mean I can chop and change freely. If there are 20 students to lecture to, I have to be there. I am able to attend some meetings, but not to be a systematic party to it. At the time when I saw the material to which I described above it was a slide that was being used and imported into a paper one of my colleagues was using. I said, "Hey, I think this needs another hard look at before it goes any further".

Q18 Dr Iddon: I think what you are really saying, Professor Kelly, is that you should not always be responsible for trying to find out what is going on in the department but the committees that are meeting on various aspects of policy, if they require engineering or scientific advice, they should be coming to the Chief Scientific Adviser and saying, "Have we got this right?" and they are not by the sound of it.
Professor Kelly: You are correct. It is important to realise that some of these people do not appreciate the finessing of some of the issues in front of them. I have a different version of this. If you look at all the 30 odd policy measures out there for reduction of carbon emissions in buildings, I have been asking for two years what exactly is the expectation in terms of actual carbon savings by 2015. That is a hard engineering question so that we will know in 2012 if we are on the trajectory. I am afraid I cannot get that answer. It is not just the responsibility of my department; it is for several departments to get that information.

Q19 Dr Iddon: Can we assume, Professor Kelly, that the carbon efficiency problem is now fixed?
Professor Kelly: I do not have it by the throat, but wherever I have been able to intervene I am content with the quality of the work that is coming out. It is fit for purpose.

Q20 Dr Iddon: I wonder whether our other two witnesses could give any examples of successes or failures where engineering policy is of concern.
Professor Hall: I can. On energy, for example, the CST reviewed the Government's nano-technology policy recently, in the last year. That was taken very seriously and has really raised that up the agenda, we believe. I also remember a meeting we had with Tony Blair when he was Prime Minister about energy supply in the UK. There was a startling moment when our experts in this area showed him the graphs of what would happen if we did not renew the nuclear options. That was taken very seriously but then you see policy being made, if I may use the expression, on the hoof later about alternative energies where really we are raising issues about: is the National Grid up to what is being talked about here? These are big engineering problems. These calculations have not been done. This advice is being ignored—not ignored but it is not being taken up at the moment. I would also say that in my area of computing, software engineering is what runs this country; the infrastructure of this country is built by software engineers almost. There have been many reports about how the procurement of large-scale software systems should be done differently that have been ignored.

Professor Fisk: In my evidence I focused on Treasury. Treasury does not have a Chief Scientist; it does not have a science stream inside it. As a taxpayer sometimes I am grateful that it does intervene in the shaping of policies protecting my interests but there are a number of areas in which the engineering as we have been describing it here would have been a major input into a policy that does not seem to been informed in that way. I had an opportunity to interview the team that designed rail privatisation. It turned out it had never occurred to them that the track and the wheels that rest on it are a coupled spring system. They were not all mechanical engineers. They had in their mind the sort of model you would get owning a train set when you are a boy. So they thought them quite independent and very easy to divide the market in that way. They may still have been right to stratify the market for rail privatisation as they did but what they did not realise was that there would be an engineering cost for making the break where they did. A second example would be when there was a dispute between the Mayor of London and I guess the Treasury essentially about how the ownership of track repairs should occur in the London Underground. Again, there may be good economic reasons for doing it one way or another but it was pretty clear it became presented as a political argument between the players when actually there is a real engineering issue about managing the way men can work in tunnels. It is a very difficult issue in terms of managing cost overruns. So there is a thread in which sometimes the Government Economics Service takes upon itself the engineering realities, having assumed it understood the engineering. There is another last case I might give you, and again all these cases were well-meaning Treasury interventions; they were not trying to do anything wrong. There was the classic case in the 1980s of one of the very earliest green taxes that Treasury tried to introduce, which was intended to be more friendly to cars with low NOx emissions than high ones; it was roughly proportionate to the size of the engine. The tragedy there is that small engines, because they are under so much more strain, actually produce more NOx than very large ones for each kilometre they travel. The Treasury had no internal way of checking that what they thought in man in-the-street way it would work would actually work. This has a large effect on the design of many of the institutions we look at. When the Treasury is protecting our interests it does not always do it with a great deal of engineering knowledge.

Q21 Dr Iddon: Professor Fisk, you are clearly in agreement with this Committee that there should be a CSA in the Treasury. Do our other two witnesses agree with that?
Professor Hall: Absolutely.

Q22 Dr Iddon: Turning to you, Professor Hall, the Royal Academy of Engineering and the engineering institutions, of which there are a great number of course, too many perhaps, have said that more use could be made of the Council for Science and Technology. Do you agree with that? Perhaps you could expand on how that could be done?
Professor Hall: Yes, I would agree. I am a member of that. We are not asked to do enough. We produce reports, which I believe are extremely useful and generally well received. We have a lot of deliberations about what we should do our work on. We want to do things that cut across departments and that cannot be done by one department or another, or one sector or another, but we do not feel we are asked for advice enough about where the Government should be. We are called the Prime Minister's Council of Science and Technology. We used to meet Tony Blair. We are meeting with the current Prime Minister soon, but it will be the first time in this government. We meet with advisers and Chief Scientific Advisers and we have lots of very influential people come to the committee but we do not feel we are giving the advice at the level at which we were commissioned to give it. Other international comparisons show that their top level science committees do talk at the top level to give advice.

Q23 Ian Stewart: Professor Hall, You cite there the different situation now in relation to relations with the Prime Minister. What actions have the institutions taken to put that right?
Professor Hall: We have had meetings with his advisers and talked about the work we do. The secretariats have worked a lot behind the scenes.

Q24 Ian Stewart: In your view, is that a weakness on the part of Number 10 not understanding or is it a weakness on the part of the academies and institutions or is it both?
Professor Hall: I was talking about CST. You must not link that with the academies. One could say the same sort of thing. With CST I think that a meeting should have been set up earlier than it was, or at least what we were doing should have been taken into account when the science and engineering policy was being developed.

Q25 Ian Stewart: Is that a symptom of a lack of confidence in the engineering role?
Professor Hall: You are confusing two things. We are the Council of Science and Technology. You could argue it is a lack of confidence in what the CST does. The evidence is that the reports we have produced and the feedback we have had and the reviews for that have been very positive.

Q26 Dr Iddon: Can we be clear about who organises the CST meetings? Is that arrangement made by the Cabinet Office?
Professor Hall: No, we come under DIUSS now. I think it was all part of the reorganisation of the departments that this happened. We are in GO Science, the Government Office for Science. We have two Chairs because we are half in and half outside government, which is an advantage and a disadvantage. The Chief Scientific Adviser is one of our co-Chairs and the other is a member of CST; it is currently Professor Janet Finch.

Q27 Mr Cawsey: I want to ask a few questions about how the Civil Service should be making greater use of engineers and scientists. Professor John Beddington at a previous session of the Committee said that no-one knows how many engineers there are in the Civil Service and, moreover, when pushed further, he did not even know when that information might be available in the future. Should we know? Is it important? What would we gain from having that information?

Professor Fisk: For my evidence, I had to resort to the Freedom of Information Act to extract from a number of departments how many engineers they had. I tried a very simple test. I just asked how many Chartered Engineers they had because the attraction of Chartered Engineers is that at least they have a continuing professional development programme, so we are not relying on a first degree they took three generations of technology ago. The actual record I record is pretty grim. I think the human resources in the Civil Service at the moment have rather lost the plot on professionalism in general. Unless there is a severe external attack like needing legal advice and so on, it finds it very hard to keep count of professionalism. One or two of the human resources departments I received information from clearly did not really understand what a Chartered Engineer was. One rather extreme case, Ofcom, that works in a very technical area, did not know how many Chartered Engineers they had but they did notice that they paid the fees for three. It seemed to me when I looked at the board of a number of them—the Environment Agency was one I looked at yesterday—very often the scorecards given to the board do not measure the internal competence of the organisation. They will measure how well the outside world is performing as it is being regulated but there is not a track. As you will see from my evidence, at the time I asked the question the Financial Services Agency did not know how many Chartered Accountants it had. You would think, in a body that has been under considerable pressure on its competence over several years, it would have begun to tighten on these things. I think there is a real looseness in the system. May I touch a bit on the earlier question? Comparing the UK system with some of the systems abroad, the thing that strikes me very starkly is that we have a lot of structures to give advice but we have very few structures for critical analysis; that is to say, if you were looking at some of the US material that was accessible, this is commissioned by Congress to look at what the Administration is doing. It is not, as it were, run by the Department of Energy or the Department of Defense. I think there is a sense in which a lot of the things will repair themselves if government departments were aware of that, if there was a bit more free-ranging criticism available from, say, the Council of Science and Technology, rather than reviews necessarily being a mutually agreed agenda. I think that is just a part of what would help Parliament with its task.

Professor Hall: I agree with that but may I say something to the original question? I think Government has to show leadership here. One of the issues that we have not yet touched on is the lack of engineers and the lack of young people wanting to go into careers in engineering. Part of the problem is that engineering does not have the status and knowledge of what a career in engineering is. It is not known about by people. The issue of the Civil Service having so few engineers is part of the problem. It is the same as companies that have boards without scientists or engineers on them. I really think that every sector of society should examine itself and say: we should be encouraging engineers to come into our world—the legal world, the financial world, whatever world it is. Government should be showing leadership on that. Instead of saying we should be able to identify how many engineers there are in the Civil Service, we should have a campaign to encourage people with engineering degrees to come into the Civil Service, go on the fast track and become the Permanent Secretaries of the future.

Q28 Mr Cawsey: You think it is a mixture of needing specialists for the special tasks but also policy generalists who are trained in engineering as well?

Professor Hall: Absolutely, and Government should be showing leadership in this. It would be better for the Government and it would be better for the country, I believe. If we do not do things like this at the highest level, we will never have enough engineers.

Professor Kelly: I want to cut this same question in two slightly different ways. The particular aspect of my job that I am most pleased about and the way it works in the Department is that I am one of something called the Analytical Quartet: the Chief Scientist, the Chief Economist, the Chief Social Scientist and the Chief Statistician. We meet pretty regularly to review the research profile. Until that was formed about a year ago, my knowledge of what was going on in the research agenda was more sketchy. I would like to report that. The other important matter is that it is one thing to get young engineers in. I have a particular task at the moment where I am about to second somebody from one of the major engineering consultancies for a short time to do a piece of work. This will only be for three months. I can see the advantage to both sides if major firms like Arups or WS Atkins were to second one of their engineers for a period of two or three years at a pretty senior level. The reason is that they will bring the outside experience in, but also they can go back to their parent organisation as the person with the experience of working within government. I know that DTI in its form used to do that; I have not checked whether it still does it regularly. In the 1980s when I worked for GEC I was regularly inside the DTI and talking to engineers who were on secondment from other firms.

Professor Fisk: May I reinforce that point? My own inclination would be to close the science fast stream altogether. It does not do any good and it enables the normal fast stream into the Civil Service to get off the question of why it does not recruit quite so many scientists and engineers, despite the fact that they represent something like 30% of the boards of British companies. It would be much better to focus much more on bringing people in who do have some real applied engineering expertise into the service; that is to say, they have done something, which is very much Professor Kelly's point of the added value of the engineer. That is in the weakest part of the Civil Service human resources exercise, which is bringing people mid-career into the service. Agencies have been rather better at it. If I were looking at an area that would really get engineering expertise back in, it is crucial that it is not just that they have been through mine, Professor Kelly's or Professor Hall's courses; it is that they have done some things in the real world and have an inclination of the risks and uncertainties that you need to manage in real projects. That comes, it seems to me, in your early 30s, and that is the entry point that is quite difficult at the moment, particularly in central departments.

Q29 Mr Cawsey: I was going to ask in this batch of questions about why do only three government departments use the fast stream track but you are saying perhaps that is not the best way of doing it anyway.
Professor Fisk: In my experience, those young people try to get themselves transferred to the normal fast stream as fast as possible because otherwise they walk in with a funny mark on their head for most of their Civil Service career.
Professor Hall: I was talking about the normal fast track.

Q30 Chairman: Out of interest, can I ask Michael and David: did you sit on the board of the department?
Professor Kelly: I do not. In fact I report to one Director General, so I am one further down from the Permanent Secretary, i.e. at Director Level.

Q31 Chairman: David, did you sit on the board when you were there?
Professor Fisk: No, and I think Chief Scientists who sit on the board traditionally have quite a large expenditure programme responsibility. So the Chief Scientist in Defra in the past had a responsibility for about 2000 people within the overall Defra network and therefore was a quite legitimate board member. Personally, one had contact with all board members, so I did not find the board meetings particularly added value. I tabled maybe two or three papers a year on issues relating to the research programme.

Q32 Chairman: Would you have wanted to be on the board?
Professor Kelly: I am on the board of an electronics company and I have been on other boards and I feel I would have things to say in those meetings that I would not get an opportunity or sight of doing.

Q33 Mr Cawsey: Finally from me, over the years the Civil Service has moved more and more away from in-house expertise to buying it in through consultancy as and when it is needed. Is there a danger in all of that that we are going to get to a point where we have such a scarce resource within the Civil Service that we cannot make intelligent decisions about the consultancies we need and what we need to commission?
Professor Kelly: Absolutely and I think the other point is the following. If we do retain consultants to ensure the integrity of the legacy, we are going to have to have another group of consultants to come in and peer review what they are doing. There has to be an element of internal "stand up and take personal responsibility". If something went wrong with one of these, there would be a political responsibility but where would the professional responsibility be? I do not think there is anybody in the Department who would be capable of taking that responsibility.

Q34 Mr Boswell: I have just a small point to Michael Kelly. You said, and I think it was a throw-away line, that if you have one lot of consultants you would need another lot to peer-review them. What about the peer review of your in-house consultants on the grounds that if you have people in-house, your in-house staff, they clearly would need to stand up intellectually. How do you configure that or how should you configure that?
Professor Kelly: There are a number of reviews for handling that, in particular the Government Office for Science did a review of the Department and made a number of recommendations that are due back some time this year.

Q35 Mr Boswell: That would draw on outside expertise?
Professor Kelly: Yes. A couple of people are from other departments and the majority of the people were lay in the sense of not being insiders.

Q36 Chairman: Professor Fisk, I am confused with the answer you gave to Ian Cawsey earlier about fast tract scientific Civil Service. In an earlier reincarnation we made that very strong suggestion that we should bring back a scientific Civil Service. Could you answer briefly how you would incentivise engineering within the Civil Service if you do not in fact have a dedicated stream of engineers coming through? How would you do that?
Professor Fisk: This is just a personal view. My impression is that engineers are just really attracted to very interesting projects.

Q37 Chairman: And the Civil Service is not?
Professor Fisk: If the Civil Service were open to some of the very interesting projects the public sector has, I think at competitive salaries, you would get that process. I raise in my paper that one or two of the Civil Service reforms have by accident made it extremely hard to recruit people at that middle to senior consultant level because it has tended to move into the Senior Civil Service, which has other definitions for its competency. My own view is that that would not be a problem if the price was right and the projects are interesting. There is no doubt at all that the public service is buying more complex, larger engineering than it has ever bought in its life, so I do not think there is any issue about it being

boring work in the Civil Service but the recruitment opportunities are not there and probably not at the competitive price to the consultants,

Q38 Chairman: What is the golden or silver bullet which would attract more engineers into the Civil Service at all levels?
Professor Kelly: I do not know that there is a silver bullet. I would endorse that view.

Q39 Ian Stewart: Professor Fisk, you started to allude to other models of relationship between engineering and government from outside the UK. Professor Hall, when you and I had an exchange earlier, I was trying to tease out where the responsibly lay for the lack of a good relationship between engineering and government in this country. Is there a model, one model, that we could consider adopting in this country, be it that of America or any other country?
Professor Fisk: My belief is that just importing models will never quite work because the public service in each country has an enormous number of distinctive features. There are scorecard ticks that I would notice in other countries that are not here. I would score France up very high in the sense that its basic engineering education is far superior to the UK. People leave French engineering schools able to run companies the day they leave, not absolutely packed with five years learning of technology.

Q40 Mr Boswell: Those are not simply engineering skills; those are business skills.
Professor Fisk: No, they are managerial skills. I have French interns and one of them made the rum remark that he thought it was rather quaint to come to a university to learn engineering, because clearly if you are the elite in France you go to the Ecole Nationale and have a very wide spectrum of things you do. That is a rather different model. As I made the point in the evidence, in some cases we do not really have the re-training you would need from someone who had been a consulting engineer to work effectively in the public service. The one I still would press, though, is that, given that this Committee very often rightly points to the United States as a marker for a well-focused technological nation, we should scorecard ourselves against how the US runs some of its projects. It would be very normal to talk to a US policymaker who really knew the subject. Someone from the satellite industry remarked to me that you can easily meet a UK general who has the leadership and charisma to get you to Moscow but, unlike the United States, it would probably never be a three star general who opened the conference of the Institute of Electrical Engineers. It is just simply a different view about the core competence in the system.

Q41 Ian Stewart: Can I press Professor Hall a bit more on this? The system that Professor Fisk has just described is almost an informal voluntary relationship between engineering and government, but in America there is a constitutional link. Would you be in favour of that?
Professor Hall: I was going to raise that. There are two things. I am very interested in the constitutional link with the national academies. Clearly there is not a straight yes or no to that. I really think that in this country we should review the relationship between government and, let us say, the Royal Society and the Royal Academy of Engineering in the light of what happens internationally. Ours was set up many years ago and we do not have a formal constitution. We should look at that relationship. The academies know where the expertise is and can point to the institutions that have the members who are the experts. Because the spotlight is on America and we all know a lot more about American politics than we did four years ago, I am fascinated by how they select their governments. They do not have a permanent civil service like we do but they do bring in experts from academia on secondment to run departments. We are not going to do it in the same way but we should review the way that we use the academics. The latest CST report, and I have to plug it, was called for by John Denham on the relationship between how government can get better advice from its academics and visa versa, how the academics can help the government more. I would like this Committee to pick and recommend that we really put the spotlight on that.

Q42 Chairman: We actually did that in a previous report, which was *Scientific Advice in Government*. We recommended that the Government should look at the way in which it uses the learned societies. We were ahead of the CST and we plug our report.
Professor Hall: We were asked by John Denham to do this. It is interesting in the context of engineering and now we know a lot more about it.

Q43 Ian Stewart: Moving to a different area, how can we encourage career flexibility between the public and private sector and should we be doing that?
Professor Kelly: That is an interesting question. I have been in and out. This is my third stint at Cambridge and I am wondering whether I should take a break and then have a fourth one, if they will have me back a fourth time. The times when I moved were times before I was married, so I had no other person to consider. When I have talked to people about this, their concerns have been about pension rights, the mechanisms and those basic things. I find myself in almost every environment, whether I am on other board of Laird or at a meeting in Cambridge or here, calling on all of the different experiences. The advice I can give is a synthesis of all those. Part of the reason for enjoying this job is that it is adding another range of experience for whatever I do next. The breadth is important.

Q44 Ian Stewart: How can we encourage that flexibility then?
Professor Kelly: I think you will have to go back to these mechanisms. Even inside a university, promotion from Reader to Professor has a series of milestones associated with it, which would then be stretched by somebody coming out at three years

to do something. For example, I always have a go about the nature of the research assessment exercise for engineering which puts four academic papers on a pedestal, whereas if somebody actually produces the turnaround of a company down the road and makes 0.1% of its GDP, that is a far more important engineering contribution than four technical papers. It is a systemic thing. I do not think there is one fiat that would then result in people going in and out. I have always encouraged young academics to stay off permanent jobs and on soft money for as long as possible because it gives them the flexibility to build up a kind of cadre of research capability and they can then do their teaching if they come in in their mid-30s. A lot of those people then have the confidence to move out before they are 40, and so on.

Professor Fisk: In my evidence I reminded the Committee that back in the Sixties, in fact post-war, there was a class of civil servants called Unestablished, which had a transferrable pension scheme; people moved in and out of academia and the Civil Service. I think it disappeared about 1972 or 1973, which is a great pity because it was part of the flexibility which was intended to operate after the War when there was a very close relationship with some of British industry and the public process. So we have had it before but we have just lost it, which I think is a tragedy. Universities are not a bad example, if one is thinking of engineering departments. We as academics spend only a small amount of time in industry, so we have visiting professors who spend most of their time in industry and who come and teach our students and help the design classes. We have developed a personal HR policy that works with them in a very flexible way; otherwise we would be open to a similar criticism that we have been academics all our life. It is plausible to do it, but it does require a response to a fierce recommendation by the Committee because at the moment the structures are very weak. As I think was pointed out, if you look at the National School of Government, it does not actually have any courses that would enable an engineer to be trained up to work in the public service. Its curriculum thinks some economists might come in, so there is clearly some flexibility in some areas and disciplines, but it does not even think that you might need engineering expertise to be trained to work in the public service in the sort of class the Committee has been considering.

Q45 Chairman: This is getting more depressing by the minute.

Professor Hall: Might I mention one very quick thing that we have not mentioned in this context. This Government has put money into the entrepreneurship side of universities. Many of us who are practising academics are involved in start-up companies and spin-outs as a result of that. You are never going to get a huge return to the university from that but the country can get a good return and it can inspire the academics. That is an important area.

Q46 Mr Boswell: My apologies for being late but I am trying to distil what I have heard. I suppose the clearest message I am getting from you, but please confirm or deny this, is that there is no single model; there is no advisory committee; there is no necessary professional qualification you could impart, no silver bullet to take the trick about what I think we all feel is a stand-off between engineering and government or an inefficiency in its use. If you look at it the other way round, is there an accountability issue that can be taken forward? I think you said, Professor Fisk, that some departments are winging it at some stage—we have all as politicians done it, dare I say. Is there a way in effect of centrally being able to work out, however the modalities are achieved, that the end result is achievable?

Professor Fisk: In my evidence I come to the conclusion that one had to explain, if there were not very many engineers, why there was still an economics class and a legal class in the Civil Service. My conclusion is that because essentially the external world holds departments more tightly accountable for the quality of legal advice that departments use in going to the courts. The Treasury was well stocked with economists who can challenge the economics of departments. Professor Hall was indicating that the number of bodies in the body politic that can challenge what is going on in the engineering process is at the moment slightly weakened. If they were stronger and more critical, the consequence would be that the Civil Service, which is a very clever animal and allocates its resources according to its pressures, would solve all the problems that we have been wrestling with today. At the moment, if you were just looking at priorities on the Permanent Secretary's list of problems, where was it that everyone felt challenged on their engineering from the outside world? They were challenged on their press office, on their legal advice, their economics, but practically it turned out that all their advisers were just offering advice on engineering issues, which is not quite the same as challenging, "Are you really sure?" For example, Professor Kelly said earlier, "Are you really sure that you have done the sums?"

Q47 Mr Boswell: That is a common view of the Treasury. As a final question, I ought perhaps to have declared an interest as somebody who was taken into the Civil Service in mid-career to sort something out but not, I hasten to say, from an engineering backboard and I have a daughter who is a senior legal civil servant. We are familiar with the expertise. We identified pensions as being a major problem in the flexibility issue. There are two other areas. The first is the management ability because people, as they get up to, say, Grade 7 and Grade 5, are starting to do management jobs. Is that something which is going to hold back engineers or are they people who are rather good at management? Finally, is there a wider cultural issue? It was no accident perhaps that the two persons I mention on my side are both non-engineers but would we fit in more comfortably than engineers trying to do a comparable and equally responsible job?

Professor Hall: Being an engineer does not mean you cannot be a manager. I led a huge department with a £24 million budget and I am an engineer. It is just like any other profession; some people are never good at management and some people are. What people say about engineers is dreadful—you are stuck with greasy dirty hands in this geeky world. We are not. I am not a geek and my hands are very clean.

Professor Kelly: Could I reinforce that? A couple of years ago it was the case that the largest single discipline of vice chancellors in this country was engineering. It comes back to the distinction between a scientist and an engineer. Any engineer worth his/her salt has managed a complicated programme somewhere along the way. It is one of the preconditions for even consideration to be a Fellow of the Academy: what is the big project you have seen through? When it comes to management, there are short courses for civil servants on how to manage but even the management that goes on inside a department of something going on outside tends to be at arm's length and comes back to the point that David made earlier, that as long as the finances are right and there is a good line to put against each bullet point in the milestones to the project, that is it. For somebody to get up there and say, "This is going awry", or "this is going off the tracks or this will not work at some point", engineers are past masters at that.

Chairman: On that note, we will bring to an end this first session. May I thank Professor Fisk, Professor Kelly and Professor Hall. You have been an absolutely splendid panel this morning and given us great food for thought and we thank you very much indeed for your contributions.

Witnesses: **Lord Broers**, a Member of the House of Lords, former President of the Royal Academy of Engineering, and **Professor Christopher Snowden**, Vice-Chancellor and Chief Executive, University of Surrey, representing the Royal Academy of Engineering and the engineering institutions, gave evidence.

Q48 Chairman: May I welcome our second panel this morning and welcome to the Committee Professor the Lord Broers, former Chairman of the House of Lords Science and Technology Committee and former President of the Royal Academy of Engineering. I presume you were delighted to hear the last comments as former Vice Chancellor of Cambridge University. May I welcome Professor Christopher Snowden, the Vice Chancellor and Chief Executive of the University of Surrey and President Elect of the Institution of Engineering and Technology. Thank you both very much for your presence this morning. Could I start with you, Professor Snowden? We had a discussion earlier this morning about the distinction between engineering and science. Are they two sides of the same coin or do you make a specific distinction?

Professor Snowden: I think there are differences. Obviously there are areas of overlap. Putting it simply, in my own mind engineering in a sense is the appliance of science. You obviously have to have a sound knowledge of the science to apply it. As we heard earlier, engineering nowadays has a very far-reaching influence. In my own mind, for example, you have to have an appreciation of the socio-economics of what you are doing to be a fully fledged engineer. Following on from some of the points that were made earlier, engineers are well placed today to be businessmen. I am an engineer by profession and I have been a chief executive of a multinational company as well as an academic. This was based on the discipline I learnt from my early days and training as a student. We also heard that the position of Chartered Engineer and the rationale for professional engineering is well placed if we want to have reliance on a trusted source of knowledge. To round out the answer, engineering, in a sense, as I say, is the application but also the extension into the real world to science.

Q49 Chairman: Lord Broers, the Royal Academy in its evidence made a clear distinction between the scientist and the engineer in terms that Government should recognise that these are different disciplines. Do you support that?

Lord Broers: No, I do not really. You have to remember that I am sitting here representing nobody but myself. I think there is a strong overlap and that people move from being engineers to being scientists and back again. Of course I spent my working career in industry in the United States and there we did that all the time. We would even be both scientists and engineers almost simultaneously. I managed large projects during the day and in the evening I looked at viruses in the scanning electron microscope that I had built. I think they overlap. It depends how far down you take engineering. The difference in this country is that engineering to the man and woman in the street represents a huge spectrum, a much broader spectrum of activity than it does in the United States or China or anywhere I have been. I happen to be a member of the United States' and the Chinese Academies as well as the Australian one. The Australians are similar to us here. Their technicians are called engineers. This is the big problem in this country, so that the upper grade of engineer in my mind and the research engineer looks very much like the scientist a lot of the time; they just have to know more than the scientists. They have to know the economics and the manufacturability of things as well as just the science.

Q50 Chairman: You have just heard, Lord Broers, because you were in the room at the time, Professor Hall make an impassioned plea for engineers to be recognised as, if you like, a chief engineer within

departments alongside Chief Scientific Advisers, but you seem to be saying that these are opposite sides of the same coin and that therefore we do not need to make that distinction.
Lord Broers: I think that is the case but I would have approached this problem from a different point of view. I would have asked the question: is it necessary to have a Chief Scientist alongside the Chief Engineer?

Q51 Chairman: What is your answer?
Lord Broers: Probably not in many instances.

Q52 Chairman: So you would have a Chief Engineer?
Lord Broers: Yes.

Q53 Chairman: Would you settle for a Chief Scientific and Engineering Adviser?
Lord Broers: I would settle for a Chief Engineering and Scientific Adviser.

Q54 Chairman: Professor Snowden, what do engineers offer policy makers that scientists do not?
Professor Snowden: I think that would be a broader base of advice. As I mentioned earlier, to be an engineer in the first place, you have to have a clear understanding of the science behind the issues you are addressing. At the same time, you also have to understand (a) how it is applied, (b) how it would be implemented, so that has cost implications, reliability implications and it also has, as I said earlier, socio-economic implications. For example, if you look at transport planning, or as we were hearing earlier in terms of information technology, it is very tempting always to think of engineering in terms of either civil engineering or mechanical engineering in a very limited fashion, but in fact, as Lord Broers was saying, it is a very broad discipline nowadays.

Q55 Chairman: The Royal Academy of Engineering, of which Lord Broers was a Past President and now disassociates himself from policy, have made it clear that they feel that there ought to be a separate Chief Engineering Adviser to Government. First of all, do you agree with that position?
Professor Snowden: Yes, I do. I am actually the Vice President of the Royal Academy of Engineering and I chair their Engineering Policy Group, so I suppose you would expect me to support that. I am happy to explain this. If we look across all of the government departments, it is quite clear that a chief engineer would be more suitable, for example, in some of those departments than a chief scientist, so, for example, in DBERR, I would suggest, a chief engineer would fit the bill very well, and perhaps a chief scientist may be more appropriate in DIUS, for example, so it is really an extension of what we were agreeing a few minutes ago, that it is fitting the right person to the right role.

Q56 Chairman: Because that was going to be my next question, as to whether in fact there would then be, if you like, an element of competition between the scientists and the engineers because there is clearly some competition between the Government's Chief Scientific Adviser and departmental scientific advisers, so your solution would be quite a neat one.
Professor Snowden: Well, I would recommend that, I think that would work very well. I would like to add that I have been in a company in the United States, I was a chief scientist there, and I actually worked in parallel with their chief engineer and, I have to say, we did not see the differences there. Similarly, in my own companies, I have had similar roles, so I do not see them as competitive, I see them as complementary.
Lord Broers: I would agree with all of that. To correct perhaps what I said before, I do not necessarily disagree with the Academy's policy on these things, but I think we must be flexible in looking at this and realise the breadth of a top engineer because a top engineer has to know as much science as others. I have watched some very good scientists in effect become engineers before they can apply what they do and they are not always aware of what they are doing and it is not necessary to adopt the label necessarily, but a good physicist who wants to apply his ideas has to learn about costs and manufacturability and reliability, et cetera; it is the big lesson that one has when one goes into industry. I would add a little because of the earlier conversations that we had or you had about taking people into the Civil Service and so on as engineers. Now, I do not think engineers are engineers until they have been out there doing something for many years, so to taking graduate engineers in, I do not think, would solve your problem and I think that is what Professor Kelly and others were saying. You need engineers to actually do something before they are taken on as advisers.

Q57 Ian Stewart: One of the things the Committee has come to realise is that in the evidence given there are claims that, for example, engineers were not consulted properly in, say, initiatives like eco-towns. Do you have any examples of where major government initiatives have either failed or not been as strong as they could have been because of not taking advice from engineers?
Professor Snowden: I will happily talk through one example. In 2000–01, I was involved with the National Advisory Group in relation to semiconductor technologies in the UK and, after some time, the policy was delivered and it was suggested that many of these technologies were not regarded as strategic, and that has had a significant impact on, I have to say, investment by companies in the UK, and I was actually leading a company at that time. Subsequently, by 2005, that view had been completely reversed and in fact, if you look at the Defence Technology Strategy document today, it cites a number of highly strategic technologies, most of which no longer are present in the UK and that is because policy had a significant impact on the way industry reacted to government strategies.

Q58 Ian Stewart: Is that the example of taking advice too late or not taking advice at all?

Professor Snowden: It was not sought widely in the first place and we tried strongly to influence it, including senior industrialists, but our views were not taken on board.

Q59 Ian Stewart: That is interesting, so thank you for that. Now, the evidence that we have received claims that estimates about the contribution of non-fossil fuel sources to energy supply and carbon emissions have been unrealistic. How damaging have those estimates been and can you give us any idea of what the real figures should be?
Lord Broers: I think that that is something where it would be a good idea to turn to the Royal Academy of Engineering for a detailed report. I raised this in the Lords only yesterday or the day before, that the new commitment to 25 gigawatts of offshore wind by 2020 is, to say the least, going to be a massive, if not impossible, challenge. It is going to mean installing 10 large turbines a day every day that you can practise in the North Sea, which is about 60 days a year, until 2020, 10 a day every day until 2020, and there is one barge at the moment that is capable of carrying, and erecting, one of those towers, so you do not gain engineers' confidence by having a strategy that just states that there is going to be 25 gigawatts of offshore wind in the North Sea.

Q60 Chairman: Is this a clear case though, going back to the earlier panel, of engineers not being there at board level when these decisions are made?
Lord Broers: Yes, well, I am afraid, Chairman, even I am ignorant of quite where these decisions are made. My experience, having chaired the Science and Technology Committee, is that we are always trying to bring back decisions that were made somewhere, but I was never quite sure where, to bring sanity back to the case. In fact, as you know in your Committee, my Committee, when I chaired it, was quite effective in many instances in bringing things back by taking the right evidence from the right people and establishing what is the sensible strategy, but I am not sure where these strategies originate. They are made somewhere deep inside departments, I suppose.
Chairman: I think what we are trying to do with this whole inquiry is really to try to add value to the government process by saying, "Why should engineering actually appear within it?" That is really sort of the core, to make sure that in future the sorts of decisions which you have just been talking about to Ian Stewart do have in fact that engineering scrutiny at the very highest level before in fact they get embedded into policy.

Q61 Ian Stewart: Before you answer that, if I can just add to the Chairman's point, are you really saying not that the scientific approach is wrong, but that it is the lack of the doing element that engineers have that makes these estimates wrong in terms of that? Is that what you are really saying?
Professor Snowden: Absolutely, because you have got a classic example here of policy delivery being expected to be delivered by the engineers, but not being involved in the policy development because, as you have just heard and as you can imagine, if the reality of the resources the UK has had been taken on board in the policy development, we would have had a more realistic policy produced in the first place. Engineers so often have to come along and sort of represent the fix afterwards, and you will probably see that that is simply not a practical proposition, this particular example, so it would have been much wiser to consider that policy development in the first place because the knock-on effects are substantial. We hear about an 80% reduction in the carbon target, well, that relies on the delivery of, as you can hear, potentially undeliverable elements of renewable energy.

Q62 Ian Stewart: Okay, so let me put you both on the spot then about these eco-towns and the way that has developed. If engineers had been consulted in the first place, would we be now talking about implementing eco-towns?
Professor Snowden: We might be implementing them in a different way. I am well aware of one eco-town site that, for example, does not have the transport infrastructure to connect it to the economy it would have to serve, so I would suggest that that is a fairly serious problem in terms of the rationale for the eco-town.
Lord Broers: Yes, vast housing proposals have been made that I have noted particularly while we were conducting an inquiry into water management only to find that all of these housing proposals had been made without any consideration of water supply. Engineers would have stopped that immediately.

Q63 Ian Stewart: So you are actually arguing that engineers have almost a unique perspective on risk assessment?
Lord Broers: Well, it is their discipline. I can recall myself doing a PhD at Cambridge and building scanning microscopes and making some of the smallest structures in the world with these things and rushing off to IBM in America, thinking I was going to revolutionise the world. I spent about six to eight months discovering that my techniques were hopelessly expensive and would be impractical in a manufacturing environment, and that was a very cold shower, as it were, but you learn that when you are an engineer because you have to deliver, so you start thinking that way. You have got all the ideas from science, but your first thought is, "Is it really practical? How could we implement it? What risk can we take that we can solve that problem?" and that is our discipline.

Q64 Chairman: Can I just probe you on the issue of advice to the Government because the Government, in its evidence to us, cited the Defence Science Advisory Council as an example of good practice as to where in fact it gets its advice in that area. The Academy and indeed some of the institutions have highlighted this as a major problem. How do we get such major discrepancies between the learned societies and professional bodies and the Government? Professor Snowden, what is your assessment?

Professor Snowden: Well, I am a member of DSAC, so I can comment actually having worked there.

Q65 Chairman: It was the reason for the question.
Professor Snowden: Well-placed! Let me say straightaway that I think the starting point is a question of what role the consultant or the membership, for example, of DSAC has. For example, I have reviewed reports and processes that have been involved in the Ministry of Defence and have been able to offer obviously strong technical advice, but you have got to bear in mind that that is an after-event type of process rather than being involved at the initiation of projects. I will give another example, that wide use is made of consultants, as we have heard, and they are used on both short-term and long-term bases. I think the rationale for short-term consultants is well-founded, but in GCHQ, for example, as a matter of policy, consultants have to be used on a long-term basis to satisfy many of the engineering and scientific skills that there are now. I have to say, I would challenge the rationale for that because surely, if it is a long-term need, that ought to be part of the core know-how within GCHQ, for example, so I think the problem we are looking at here is one of where the advice comes. Turning specifically to a point you made about, for example, the roles of the Royal Academy and the institutions, we are quite often consulted very far down the process. In one particular case this year, we had 48 hours' notice to provide a consultation on a paper on energy, which, as you can probably appreciate, provides a very limited ability to usefully input to that process and it is far too far down the process. The key point I would make is that engineering input needs to be in the developmental and formulation phase of the policies and strategies, not as an afterthought or in the implementation phase.

Q66 Chairman: But, unless the Government is an intelligent customer and it actually has at board level or certainly at the very highest level that sort of advice, that critical advice, then, no matter how many consultants you have thereafter, if you have made an initial policy decision which is flawed, you are living with it thereafter, are you not?
Professor Snowden: You may be.

Q67 Chairman: Well, if that is obvious to me and it is obvious to you, why is it not obvious to the Government?
Professor Snowden: Because they have not got the advice in the first place or the training. It is a serious point, and I will give an example. You may wonder why these things arise, but, if you look at the makeup in other countries of governments, you will find that engineers and scientists populate a large number of these places. The President of China himself is actually an engineer, so is his Vice President. They are not practising engineers today obviously, but they do have an appreciation of the skill-set. Now, I am not suggesting everybody needs to be engineers, but it is useful to have some content of that from the point of view of having input at that early stage.

Q68 Chairman: Lord Broers, you would support the idea that engineers should at least be on the board of most departments?
Lord Broers: Absolutely; engineers are essential to all things in life. I have just participated in this study with the National Academy of Engineering in the States on the grand challenges for engineers at the beginning of this century and, when you look at this, there are just 14 challenges which are identified, but three of them are related to medicine and deeply embedded in societal needs, there are the energy ones of course, the infrastructure, and everywhere you look engineers are determining how we live and whether or not we will destroy the planet, if the truth be known, so, if they are not central to decision making we are in a hopeless position, as far as I can see.

Q69 Dr Iddon: During this inquiry, we have obviously picked up a great deal of criticism from the engineering institutions and the engineers themselves that their voice is not being heard, and that theme has run through this morning's sessions as well. However, is this not a two-way process? What are the engineers doing to make sure their voices are heard?
Professor Snowden: Well, it obviously is a two-way process, that is the nature of communication, but, I suppose I would have to say, someone would have to be listening to be heard. What I mean by that is that it is rather like the voice of industry is often not heard by the Government, it is said, and that is because there is a question of whether you understand what they are saying to you. For example, I think the Royal Academy of Engineering and the institutions are very willing to work with the Government, in fact very keen to do so, and I think often, when their views are sought, as I said earlier, they are sought far too late, so the influence they can have is quite finite. If their views were sought very early on in the process, I think the type of input and the influence would be greater and, therefore, both the Academy and the institutions would feel that their views were more highly valued. Similarly, I would suggest that the Government would equally feel that their views were of more use to them because they are able to inform the process on policy development much earlier on so that perhaps the right decision will be made when an inappropriate decision would otherwise have been made.
Lord Broers: Let me take a broad view of this. To me, engineering is an effect rather than a cause, and I will explain what I mean by that. We have not been good in the last couple of decades in creating large engineering-based technology companies. We have been getting quite good at forming small companies, and universities are improving in their capability to be innovative and to look at it that way and create small companies, but we have not been good at growing companies. Our economy has depended on the financial world and other things that do not involve engineering, so engineers have been declining in their volume and presence in society just by the nature of British society. A lot of our large companies have been shrinking rather than growing,

they are becoming global, and a lot of the good engineering maybe has been going overseas, so engineers are not of influence just because there are not so many of them and they have not been so important to our economy. Now, I think that is a plain fact and, if one could fix the problem of growing larger engineering-based industries, that problem might mend itself. When you look at those two buildings, those of the Mechanical Engineers and the Civil Engineers, on Birdcage Walk, built at the turn of the century and in the post-Victorian age, you realise that engineers did not have any problem being heard, and it was not just because of the personality of a few of them or that they had very loud voices, but they were very important in the British economy and the scene and Engineering has been declining, so, if one fixed that problem, the voice of engineering would re-emerge. I think for engineers to shout loud from their diminished position is just not effective.

Q70 Dr Iddon: But there are still over 40 engineering institutions. How on earth can the Government decide where to go? With science, it goes to the Royal Society and, I suppose, with engineering, it goes to the Royal Academy of Engineering first, does it, or does it go to the individual institutions? There are just so many of them. Do you think that is a good thing or a bad thing, and do you think some rationalisation of the institutions is now necessary?
Professor Snowden: Rationalisation is occurring. In fact, as you have heard, I am President-elect of an institution that actually has absorbed together three other institutions and changed its name to reflect the mergers. I have to say, science is not so different from engineering in that sense because you have the Royal Society and the Royal Academy of Engineering, you have the Institute of Physics and then you obviously have the chemists and the mathematicians and there are many, many behind them too, so these are membership organisations and, quite naturally, people who work in a very similar aspect of the profession will wish to associate through membership organisations. Clearly, the united voice of engineering is through the Royal Academy of Engineering just as the Royal Society represents the peak of the academy for science. Again as Lord Broers says, I am also a Fellow of the Royal Society, so the overlap between engineering and science is clear too. To provide you with a simple answer, I think the starting point would be to go to the Royal Academy of Engineering who could also then quite easily liaise with the relevant institutions for the expertise that the Government would need. It would be a very straightforward thing to do.

Q71 Chairman: Lord Broers, your analysis as to why in fact the engineering voice is not heard as loudly as it should be and your analysis in terms of the engineering community in terms of large companies, that it has been declining with an emphasis on financial services, et cetera, in terms of running the company, the same could be said about science, but the scientists do have a loud voice. Is that largely as a result of people like Bob May and David King that have shouted from the rooftops? Do we need somebody of that ilk to really make the case for engineers both within the Government and within the country?
Lord Broers: Well, the engineers live in a different world. For engineering to practise effectively, the Government does not fund it, industry funds it. It is part of a big industrial base. Pure science relies on the Government for funding, particularly today. There was a day when industry funded more science, but, even in America, that tends to have disappeared today, so it is a different world, so the scientists have always had to shout very loudly in government circles, but what is an engineer going to do? Government is not going to suddenly start funding big engineering projects. It is up to industry to do that, and I think that is my point, so it is no good our standing up there and saying, "Look, we must be the centre of society. We're great" and telling the Government that. Government can, quite rightly, turn around and say, "Well, that's not really our business, that's industry's business", and quite what the Government can do is what I struggle with all the time. I came back to this country in 1984 when we had just had the Alvey Committee and I was asked to review what had happened in the Alvey Committee, and then there was the Bide Committee that followed that. I was in effect witnessing the death of the indigenous microelectronics industry at that time. Now, there was one thing that the Government could have done there. Government could have done what Ronald Reagan did in the States which was to give encouragement and a small amount of money so that a central research establishment could be set up that the semiconductor companies could cluster around. I wrote to Margaret Thatcher about this and I got a letter back from Eric Forth, saying that that was nothing to do with the Government, that it was strictly a matter for industry. Probably they were right, but there was an intermediate ground, and I think it is making my point. Subsequently whole sectors of industry died and were dragged down because they did not have electronics. For example, we no longer have a really indigenous car industry. It was sort of a fatal decision, but the fact is that it has happened and we now lack that engineering presence in industry.

Q72 Chairman: Much as I hate to disagree with you, could I perhaps throw in another point here, that, if you actually look at the huge infrastructure projects which are being carried out in the UK, if you look at the Olympics, if you look at Crossrail, if you look at the procurement budget of the UK Government, a significant element of it is actually involving engineers in massive construction projects, which dwarfs what we are actually putting into basic science. Surely, that is a good enough advert to say that we have to have engineers and engineers are very much at the heart of British society? We are spending more money now than we have ever done ever.

Lord Broers: Well, the civil engineers do quite well actually, and they are practising away and being very effective for the country in fact, but the range of engineering enterprises has narrowed down now so that my sort of industry has declined very much from what it was two decades ago.
Professor Snowden: If I can perhaps offer one thought on the Olympics—

Q73 Chairman: Will you be more enthusiastic?
Professor Snowden: Well, there is no question in my mind that often, when we talk about scientists, we are talking about engineers in terms of the public's vision of what actually happens, and the Olympics is a very good example. I would like to suggest that, if engineers had been more involved in the formative phase of what we were going to do for the Olympics and the Olympic site, we would have had a more realistic costing of it because I have talked to many senior civil engineers who have said that it could never have been done, what was originally suggested, so the point I am—

Q74 Ian Stewart: Maybe that is why you were not consulted!
Professor Snowden: You could be right, but the point I am trying to make is that it would still be a pretty good thing to know, I would have thought, before you knew this in detail. I did cite an example, and I agree with you, that in terms of the visibility of engineering projects, and Crossrail is another example, I would suggest to you that to compare what is happening in the UK with what is happening in other major OECD leading countries where engineering has a much higher profile, and I do not mean just in terms of the social respectability, but the impact it has on the economy, the government recognition of the role that engineering has in the economy is much stronger. Again, I am not just talking about the traditional areas of mechanical and civil engineering, I am talking about the information technology areas, I am talking about energy, I am talking about the environment, and these are engineering areas today and it will be engineers that offer the solutions to these areas, so I would like to suggest that it is exciting, but the Government has to reflect that excitement in the engineering element of it if we want young people to take this up and if we want to see the benefits of it.

Q75 Mr Cawsey: Well, let us try and finish off with a few next steps of where we might go from here then. This Committee obviously receives all sorts of recommendations all the time that people would like us to pass on to the Government, but, looking at the engineering community yourselves, what do you think the community could do to improve the status of engineering and the quality of engineering advice that goes to the Government?
Professor Snowden: You mean the engineering community?

Q76 Mr Cawsey: Yes.
Professor Snowden: Well, I think the engineering community is already poised to be able to do that and I would suggest that, for example, if the Government were to encourage chartered engineers to be present in their own departments, there would be greater uptake of chartered engineering. All of that is available to do today, the process is well-established, and in some of the aspects of engineering, and it is civil engineering we were just talking about, it is de facto, but it is not in other areas, and it is partly because there is no formal requirement for it. I will give you an example. If the Government were to require chartered engineers to be part of the formulation and development policy for information technology projects, I believe the projects themselves would be better and again you would be seeing more engineers coming through down that avenue. I think the Government will have a key role in this by not only, as I say, having a requirement for chartered engineers, but quite clearly expressing through all of their policies, not just through DIUS and through the schools the need for engineers, but to see it as a core capability.
Lord Broers: I think you have been talking about a lot of the things that can be done, and we go back to the beginning. I would advocate having chief engineers, and I think Professor Snowden's suggestion was very good, that DBERR should have a chief engineer, not a chief scientist, and perhaps DIUS a chief scientist, but, to get back to your remarks, Chairman, about scientists and their voice, it is quite obvious with Bob May and Dave King that they were chief scientists, there is not an engineer, and they had the megaphone for a start. Apart from my argument, which I still stand by, because engineering is a different part of things, I think that, if we got engineers with experience into departments at the origins, at the fountain where the decisions are made first, then we would not get into some of these problems and I think this will be a very practical way of going about solving this problem rather than trying to solve it from a status point of view, which I think is in many ways a lost cause. Engineers should be put in effective places where real decisions are made. The other thing I would say quite strongly, and a lot of people will not agree with me on this, but the Royal Academy of Engineering should be the place where the Government goes almost all the time on issues of engineering policy.

Q77 Chairman: But it does not.
Lord Broers: It does not, I know it does not.

Q78 Chairman: So why is the Royal Academy not shouting from the rooftops to make its presence felt?
Lord Broers: Well, it is a very difficult issue, as you understand. In the engineering community, there is a lot of competition from the institutions who want their voices heard as well. I would stick more by the American model wherein my discipline, the IEEE, which is a huge organisation, deals with the professional side of their subject, so they accredit people, they have conferences, they make sure their

subject is moving and they are not so much in the policy game. Government policy resides in that academy's building, it is where I was a few weeks ago, and there was just myself and two others representing Obama and McCain and we had a debate on where engineering sat in the United States. The engineers participating in this debate were in the academies, they were not diluted all over the place. The institutions saw their jobs as different. Here, we have a very confused issue, so the Royal Academy of Engineering, and I cannot speak off the record here, but the Royal Academy of Engineering has to tread very carefully because the institutions are very jealous of their ability to advise as well, so the result is that you get a whole lot of confusion and the Government, instead it turns to individuals, and obtains has personality-driven strategies, and some have been absolutely incredible where some major, and I will not name these—

Q79 Chairman: Do!

Lord Broers: Well, would you choose, in order to get a transport policy, the ex-CEO of British Airways? Is that the way to get a transport policy for the country? Surely, one should have gone to the Royal Academy of Engineering.

Q80 Mr Cawsey: But this is back to my whole point really of what can the engineering community do for themselves. Everything you have just described to me reminds me of a former life when I used to be involved in local education authorities and teachers were separated into several unions which all pathologically hated each other, but made no progress to resolve, and then I chaired a police authority where the Federation represented everybody up to the Chief Inspector, and it was a tremendously effective organisation because of that. Is this not a problem that you are creating for yourselves in your community because the Academy is just one of so many things, so do you not need to sort your own act out if you want to be influential with the Government?

Professor Snowden: Well, I have to say, I think there has been a lot of evolution. I think some of the conflict that you suggest actually is not present today. For example, my own institution, which represents 150,000 engineers, actually works very well with the Royal Academy and works well with the Engineering Technology Board, so this sense of competition is not there. I think that one of the problems is because the Government has not identified itself the sort of route it would like to work with. If you were to say, "Well, actually we're going to talk to the Royal Academy of Engineering and we're going to talk to the Royal Society and they will be our two avenues", then it is very easy for the Royal Academy of Engineering and the institutions to line up their ducks. Since different departments in government are very happy to go to different institutions, completely bypassing the Academy in the first place, needless to say, you are going to get this diversity of input.

Q81 Mr Cawsey: Yes, but the structure allows them to do that.

Professor Snowden: It happens in science too with the Institution of Physics and of Chemists. I am well aware of the fact that they are consulted in just the same pattern and it does not always go to the Royal Society there either, even though, I would absolutely agree, their voice is more strongly heard.

Lord Broers: If I can make a point here too, we must include the Academy of Medical Sciences in the medical world because very much of the future of engineering lies with medicine at the moment, and you see that in all major US universities now where they are forming departments of engineering in medicine and that is where the US has it right again. They have got the three academies and the research councils all sitting right in the middle of Washington, on Constitution Avenue, in the centre of it.

Chairman: Well, there is food for thought there. Could I thank you very, very much indeed, Professor Snowden and Professor Broers, for your excellent evidence this morning. Thank you very, very much indeed.

Written evidence

Memorandum 169

Submission from the Department for Innovation, Universities and Skills (DIUS)

Introductory Remarks

1. Engineering has a role across many areas of Government work, and will be critical to the success of a number of key challenges, such as mitigating climate change and security. Amongst other activities, Government engineers contribute to policy, provide capability to respond to emergencies, set standards, develop national and European legislation and provide an "intelligent customer" function for buying-in advice from industry.

2. Many, if not all, of the big challenges faced by Government will demand creative, flexible, multidisciplinary multi-agency approaches to tackle them effectively. Engineering disciplines and engineering approaches will clearly continue to have a crucial contribution to make. However, in determining the best way forward, it is probably most helpful not to consider science and engineering in traditional terms—as separate disciplines with discrete boundaries—but rather as a continuum of knowledge that can be used and applied with other relevant evidence to address future challenges.

3. The Government Chief Scientific Adviser (GCSA), supported by the Government Office for Science (GO-Science), works closely with departments, departmental Chief Scientific Advisers (DCSAs) and Heads of Scientific and Engineering Profession (HoSEPs) and with independent advisory bodies, such as the Council for Science and Technology (CST), the Royal Society and the Royal Academy of Engineering (RAEng). The aim is to ensure that Government policy decisions and delivery are supported by robust evidence and stand up to the challenges of credibility, reliability and objectivity. Consequently decisions makers can be confident that advice also stands up to these challenges, that engineers in Government are supported, and that the public are aware (and are in turn confident) about the engineering advice supporting the Government's work.

The Role and Effectiveness of the Government Office for Science and the Chief Scientific Advisers in Providing Engineering Advice Across Government and Communicating Issues Relating to Engineering in Government to the Public

The Government Chief Scientific Adviser and the Government Office for Science

4. The Government Chief Scientific Adviser (GCSA), Professor John Beddington, is responsible for advising the Prime Minister and Government on key science, engineering and technology issues affecting policy and delivery challenges. This is achieved through meetings with and advice to the Prime Minister, Secretaries of State, key Ministers, Cabinet Committees and through participation in strategic emergency planning and emergency response. He pays particular attention to issues that traverse departmental boundaries, engages international policy makers (including Devolved Administrations on non-devolved matters) and supports long-term strategic planning processes inside departments. The GCSA heads the Government Office for Science (GO-Science) and works in concert with the community of Departmental Chief Scientific Advisers (DCSAs),[1] the Director General of Science and Research in Department for Innovation, Universities and Skills (DIUS) and other heads of analytical professions. He also sets standards of good practice and quality assurance across Government and heads the Science and Engineering Profession in Government.

5. The issues on which the GCSA and GO-Science are involved cover many disciplines, from natural and physical sciences through engineering and technology to mathematics. For convenience, they are normally referred to collectively under the umbrella expression of "science". And, as far as advice into Government is concerned, science and engineering are treated as an integrated subject, where the analytical approaches from one discipline flow through to another in a continuum and within the context of the wider evidence base. A prime example of this is the new and increasingly important area of synthetic biology.

6. Moreover, from a policy or delivery perspective, even the traditionally separate engineering disciplines benefit from being considered from an integrated perspective, with most modern engineering challenges requiring a multidisciplinary engineering approach. Both plastic electronics and environmentally friendly buildings, for example, require input from many different engineering disciplines, as well as science and social research.

7. The roles and linkages that help embed scientific and engineering evidence into Government can be found across a wide range of policy documents and statements (see Annex 1).

[1] A significant proportion of these are engineers (see paragraph 11).

8. The Select Committee on Science and Technology heard evidence from the former GCSA, Sir David King, to inform its Report on Scientific Advice, Risk and Evidence Based Policy Making and received copies of the GCSA's revised Guidelines on Scientific Analysis in Policy Making (2005), which encompassed engineering within the general term of "science".

Departmental Chief Scientific Advisers

9. Departmental Chief Scientific Advisers (DCSAs) have direct access to Ministers and their own Departmental Boards to bring to bear science and engineering advice in wider Departmental policies, finance, and strategy. For example, a recent intervention by the Department for Transport's (DfT's) DCSA is proving successful with a very large rail project in making evidence of achieving performance targets more robust and revealing previously unknown issues.

10. DCSAs also provide professional leadership for the science and engineering personnel in their departments and Agencies—though in some cases the role of departmental Head of Science and Engineering Profession (HoSEP) is performed by another person—as well as supporting the intelligent customer function in Departments for science and engineering advice. For example, the Ministry of Defence's (MoD's) DCSA is a member of the Defence Council and the Defence Board, and attends the Defence Ministerial Committee by invitation; Chairs the Investment Approvals Board and the Research and Development (R&D) Board and is the UK Principal for the 1958 UK-US Mutual Defence Agreement.

11. Many issues are best tackled using a collaborative approach to generating a robust evidence base. Departmental Chief Scientific Advisers (DCSAs) work together under the leadership of the GCSA to support each other and to address and provide cross-cutting advice. The principal mechanisms for dealing with issues relating to science, engineering and technology are the Chief Scientific Advisers Committee (CSAC) and the Core Issues Group (CIG) of Chief Scientific Advisers. Representation on the committees includes both science and engineering—with four of the nine members of CIG having a background in engineering and three being Fellows of the Royal Academy of Engineering (FREng).[2]

Communicating issues relating to engineering in Government to the public

12. The GCSA and DCSAs communicate in specialist high-level fora and, as appropriate to the general public through mass media.

13. The Freedom of Information Act presumes openness and transparency in the publication of expert advice by departments. One of the ways in which the GCSA tests the effectiveness of this in relation to science and engineering is through his rolling programme of departmental Science Reviews, which look at (amongst other things) the publication, dissemination and debate of findings and results.

14. A key aspect of using engineering evidence and advice well in Government involves understanding, managing and communicating risk effectively. This is too often over-simplified, and scientific and engineering advisers, policy makers and those involved in engaging the citizen and the media need to be fully sensitive to the complexities involved, as well as ensuring that they have the best possible evidence base. The establishment of the Risk and Regulation Advisory Council in January 2008 was a key step forward in that respect, with the aim of a major change in policy-making culture in Government. The Better Regulation Commission's report *Public Risk—the Next Frontier for Better Regulation*[3] highlights the progress made in mature analysis, discussion and planning inside and outside Government of the management of risk, but it rightly points out that there is much further still to go.

15. On 18 July, DIUS launched a three-month public consultation on developing a new *Science and Society strategy* to realise the vision of a society that is excited by science (in its broadest sense), values its importance to our social and economic wellbeing, feels confident in its use, and supports a well-qualified, representative workforce. The participation of the engineering community was recognised as being essential to this process. Working closely with the main engineering institutions, the Royal Academy of Engineering (RAEng) is co-ordinating the UK engineering profession's response, which will help ensure that the resulting strategy reflects engineering appropriately and takes full account of the needs of the UK's engineering community.

Promoting Engineering

16. Last year, the Engineering and Technology Board and the RAEng jointly published the findings of the first national survey of public attitudes and perceptions towards engineering and engineers. The report revealed fundamental misconceptions of engineering among young people that could worsen the UK's shortfall in engineers, if it affects their future career choices.

[2] Professor Michael Kelly, Professor Mark Welland and Professor Sir Gordon Conway.
[3] *Public Risk—the Next Frontier for Better Regulation*, Better Regulation Commission, January 2008: http://archive.cabinetoffice.gov.uk/brc/upload/assets/www.brc.gov.uk/public_risk_report_070108.pdf.

17. To improve the perception of engineering, a large number of campaigns, projects and initiatives exist, particularly aimed young people. To provide coherence to these activities (some of which are discussed below), the engineering community has agreed to work together under the banner of the RAEng's Shape the Future campaign to improve the promotion, delivery and information systems that will provide better co-ordinated support for engineering and technology in schools and colleges.

STEMNET

18. DIUS is investing £19 million (2008–11) in STEMNET—the Science, Technology, Engineering and Mathematics Network, which aims to ensure that more young people in the UK make a choice to enter careers related to these subjects, and that future generations are properly informed about the science and technology that surrounds them.

Science and Engineering Ambassadors (SEAs)

19. An important strand of the Government's STEM policy is the successful and expanding Science and Engineering Ambassadors (SEAs) programme. Over 20,000 ambassadors—two thirds of whom are engineers—are acting as role models in schools, inspiring young people to study STEM subjects and pursue related careers.

Engagement with Engineering Development Trust GO4SET[4]

20. In 2007, the Engineering Skills Director of MoD's Defence Equipment and Support (DE&S) sponsored 10 schools in the Bath/Bristol area as part of the South West scheme. Engineering staff volunteered as mentors to promote careers in science, engineering and technology to young people through participation in a competitive project. Other staff provided interactive demonstrations of engineering principles, sustainable development and physics during school visits to Abbey Wood.

Engineers of the 21st Century Programme

21. Complementing the activities run under the Shape the Future framework, the Government is involved with various other initiatives to encourage young people. For example, the Department for Environment, Food and Rural Affairs (Defra) supports the Engineers of the 21st Century programme run by Forum for the Future.[5] The programme has been running for nine years and, within the programme, projects have been carried out looking at Higher Education for Engineers and the delivery of sustainable buildings and future challenges for the built environment. Defra also supported the establishment of the Chair of Sustainable Engineering at Cambridge.

The Use of Engineering Advice in Government Policy Making and Project Delivery, including Examples of Policy Decisions or Project Delivery that Have Been or Will Be Taken With or Without Engineering Advice

22. Engineering plays a significant part in policy and delivery across many areas of Government work, and will be critical to the success of a number of key challenges, such as mitigating climate change and security. A small sample of the wide-ranging use of engineering being made by Government is provided below.

Keeping Hostile Vehicles at Bay

23. Experts, including civil and structural engineers and materials scientists,at the Centre for the Protection of National Infrastructure (CPNI) are at the forefront of developing effective (and aesthetically-sensitive) countermeasures, in the form of protective security barrier systems, which can keep Vehicle Borne Improvised Explosive Devices at safer distances from critical assets.

24. Traditionally, protective security barriers, such as bollards, planters and gates, have required deep and/or wide structural foundations which have large cost and time implications for excavations and the relocation of underground utilities. CPNI has been working with industry and specialist advisors (such as the Transport Research Laboratory and MIRA Ltd) to push the boundaries of science and engineering to better understand the dynamic loadings on various types of barrier during vehicle impacts, to identify the thresholds of success/failure and to identify new materials and alternative construction methods that can better cope with both vehicle impact and explosion. This work has allowed systems to be engineered with

[4] An initiative involving students, engineers and companies in projects to stimulate the interest of young people in Science, Engineering and Technology (http://www.go4set.org.uk/).

[5] The Engineers of the 21st Century (E21C) Programme started from the perceived need to accelerate change in the engineering profession to enable it to respond fully and positively to the challenge of sustainable development (http://www.forumforthefuture.org/node/1369).

far less extensive foundations and is already paying dividends on site—for example with the use of bollard systems requiring only 112mm (4.5 inches) of excavation. Pioneering structural measures are currently being sited within the iconic Whitehall streetscape, that are not only sympathetic with the environment but provide significant improvements to the area, such as better use of public space and improving the visitor experience by widening footways.

Buncefield

25. The explosion at Buncefield had major implications for the fuel storage sector both in the UK and overseas. Initially, following the incident, many of the Health and Safety Executive's (HSE's) engineers were deployed to investigate and understand what had gone wrong. Later, the Buncefield Standards Task Group was formed consisting of representatives from HSE and industry, with the aim of translating the lessons from Buncefield into effective and practical guidance that industry would implement as rapidly as possible. In the longer-term, HSE's research programmes will deliver further intelligence to develop standards in the industry.

Major Public Events

26. A key component of the planning process for major public events is an understanding of the threat posed by improvised explosive devices and the potential effects should one be used. This advice is provided by explosion protection engineers—for example, the Explosion Consequence Analysis or Structural Vulnerability Assessment reports compiled by the Home Office's Scientific Development Branch on the locations proposed for major political party conferences and other high profile events.

European Community Whole Vehicle Type Approval

27. The European Community Whole Vehicle Type Approval (ECWVTA) is a major project that will result in the application of common construction standards to road vehicles.[6] Currently construction standards only apply to cars, but this project will extend application to lorries, vans, buses, coaches and trailers. The activities associated with ECWVTA involve all areas of engineering in Government. This includes technical research, establishing performance criteria for Directives, and then implementation in the UK of these standards (by multiple agencies). The work has been underway for five years, and will be implemented in the UK on 29 April 2009.

Nimrod

28. Ensuring that military aircraft are and remain airworthy is a responsibility that can be met only through the expert competence of the MoD's engineers. Military aircraft are operated often at the limit of their performance and in extreme, adverse environments. MoD engineers, working closely with Industry engineers, define the complex design standards used in the procurement, certify military aircraft acquired as airworthy and sustain their usage in service through maintenance and modification. When Nimrod XV230 was lost over Afghanistan in 2006, MoD engineers were instrumental in determining the immediate remedial work needed to restore airworthiness and return the aircraft to service in support of ground operations. They worked closely with industry and the scientific community to understand the complex engineering issues identified by the accident and to define changes to military airworthiness policy, regulation and guidance.

Fire Fighting

29. The development of fire core temperature monitoring has developed from science through engineering and should deliver an effective workable product which will improve the safety of emergency workers when they are fighting fires.

30. In addition, the new Incident Recording System and the Fire Service Emergency Cover for the Fire Service are two examples of software engineering that is near completion, leading to reduced data burdens on local authorities and an improved evidence base for both local and national policy.

Salcey Aerial Walkway

31. The Royal Forest of Salcey is an ancient woodland offering a rare and varied wildlife habitat. Civil engineers in the Forestry Commission played a major part in the development of the Salcey Forest—including constructing a unique, 300 metre long tree top walkway to take visitors of all ages and abilities from the forest floor to the upper canopy. The project won the Environment category of the British Construction Industry Awards in 2006 and, since the project's completion, visitor numbers have increased from under 100,000 to over 250,000 a year.

[6] These are standards designed to improve road safety.

Severn Bridge Cable Corrosion

32. This major suspension bridge is suffering a significant corrosion of the supporting cables. Engineers from the Highways Agency are working with other client authorities who have similar problems around the world and with specialist engineering consultants, weighing-up the evidence and risks and interpreting design standards so that cost-effective decisions can be taken whilst ensuring safety is not compromised. This has led to a management strategy for the Severn Bridge with little or no impact on road users.

Adaptation and mitigation of climate change

33. Looking over the next 10–20 years, one of the biggest challenges facing society is climate change. Engineers at Defra are working on adaptation measures (such as making the Thames more flood resilient) and mitigation (developing energy efficient technologies and increasing renewable energy) to respond to this challenge.

Thames Estuary 2100 Flood Risk Management Strategy

34. In flood and coastal erosion risk management, Defra engineers collaborate with the flood and coastal erosion risk management operating authorities (the Environment Agency, local authorities and internal drainage boards) and practitioners and are at the forefront of policy development and the consideration of strategic solutions. Direct involvement is mainly through review of major projects that fall outside the delegated authority of the operating authorities.

35. For example, the Thames Estuary 2100[7] project is a joint initiative between the Anglian, Southern and Thames regions of the Environment Agency, which aims to determine the level of flood protection needed for London and the Thames Estuary for the next 100 years. Defra engineers represented the department alongside Environment Agency staff on the Quality Review Panel, which provides ongoing review of the development of the strategy, in advance of the formal submission to the department and HM Treasury for agreement.

Development of energy efficiency technologies and renewable energy projects

36. Currently underway is a Severn Tidal Power Feasibility Study to assess the potential for tapping the tidal power of the Severn Estuary, which has the second greatest tidal range in the world. The tidal range in the Severn has the potential to provide around 5% of the UK's electricity needs. This represents a major opportunity for the UK to mitigate the effects of climate change and to meet our proposed EU target to source 15% of all our energy[8] from renewable sources by 2020 and the Government's own Renewables Obligation for 20% of our electricity supply to come from renewable sources by then.[9] It is expected that a short list of preferred proposals will be announced by the Department for Business, Enterprise and Regulatory Reform (BERR) at the end of this year.

Energy Research Partnership

37. The GCSA is a member of the joint public-private Energy Research Partnership (ERP), which provides enhanced leadership and coherence to the total UK investments in energy research and innovation. An early initiative of the Partnership was to support the establishment of the ETI (see below). Other work by ERP has included developing a vision for the UK's future energy research, development, demonstration and deployment (RDD&D) funding landscape, as well as inputting to the development of a new Environmental Transformation Fund, providing support for the demonstration and early stage deployment of low carbon technologies, and assisting the development of a new renewables energy strategy, published by the Government for consultation in June 2008.

Energy Technologies Institute

38. The Energy Technologies Institute (ETI) brings together some of the world's biggest energy and engineering companies—BP, Caterpillar, EDF Energy, E.ON UK, Rolls-Royce and Shell—in a 50:50 partnership with Government. Detailed calls for proposals in offshore wind (in collaboration with Carbon Trust), wave and tidal stream energy were made on 17 December 2007. ETI announced its third technology programme—on distributed energy—in April 2008. More programmes will follow in due course. ETI expects to announce the outcome of its first two calls for proposals (in the areas of Offshore Wind and Marine energy) in Autumn 2008. The GCSA attends ETI Board meetings, and the Chairman of the Board has a very strong background in engineering.[10]

[7] Formerly Planning for Flood Risk Management in the Thames Estuary.
[8] Electricity, heat and transport.
[9] In 2007, 5% of the UK's electricity supply came from renewable sources.
[10] Sir Robert Margetts CBE FREng FIChemE is a Governor and Fellow of Imperial College of Science, Technology & Medicine and a Fellow of the Royal Academy of Engineering and Institution of Chemical Engineers.

HOW GOVERNMENT IDENTIFIES THE NEED FOR ENGINEERING ADVICE AND HOW GOVERNMENT SOURCES ENGINEERING ADVICE

39. A variety of routes exist whereby the need for engineering advice is identified. These include: when an engineering or policy solution is required to solve a particular issue (for instance, to protect occupants in vehicles should a crash occur), the provision of independent advice from academia or advisory bodies (such as the Council for Science and Technology), the result of a literature review or consultant's report, or through futures work.

40. The route chosen will be determined on a case-by-case basis depending on the task in hand and the internal resources available—which vary widely between Departments.

41. If expertise does not exist in-house, it can be bought in from external consultants, or developed internally where long-term requirements have been identified. Where external engineering advice is needed, this may be sourced either through the operating agencies (such as the Health and Safety Laboratory for HSE or the Environment Agency in the case of Defra) or by employing specialist consultants directly.

Royal Academy of Engineering and the Engineering Institutions

42. The RAEng is a major source of authoritative, impartial advice for Government on issues with an engineering dimension. As the UK's national academy for engineering, it provides overall leadership for the UK's engineering profession—along with the Engineering Institutions. The Academy's membership of 1,375 Fellows brings together the UK's most eminent engineers from all disciplines.

43. The Government engages with the RAEng and the engineering institutions on a variety of issues, such as sustainable energy and climate change, health and wellbeing, food security and counter-terrorism. At the invitation of the GCSA, the RAEng has also recently become a member of the Global Science & Innovation Forum (GSIF), a vehicle for cross-Government exchanges of information and ideas to improve co-ordination of UK effort in international science and innovation collaboration, providing strategic guidance and systematic horizon scanning for new and emerging issues.

44. As part of its independent advisory role, the RAEng provides advice on the membership of Government committees to help ensure that policy debate is informed by the best engineering expertise. This includes formally nominating one member of the Home Office's Science Advisory Committee.

45. Departments work directly with individual engineering institutions. These arrangements are often reciprocal; DfT, for instance, is represented on the Institution of Engineering and Technology Sector Panel.

46. Whilst there is already much interaction between Government and the engineering community, there is scope to do more. The GCSA is working closely with the RAEng and the leading engineering institutions to develop the role and accessibility of the engineering community for Government departments and organisations seeking engineering advice and opinion. He has initiated regular meetings with Chief Executives of the RAEng and Engineering Institutions' and has addressed the RAEng and engineering institutions at several of their events, for example the RAEng Council dinner in April 2008, where he outlined his priorities and plans for GO-Science.

Scientific Advisory Committees and Councils

47. Government departments also seek specialist expert advice through Scientific Advisory Committees and Councils. Some of these bodies either have engineers in their formal membership or co-opt engineering experts to meet particular issues. For example, engineering expertise is provided within membership of Defra's Committee on Radioactive Waste Management (which currently has three more engineers than are formally required) and also on the Royal Commission on Environmental Pollution. Defra's Scientific Advisory Council includes two engineers. MoD's Defence Scientific Advisory Council requires that eight of its members have engineering expertise. Similarly, engineering advice is also contained within the Home Office's Science Advisory Committee and several of its specialist advisory committees.[11]

[11] For example, there are presently three serving members on the Home Office Scientific Advisory Committee who are engineers and two engineers serving on the Biometrics Assurance Group.

[12] Professors Wendy Hall and Michael Sterling and Dr Sue Ion and Dr Phil Ruffles are all former Vice-Presidents of the Royal Academy of Engineering—Dr Ruffles is also a past member of the Nominations Committee and Professor Sterling a former Chair of its Membership Committee, as well as past President of the Institution of Engineering and Technology. Professor Michael Sterling, Dr Hermann Hauser and Dr Raj Rajagopal are all Fellows of the Royal Academy of Engineering, with Dr Rajagopal also being a Fellow of the Institution of Electrical Engineers and a Fellow of the Institution of Mechanical Engineers. Additionally, Professor Hall is a Fellow of the Institution of Engineering and Technology and a Fellow and past President of the British Computer Society.

The Council for Science and Technology

48. The Council for Science and Technology (CST) is the Prime Minister's top-level independent advisory body on strategic science and technology policy issues. The 17 members of the Council are all respected senior figures drawn from across science, engineering and technology—six of these 17 are engineers.[13]

49. The CST's report *Strategic Decision Making for Technology Policy Making* (November 2007) had a strong engineering focus in terms of the key technology areas where it considered that a greater focus by Government could accelerate the real returns for the UK within a five-year timeframe. These included carbon capture and storage, disaster mitigation technologies, low carbon distribution networks for electricity generation, medical devices, and a detailed case study on plastic electronics which recommended a comprehensive value-chain analysis of the plastic electronics sector, a strategic role for Government in bringing the key players together to facilitate interaction between users of the technology and the science base, and an assessment of the training needs for the workforce.

Research Base

50. To support their work and share thinking on developing policy with key stakeholders, departments maintain close links with the research base through the individual Research Councils, the TSB (see paragraph 83), and on energy issues through the GCSA's involvement with ERP and ETI (see paragraphs 35 and 36). The GCSA has also initiated three meetings a year to bring together the Chief Executives of the Research Councils and DCSAs so that issues of common interest can be explored. The first meeting was held on 7 July 2008, where the main topic on the agenda was the cross-council Living with Environmental Change (LWEC) programme.

51. A number of departments maintain close links with the Research Councils. The Home Office maintains close links with the Engineering and Physical Sciences Research Council (EPSRC) and, at strategic level their DCSA meets with EPSRC's Chief Executive annually. Additionally, two DCSA are closely involved with EPSRC—MoD's DCSA (Mark Welland) is a Council member and DfT and BERR's DCSA (Brian Collins) is member of the Technical Opportunities Panel.

52. The Research Councils are also represented on a number of important advisory bodies and departmental Scientific Advisory Councils and Committees. Dr Sue Ion (an EPSRC Council member) is a member of the CST, Professor Christopher Snowden (another EPSRC Council member) is a member of the Defence Scientific Advisory Committee and the UK Committee for National and International Hydrology, is chaired by Professor Alan Jenkins from the Natural Environment Research Council (NERC).

Other sources of advice

53. The list above is not an exhaustive one, and novel and new associations are continually being made to solve particular problems. One example is provided by the Home Office's recent work with the Smith Institute in order to bring together expertise to help model and understand the process of "entanglement" (net-like barriers in the water), which might be used by law enforcement agencies to stop suspect vessels relatively safely, by fouling up their propulsion units. Whilst this was conceived as a mathematical approach, it is one that has been used to understand better an engineering problem.

Longer term planning

54. Longer term planning of departmental policies and resources are supported by the Horizon Scannning Centre (HSC) within GO-Science alongside other departmental long-term policy planning resources. Collectively, these resources identify enablers and inhibitors in emerging areas of science and technology that are most likely to inform future departmental policies from only a few years hence up to 30 years or more.

55. One of the key principles of horizon scanning is to look broadly. The HSC is part of the GO-Science Foresight Programme. The HSC seeks and uses evidence from multiple disciplines in all its work, and engineers have made significant contributions to a number of HSC projects and activities. Examples include a project on the defence implications of synthetic biological engineering (see Annex 2); and another on Emerging Technologies to inform the Comprehensive Spending Review 2007, which identified and described for HM Treasury a set of eight "clusters" of key areas of science and technology that, over the period of approximately 2015–20, have the potential (either as enhancers or disruptors) to: transform the delivery of public services; challenge society; and/or affect wealth creation.

[13] Professors Wendy Hall and Michael Sterling and Dr Sue Ion and Dr Phil Ruffles are all former Vice-Presidents of the Royal Academy of Engineering—Dr Ruffles is also a past member of the Nominations Committee and Professor Sterling a former Chair of its Membership Committee, as well as past President of the Institution of Engineering and Technology. Professor Michael Sterling, Dr Hermann Hauser and Dr Raj Rajagopal are all Fellows of the Royal Academy of Engineering, with Dr Rajagopal also being a Fellow of the Institution of Electrical Engineers and a Fellow of the Institution of Mechanical Engineers. Additionally, Professor Hall is a Fellow of the Institution of Engineering and Technology and a Fellow and past President of the British Computer Society.

56. The Foresight Programme aims to strengthen strategic policy making by embedding a futures approach across Government. The Programme also runs major projects which look in greater detail into particular scientific areas of interest which can help decision-makers to get a better understanding of and find new ways to tackle major societal challenges, such as the project on Flooding and Coastal Defence. This groundbreaking study drew heavily on leading experts from the UK's engineering and science communities. The project report, *Future Flooding*, provided a cornerstone for local and national policy, such as Making Space for Water, the Government's 20-year strategy for managing long-term flood risk in England. The report has also attracted considerable international interest. For example, a major Foresight-style "flagship" project on flood-risk management is underway in Taihu, China, which is supported by Chinese government departments and is being led jointly by Chinese and UK engineers and scientists.

57. Another Foresight report *"Intelligent Infrastructure Futures"* explored the scope for engineering the future environment so that over the next 50 years efficient and sustainable movement of people and goods can be achieved by the introduction of common systems. Importantly the study stimulated close working between Government and both the research and business communities in moving towards the development of robust technology solutions to these challenges.

58. Obesity is another key challenge for Government, and the Foresight report, *"Tackling Obesities: future choices"* demonstrated how external determinants such as the built environment will have a crucial role to play in combating the future threat of obesity. In particular, it is essential that the space in which we live and work will be developed and engineered to maximise its "walkability" and "cyclability" and to encourage and promote other forms of physical activity and recreation.

Succession planning

59. Over the medium- and longer-term, departments need to consider their need for specialist advice and ensure that the range and deployment of engineering advice they have remains in line with their evolving business needs. A number of departments have identified issues surrounding the age profile of their specialist expertise and are considering how they should recruit, manage and foster expertise to ensure their engineers continue to be able to work effectively and with authority.

60. Some departments, such as Defra, have created science and engineering "career homes", one of the functions of which is to evaluate departments' capacity and capability in relation to expertise.

61. Again, the GCSA's programme of Science Reviews looks at departmental capacity and capability with respect to science and engineering expertise.

The Status of Engineering and Engineers within the Civil Service, including Assessments of the Effectiveness of the Science and Engineering Fast Streams, and the Role and Career Prospects of Specialist Engineers in the Civil Service

The role and status of engineers with the civil service

62. Government engineers may be leading experts in their chosen fields working in specialist posts, or have general engineering backgrounds that can be applied to address more wide-ranging policy or delivery needs.

63. There are estimated to be around 18,000 scientists and engineers in the civil service—about 3.7% of the total number of civil servants.[14] The majority of engineering specialists are based in MoD.

64. Members of the profession play a part in a wide variety of issues across Government, from those with an obvious engineering angle such as better traffic management to those that may be less obvious such as reducing Healthcare Associated Infection. Their expertise spans the wide range of occupational settings they work in, including mechanical, electrical, chemical, civil and structural, highways, military, nuclear and water engineering. Some are highly specialised, such as those dealing with explosives, non-ionising radiation and biological agents and nuclear propulsion.

65. Engineers contribute to a broad range of work throughout Government departments, agencies and laboratories, including:

- interpreting science and engineering evidence to support policy and delivery;
- providing capability to respond to emergencies;
- providing the role of intelligent customer capability for departments so that they can commission and use science most effectively;
- undertaking essential work which cannot be or is not done outside Government, for example for reasons of national security;
- standards setting/benchmarking;
- policy making;

[14] There are currently 490,000 civil servants. Source: Civil Service statistics, updated on 16 July 2008 (http://www.civilservice.gov.uk/about/statistics).

— supporting risk management and improving public confidence;
— meeting ongoing commitments in the Government's role as a regulator; and
— conducting research in laboratories.

66. As well as the specialist expertise they bring, Government engineers are valued for their generic problem-solving skills and their ability to produce practical solutions to problems and drive delivery through project management skills. A high proportion of engineers joining the new Science and Engineering Community of Interest (see below) identified project management as one of their key skill areas.

Head of Scientific and Engineering Profession

67. GO-Science supports the GCSA in his role as Head of Scientific and Engineering Profession (HoSEP), where he seeks to give leadership and greater visibility to the role of scientists in support of overall Government policy. This role complements that of Departmental HoSEPs and corresponding heads of profession for other analytical disciplines.

68. A number of departments have reported the need to make better and timelier use of science and engineering in business planning and policy development, and to improve career options for specialists. Recognising this need, the GCSA has substantially developed and revitalised the HoSEP function since beginning his tenure in January 2008—setting a number of key deliverables to be achieved during his first 12-18 months in office, including:

— holding the first annual conference for the science and engineering community to give members a chance the share knowledge, voice their concerns and create a sense of belonging;
— creating a Professional Skills for Government (PSG) framework for scientists and engineers below Grade 7 and refreshing the existing framework for Grade 7 and above (see below); and
— exploring other measures with outside organisations aimed at furthering people's careers and improving knowledge transfer, such as Pairing and Fellowship schemes.

69. Whilst a few departments have a clearly identified science and engineering community, a fundamental obstacle to progressing the HoSEP agenda has been the lack of comprehensive data on scientists and engineers across Government. To address this, the GCSA has created a cross-Government community of interest of scientists and engineers. To date, 1,316 people[15] have joined the community of interest, of which 703 have identified that science and/or engineering is essential to their post. Whilst not directly comparable, these numbers equate favourably with the other analytic professions, whose total membership is as follows:[16]

— Government Economic Service (GES)—1,472;
— Government Statistical Service (GSS)—1,382;
— Government Social Research (GSR)—around 1,000; and
— Government Operational Research Service (GORS)—371.

Skills

70. A cross-government skills strategy agreed by all Permanent Secretaries, *Building Professional Skills for Government*, was published in April 2008. The objective of the three-year strategy is to raise standards and enhance individual performance, improve organisational capability and ultimately improve the quality of public services. The GCSA and departmental HoSEPs (along with all other Heads of Professions across Government) have a central role in ensuring the skills strategy is a success.

71. The implementation of the skills strategy will make a real difference to the individuals within the profession, giving them better chances of identifying and developing the skills that will enable them to succeed in their chosen careers.

Career prospects of specialist engineers in the civil service

72. It is important that engineers within the civil service are valued for their expertise and that they are well informed about the attractive career and development opportunities that are open to them. To a large extent this is managed within individual departments, and a number of departments and Government research institutes have formal arrangements to support their staff in continuous professional development.

73. One issue which arises in creating attractive career structures for engineers is how to retain and reward those working as "deep specialists". Due to the needs of particular post or engineers' focus on their area of professional expertise, some deep specialists may not have the opportunity (or the desire) to obtain the

[15] Data up to and including 21 August 2008.
[16] Membership data provided by GES, GSR and GSS on 22 August, and GORS on 27 August 2008. Actual numbers in post may be lower than this due to study leave, associate membership, etc; for example, the total number of GES in post is 1,115 compared to a total membership of 1,472.

broader skills needed to qualify for promotion to the Senior Civil Service. The MoD has made arrangements to reward and recognise such specialists; the GCSA has drawn departments' attention to this initiative through the HoSEP network, which will continue to pursue the area of reward and recognition.

74. It is also important that professional engineering work carried out within Government is not isolated from that being carried out outside, whether in academia, business or elsewhere. Departments provide encouragement and support for:

- secondments into and out of the civil service;
- support for the acquisition of relevant qualifications; and
- the provision of time and resource to attend conferences and work with their counterparts outside.

75. For example, to provide variety to careers as well as giving experience required for specific posts, engineers in MoD may undertake secondments to international posts in NATO, UK embassies abroad, joint project offices, academic posts and other Government departments. In addition, the new DE&S Specialist Fellowship Scheme for engineers aims to reward and recognise the small number of civilian experts who are required by MoD to develop and maintain their world class specialist status.

76. Defra is in discussion with both Forum for the Future and the EPSRC about the possibility of Engineering Fellowships, placing either young private sector engineers or engineering research post-docs in Defra policy teams for 3–6 month projects.

77. Government engineering specialists are highly competent, many holding academic qualifications underpinned by membership of relevant professional bodies. This is a necessity when, for example their views are subject to robust formal challenges (eg as expert witnesses in legal proceedings or as Government representatives in a wide range of formal and informal meetings with experts from industry and other national and international bodies).

78. A number of departments and Agencies across Government, such as the Home Office and Environment Agency, encourage their engineers to gain chartered status through the appropriate institution. In addition, Chartered Engineer is a requirement of certain posts in the MoD, and has been adopted as the benchmark for professional engineering posts in DE&S.

Graduate Entry to the Civil Service

Science and Engineering Fast Stream

79. Graduates entering the civil service through the Science and Engineering Fast Stream (SEFS) do not enter specialist science or engineering posts. Rather, they undertake the same policy delivery, operational delivery and corporate delivery roles as other Fast Streamers in order to equip them for future senior management positions, the only difference being that they go into departments where their scientific or engineering knowledge will be useful to them.

80. The three departments which recruit from the SEFS (MoD, DIUS and BERR) report that entrants from the SEFS are in high demand by managers because of the skills and experience they bring to the departments' work, particularly on issues relating to science, engineering and technology, but also across the broader spectrum of their work (such as procurement or project delivery).

81. In addition to the entrants they take from SEFS these departments also recruit from the other parts of the Graduate Fast Stream. Many of those recruited will have taken science and engineering degrees but chose not to join through the SEFS.

Other Schemes

82. Some departments and their agencies run their own graduate recruitment schemes. MoD recruits civilian engineers through the Defence Engineering and Science Group (DESG) Graduate Scheme, and the Vehicle and Operator Services Agency (VOSA) runs a Graduate Mechanical Engineer Training Scheme that has been designed in such a way that it meets the Institution of Mechanical Engineer's Monitored Professional Development Scheme criteria—enabling graduates to become Chartered at the end of it.

The Role and Effectiveness of Professional Engineers and the Engineering Community in Promoting Engineering and Providing Engineering Advice to Government and the Civil Service

83. As previously noted, there is a growing enthusiasm on the part of the RAEng, supported by the leading Engineering Institutions, to work more collaboratively than ever before and with Government to help tackle the big challenges it faces and, at the same time, better promote the UK engineering profession. Regular meetings with the GCSA, Ministers and senior officials help ensure that the engineering community has high-level input to policy making in a wide range of areas.

The National Measurement System

84. The National Measurement System (NMS), sponsored by DIUS, maintains and develops the UK's measurement infrastructure delivering world-class measurement science and technology and providing traceable and increasingly accurate standards of measurement. It has a mission to enhance UK innovation and industrial enterprise, facilitate trade and improve the quality of life in the UK. The NMS supports innovation by enabling the benefits of new products and processes to be measured and, specifically, by stimulating new product development in the instrument sector. It also raises productivity through improved process and quality control. Measurement also underpins a wide range of public goods, including consumer protection, forensic science, environmental controls, medical treatment and food safety regulation, as well as the technical standards that ensure barrier-free trade.

85. The NMS is organised into 12 programmes. One of these "Engineering and Flow Metrology" addresses dimensional, mass and flow measurements. Other programmes such as "Materials and Thermal Metrology" and "Physical Metrology" also contain a significant element of work relevant to engineering. Since measurement plays such a fundamental part in our lives, it is important that the accuracy of the measurement is fit for purpose. In order to ensure that the NMS serves the needs of users throughout the economy work programmes are guided and prioritised by expert advisory groups. These groups are comprised of scientists and engineers recruited from universities, industrial companies developing or making use of the technologies concerned or regulatory bodies, where this is appropriate.

Technology Strategy Board

86. The DIUS funded Technology Strategy Board (TSB) is a business-led, business focused body that plays an important leadership role across all sectors of the UK economy—with a particular focus on stimulating innovation in those areas which offer the greatest scope for boosting UK growth and productivity. The Chief Executive and four members of the 12 strong TSB Governing Board are engineers.

87. To help to focus their work TSB have identified a number of Key Application Areas—broad fields where technological innovation has a major role to play and which represent major societal challenges or are associated with the challenge of maintaining a world-leading position. A number of these have a strong engineering component, for example: Environmental sustainability, Energy generation & supply and, the Built environment. TSB have also defined several Key Technology Areas which allow them to focus initiatives and interventions on core technologies that are critical to the UK's success. These include: High value-added manufacturing processes; Advanced materials; Nanotechnology; and Photonics & electrical systems—all of which have strong engineering dimensions.

88. TSB Innovation Platforms (IPs) pull together policy, business, Government procurement and research perspectives and resources to generate innovative solutions. The first two IPs, Intelligent Transport Systems & Services, and Network Security, involved the TSB working with DfT and the Home Office respectively to address these two important underlying challenges facing modern society. Three more IPs have now been announced—Low Carbon Vehicles, Assisted Living and Low Impact Buildings—each again addressing a specific societal challenge requiring considerable engineering input.

89. TSB also operate Knowledge Transfer Networks—single over-arching national networks in specific fields of technology or business application which bring together people from businesses, universities, research, finance and technology organisations to stimulate innovation through knowledge transfer. Many the KTNs have a significant engineering component, for example Aerospace & Defence, Cyber Security, and Intelligent Transport Systems.

UK Trade & Investment

90. UK Trade & Investment (UKTI) is the Government organisation that helps UK based companies succeed in international markets and assists overseas companies to bring high quality investment to the UK's economy. UKTI's Sectors Group focuses on strategic and political Government assistance to UK business in pursuit of overseas opportunities on those sectors and activities where it can best add value.

91. UKTI's sector teams takes advice on developing and implementing international trade and inward investment marketing strategies from business advisory groups, including the Advanced Engineering Sector Advisory Board (AdESAB), who are also actively engaged in international marketing campaigns. Members of the AdESAB are drawn from advanced engineering businesses and are actively involved in the sector, providing insight into the challenges and opportunities facing large, medium and small enterprises and the different sub-sectors of advanced engineering.

International Examples of How Engineers and Engineering Advice are Embedded in Government

92. As illustrated by the examples below, countries source and manage engineering advice into government in very different ways.

United States

93. Like the UK, engineering policy is generally considered as part of the science policy agenda in the United States (US). Engineers are spread far and wide within the US Government, and are probably one of the best-represented disciplines. Many agencies and programs in the US share engineering policymaking and oversight responsibilities. The split is such that there is no true primary engineering agency, nor is there an agency that holds primacy in funding engineering research.

94. The major agencies and departments employing and funding engineers and engineering research are the Department of Defense, the Department of Energy, the Army Corps of Engineers, the National Science Foundation, the National Institute of Standards and Technology, the National Aeronautics and Space Administration, the National Institutes of Health, the Environmental Protection Agency, and the National Oceanic and Atmospheric Administration.

95. Beyond these agencies are several other groups with significant say in engineering policy.

France

96. France has a network of civil service schools—including a number of engineering schools[17]—which provide initial training to future civil servants before and so that they are given a post in the civil service. Training mainly consists of practical knowledge, professional skills and work methods necessary for the future working environment.

Germany

97. Germany has no equivalent of the GCSA. Instead, government seeks scientific and engineering advice from academies, research organisations, appointed advisory bodies, and professional and trade associations. For its 2007 G8 and EU Presidencies, the German federal government appointed a top German climate scientist and a top energy industry representative as special advisers.

India

98. Most key government departments/ministries in India have an engineering arm; notably in Ministry of Transport (Civil Engineering), Ministry of Railways, and the Ministry of Urban and Rural Development.

99. Public sector enterprises also play an important role in the heavy engineering sector in India. There are 34 public sector enterprises in this area.

Japan

100. Japanese ministries manage no permanent scientists, engineers or technologists inside their organisations, except some for nuclear safety and regulation. Instead, expertise is provided by companies, trade associations and national research institutes, with whom the Japanese government has close links. A scheme for recruiting specialists from such organisations on a temporary fixed-term basis is used when specialist advice is required.

101. It is understood that more detailed information will be provided by the British Embassy in Tokyo, ahead of the Committee's visit to Japan in October.

Spain

102. There is an autonomous organisation within the Ministerio de Fomento (Ministry of Development) that gives comprehensive engineering advice across a range of topics from infrastructure, environment and planning.

September 2008

[17] These include the École Polytechnique, the École des Mines and the École des Ponts et Chaussées (Bridges and Roads).

Annex 1

CENTRAL GUIDANCE AND POLICY DOCUMENTS

Appointing Board Members to Public Bodies—Model Guidance (October 2004), http://www.civilservice.gov.uk/documents/pdf/appointments/exec_adv_codes_practice_23oct04.pdf

House of Commons: BSE Inquiry Report—The Inquiry into BSE and variant CJD in the United Kingdom (October 2000), http://www.bseinquiry.gov.uk/report/index.htm

Cabinet Office: Civil Service Code (June 2006), http://www.civilservice.gov.uk/publications/civilservicecode/index.asp

GO-Science: Code of Practice for Scientific Advisory Committees (CoPSAC) (December 2007), www.dius.gov.uk/publications/file42780.pdf

Cabinet Office: Consultation—Code of Practice (September 2005), http://bre.berr.gov.uk/regulation/consultation/code/introduction.asp

HM Treasury: Cross-Cutting Review of Science and Research (March 2002), www.hm-treasury.gov.uk/media/E/7/science_crosscutter.pdf)

Data Protection Act (1998), http://www.opsi.gov.uk/acts/acts1998/19980029.htm

The Environmental Information Regulations (2004), http://www.opsi.gov.uk/si/si2004/20043391.htm

Evidence-based policy-making—Evidence Hot links, http://www.nationalschool.gov.uk/policyhub/evidence_hotlinks/

Foresight and HSC http://www.foresight.gov.uk/ and http://www.foresight.gov.uk/horizonscanning

Freedom of Information Act Guidance, http://www.dca.gov.uk/foi/guidance/index.htm

DTI:Guidelines On Scientific Analysis In Policy Making (October 2005), http://www.berr.gov.uk/files/file9767.pdf

Nolan Principles (Seven Principles of Public Life), http://www.public-standards.gov.uk/about_us/seven_principles.htm

Council for Science and Technology: Policy Through Dialogue (2005), http://www2.cst.gov.uk/cst/reports/#8

PSAs—Public Service Agreements (2008), http://www.hm-treasury.gov.uk/pbr_csr/psa/pbr_csr07_psaindex.cfm

Public Appointments, http://www.civilservice.gov.uk/about/public/appointments.asp

Office of the Commissioner for Public Appointments: Public Appointments Code of Practice for Ministerial Appointments to Public Bodies (August 2005), http://www.ocpa.gov.uk/upload/assets/www.ocpa.gov.uk/codeofpractice_aug05.pdf

Public engagement in SET guidelines—Government response to nanotechnology report (February 2005), http://www.berr.gov.uk/files/file14873.pdf

BERR: Regulatory Impact Assessment Guidance, http://www.berr.gov.uk/employment/research-evaluation/ria/index.html

HM Treasury: Risk and Uncertainty. Managing risks to the public—appraisal guidance (June 2005), http://www.hmtreasury.gov.uk/media/8AB/54/Managing_risks_to_the_public.pdf

House of Lords: Risk and Uncertainty. Government Policy on the Management of Risk (7 June 2006), http://www.publications.parliament.uk/pa/ld200506/ldselect/ldeconaf/183/183i.pdf

Risk and Uncertainty. The Orange Book—Management of Risk—Principles and Concepts, http://www.hm-treasury.gov.uk/documents/public_spending_reporting/governance_risk/psr_governance_risk_riskguidance.cfm

Risk and Uncertainty. Thinking about risk—setting & communicating your risk appetite, including good practice examples, http://www.hm-treasury.gov.uk/documents/public_spending_reporting/governance_risk/psr_governance_risk_thinking_about_risk.cfm

Sainsbury Review, http://www.hm-treasury.gov.uk/independent_reviews/sainsbury_review/sainsbury_index.cfm

HM Treasury: Science and Innovation Investment Framework 2004-2014 (July 2004), http://www.hm-treasury.gov.uk/spending_review/spend_sr04/associated_documents/spending_sr04_science.cfm

Next Steps—Applied to Science Base and Innovation rather than GO-Science agendas http://www.berr.gov.uk/dius/science/science-funding/framework/next_steps/page28988.html

House of Lords S&T Committee: Third Report—Science and Society (February 2000), http://www.parliament.the-stationery-office.co.uk/pa/ld199900/ldselect/ldsctech/38/3801.htm

DIUS: Science in Government, http://www.dius.gov.uk/policy/science.html

Science Reviews website http://www.dti.gov.uk/science/science-reviews/page24572.html

Scientific Advice, Risk and Evidence Based Policy Making: Government Response to the House of Commons Select Committee 7th Report (2005–06) (February 2007), http://www.parliament.the-stationery-office.com/pa/cm200607/cmselect/cmsctech/307/307.pdf

Spending Reviews: 2002 –Investing in Innovation: A Strategy for Science, Engineering and Technology (2002)—Chapter 7 (Science in Government), http://www.hm-treasury.gov.uk/spending_review/spend_sr02/spend_sr02_science.cfm

Spending Reviews: 2004—Spending Review, http://www.hm-treasury.gov.uk/spending_review/spend_sr04/spend_sr04_index.cfm

Spending Reviews: 2007—Long Term Opportunities and Challenges in the 2007 CSR (November 2006), http://www.hm-treasury.gov.uk./spending_review/spend_csr07/spend_csr07_longterm.cfm

Spending Reviews: 2007—Comprehensive Spending Review http://www.hm-treasury.gov.uk/spending_review/spend_csr07/spend_csr07_index.cfm

DIUS: Universal Ethical Code for Scientists (September 2007), http://www.berr.gov.uk/files/file41318.pdf

Annex 2

SYNTHETIC BIOLOGICAL ENGINEERING

In late 2006, the Horizon Scanning Centre conducted a small project with MoD on the defence implications of synthetic biological engineering (SBE). Engineering was explicitly included in the title in recognition that the field of synthetic biology[18] is rapidly acquiring all the key characteristics of one of the classical engineering disciplines:

- a set of standard components "BioBricks", such as the 700 available parts in a growing current catalogue co-ordinated by MIT http://partsregistry.org/cgi/partsdb/search.cgi;
- a set of rules that describe how those components can (and can not) be fitted together to produce useful devices and systems with known characteristics and predictable behaviours;
- a significant-sized skilled workforce who understand the rules, and can apply them consistently, and who have ready access to the components.

The project found that SBE may be of relevance to and influenced by a wide range of major issues affecting the UK and its position in the world. These include, but are not limited to, energy and resource availability, pollution control, health, especially drug development, and IT. There was agreement that a country with a large and well-supported science base will have an advantage in making the most of SBE as the business and social opportunities which it offers start to develop.

SBE might matter to MoD for a number of reasons, including:

- It could be used to create a wide range of devices, weapons etc.
- SBE might be used by small organisations to create threats rapidly—no long build-up times or massive factories to alert the target.
- It might offer value to the UK military, such as the ability to make sensors and other battlefield devices that run on ambient energy and which cost fractions of a penny each.
- Some of SBE's pollution-cleaning potential might be of military use, for example if SBE devices can remove radioactive or chemical pollution.
- SBE devices that could turn almost anything biological into energy would allow the military, both machines and people, to live off the land more easily. They might also be able to use sunlight more effectively than inorganic solar collectors.
- Medical SBE devices might revolutionise diagnosis and treatment in the field.

[18] The Royal Society has described synthetic biology in broad terms as "the design and construction of novel artificial biological pathways, organisms or devices, or the redesign of existing natural biological systems. It has enormous potential applications and benefits, including the development of cheap anti-malarial drugs, the production of cheap, green hydrogen for fuel and the use of programmable cells to treat cancer and similar illnesses".

Annex 3

GLOSSARY OF ABBREVIATIONS

AdESAB—Advanced Engineering Sector Advisory Board
BERR—Department for Business, Enterprise and Regulatory Reform
CAETS—International Council of Academies of Engineering and Technological Sciences
CIG—Core Issues Group
CPNI—Centre for the Protection of National Infrastructure
CST—Council for Science and Technology
CSAC—Chief Scientific Advisers Committee
DCSA—Departmental Chief Scientific Adviser
DE&S—Defence Equipment and Support
Defra—Department for Environment, Food and Rural Affairs
DESG—Defence Engineering and Science Group
DfT—Department for Transport
DIUS—Department for Innovation, Universities and Skills
ECWVTA—European Community Whole Vehicle Type Approval
EPSRC—Engineering and Physical Sciences Research Council
ETI—Energy Technologies Institute
FREng—Fellow of the Royal Academy of Engineering
GCSA—Government Chief Scientific Adviser
GES—Government Economic Service
GORS—Government Operational Research Service
GO-Science—Government Office for Science
GSIF—Global Science & Innovation Forum
GSR—Government Social Research
GSS—Government Statistical Service
HoSEP—Head of Science and Engineering Profession
HSC—Horizon Scanning Centre
HSE—Health and Safety Executive
IP—Innovation Platform
KTN—Knowledge Transfer Networks
LWEC—Living with Environmental Change programme
MIT—Massachusetts Institute of Technology
MoD—Ministry of Defence
NATO—North Atlantic Treaty Organisation
NERC—Natural Environment Research Council
NMS—National Measurement System
PSG—Professional Skills for Government
R&D—research and development
RDD&D—research, development, demonstration and deployment
RAEng—Royal Academy of Engineering
SBE—synthetic biological engineering
SEAs—Science and Engineering Ambassadors
SEFS—Science and Engineering Fast Stream
SMEs—small and medium-sized enterprises
STEM—Science, Technology, Engineering and Mathematics
STEMNET—Science, Technology, Engineering and Mathematics Network
TSB—Technology Strategy Board
UK—United Kingdom
UKTI—UK Trade & Investment
US—United States
VOSA—Vehicle and Operator Services Agency

Memorandum 170

Submission from Professor David Fisk, Imperial College London

SUMMARY

- Central Government has seen a very large transfer of engineering knowledge and skills to Agencies and more latterly the private sector.
- The engineering skills that remain in Government are an ad hoc legacy, rather than the consequence of a formal downsizing plan.
- If Governments wish to have policies and public procurement marked out for innovation rather than costly novelty it seems likely that the transfer has gone too far.
- The most effective redress would be a much tougher external scrutiny of the engineering judgements that underlie Government action.

INTRODUCTION

1. I was Chief Scientist in DOE and then subsequently DETR, DTLR, ODPM and DCLG from 1988 to 2005. My submission offers some reflections as Head of Profession over that period. I was previously Head of the Mechanical and Electrical Engineering Division at the Building Research Establishment. I am a member of the Research Assessment Exercise General Engineering Sub Panel and a Fellow of the Royal Academy of Engineering. For the purposes of this evidence I am taking "engineering" to be the art of devising something that one group of people will want to make and another group of people will want to use. This contrasts with "science and technology" which I take to be knowledge just about "things". The main consequence of this distinction is that "engineering advice" will almost always contain an element of risk and professional judgement.

3. This evidence focuses on engineering skills in Government which I choose to measure by "Chartered Engineer" status. While this is not ideal it covers some 50 accreditation bodies and ensures some formal process to keep engineering skills and knowledge up to date. There is a wider informal sphere of engineering knowledge in Government but my working "professional" definition is no more than would be taken for granted in an inquiry into, say, the Government legal service. I have no direct experience of MoD and have therefore not included its important engineering role in this evidence.

HOW MANY ENGINEERS ARE THERE IN GOVERNMENT?

4. Unlike the economist and statisticians classes, Government has kept no central record of engineers in Government since the mid-1980s. My evidence has had to rely on FOI inquiries at Departmental and Agency level. Some organisations are in the process of building their databases (as in the CAA), but in other cases (eg Scottish Executive) personal data on professional competences are not held at all. In central government the numbers of professionally qualified engineers are to say the least modest. DTI in its last year did not know the precise number of Chartered Engineers though it "could recall 10". If this is really true it is a smaller number than the number of members of the Chinese Politburo with engineering qualifications! DfT's Rail Group which undertakes much of the role of the old Strategic Rail Authority has just twelve chartered engineers in a staff of almost 300.

5. These figures are in stark contrast to those of the 1960s when a great deal of engineering was undertaken in, or close to, Central Government. Bodies like the Property Services Agency or the Central Electricity Generating Board were headed by formidable individuals with extraordinary grasp of their engineering. At this time the Civil Service had a well defined class called "Professional and Technical Officer" that paralleled "Scientific Officer" class. Between 1939 and 1959 the numbers in both classes rose from 11,000 to 70,000. The dramatic reduction since then reflects a change in Government structure rather than the amount of engineering undertaken in the name of the public sector. If anything, engineering issues have increased both in scale and complexity. When Executive Agencies and Regulators were formed they took from the home Department most of the engineers with the relevant experience. Some bodies like the Research Establishments were subsequently privatised. Pressure on civil service headcounts encouraged both Central Government and Agencies to "buy in" engineering expertise. It should be borne in mind that the small numbers quoted in this evidence for the headcount of engineers in Departments refers to individuals who were in post in the late-1980's-early-1990's. This cohort represents a vast field of personal experience. The issue of public interest is then not the small number currently in post but that coherent plans for the recruitment of their successors are hard to find.

6. Indeed the whole transformation of Departmental engineering skills took place ad hoc. While there may be no magic number for engineers in Government I can advance circumstantial evidence suggesting that the UK has undershot. The transformation did not begin from a comfortable beginning. Despite the impressive number of engineers in Government the 1960's was not a Golden Era. Sampson's 1965 Anatomy of Britain devotes a whole section to the "problems of the scientific and technical" specialists in the Civil Service and the tension with "generalists". This tension eventually led to the Holdgate Report in 1980. Even

this report limited itself to just the "science class". It was to be the last time that the Cabinet Office reflected publicly on using technical specialist advice for 20 years. Few of Holdgate's recommendations were implemented given the changes that were starting to happen in parallel.

7. Moving engineering competence out of Departments to Next Step Agencies was consistent with giving the latter more freedoms. But it is hard not to suspect that the more specialists that could be shifted the more the old tiresome tensions could be relieved. The number of engineering specialists in the Centre was further shaved by the collateral damage of other well-intentioned reforms. The Fulton Report had already removed the broad career flexibility of the "un-established" civil servant. In the 1980's wider reforms absorbed technical generalists into the main generalist policy adviser stream of the Civil Service, while retaining Economists and Statisticians as identified classes. This was also the time when MoD chose to distance itself from civil departments. The consequence was that there was no common career pool and the few engineers remaining in Departments were effectively in specialist ghettos. External pressure on staff head count encouraged both the central Departments and Agencies to outsource engineering advice rather than replace retirees.

8. The *Modernising Government* White Paper in 1999 addressed the revolution demanded by the new Administration. But it makes no reference to specialists. Its reforms included the extension of the Senior Civil Service to "Divisional Manager" level. But this meant the imposition on the natural career grade for senior specialist advisers of formal competency requirements appropriate to managers of administrative Divisions. The Senior Civil Service is no country for young expert engineers! More recently the Mottram report (*Professional Skills—Death of the Generalist*) identified three kinds of civil service function but it is hard to see where engineering experience outside of IT was supposed to fit in. The career problems of specialists are recognised in the Professional Skills for Government agenda, but this area has been left to Departments and as far as can be judged nothing has been done. Somewhat surprisingly, given these reforms, the Capability Reviews give rather little weighting to a Department actually mastering the substance underlying its patch To date the Science Reviews have not probed engineering competence at all. It became clear from my inquiries that human resources divisions have something of a general blind spot on professionalism. While seeking some kind of calibration I was told that the Finance Services Authority knows it has 2,670 employees but does not know how many have Chartered Accountant status.

9. It is too easy to focus on Central Departments and forget that most engineering decisions affecting citizens' daily lives take place in statutory agencies. Amongst enforcement agencies, HSE seemedd well informed on its expertise. Of its 4,000 staff, 252 are Chartered Engineers. The Environment Agency which has to make significant engineering judgements has 12,000 staff, 200 of which are in "engineering roles", and of those 23 are classed MEICA (mechanical, electrical, information, control and automation) engineers. It does not know if they hold Chartered Engineer status.

10. "Economic" regulators spend a great deal of time probing capital expenditure plans proposed by industry that require substantial engineering judgements. For example Ofwat has six chartered engineers in a staff of 200. Ofcom a little surprisingly given the technical complexity of its tasks in a world of information technology is not sure how many of its 800 staff are chartered engineers, but does know it pays CEng fees for six. The Civil Aviation Authority is still assembling its database.

11. Thus the numbers of engineers in agencies and regulators is higher as is to be expected but not dramatically so. Incident investigation units were the honourable exception to these modest percentages. My broad conclusion is that the strength of engineering knowledge in government is largely the result of accident; that, despite the Professional Skills Agenda, there is not much evidence of nurturing professional skills; that neither sponsor departments nor supervisory boards seem to take much interest in human capital in engineering as part of a statutory function's "balanced scorecard"; that, while there may be no magic percentage of engineers in public service, other pressures mean the UK is likely to have ended up with too few not too many.

Buying in Engineering Advice

12. Whether any organisation actually needs in-house engineering skills depends on what it wants to do. You don't need to know how to build a bus to buy a bus ticket. When the organisation intends to do something that has never been done before it needs to be equipped to make judgements.

13. The least contentious case is when in-house staff outsources engineering analysis that they could have completed themselves so that they have more time to focus on the most difficult issues. The organisation is then always able to appraise the advice it receives. The case where the organisation is able to formulate the problem but is not able to devise any solution itself is more problematic. Who bears the risk if the ill-equipped organisation takes the advice offered? Again if the issue is simple there is no issue. But if the organisation's intention is to be "innovative" without it acquiring the capacity to assess risks, the picture changes. In particular the consultant in formulating advice needs to be more diffident bearing in mind the need for due diligence. This is especially true if public discourse is content to allow a failure to be blamed on the contractor not the contract! The weaker the in-house expertise the less likely the organisation itself realises the change in the style of advice provoked by contractor risk management. Governments of course are faced with a barrage of counter proposals by lobbyists whenever they propose to act. The less able they

are to evaluate these the more likely they are to end up prevaricating. The worse case of all is when the organisation is capable of only a poor formulation of the problem let alone any assessment of conflicting "answers".

14. In my experience contractors would much prefer to work with the first case's "intelligent customers". The need for these beings has been posited since the days of the Rothschild "Customer-Contractor" model of research procurement, periodically repeated in reviews, but seldom realised. While the first case is presumably the ideal, the immediate public interest priority is to avoid the UK public sector slipping into the third case of bemused organisational ignorance.

15. As a recent example of the issues, Government accepted the recommendation of the Commission on Environmental Markets and Economic Performance on which I served to have a more technically proactive procurement policy. Innovation Nation rightly proposes obtaining private sector advice in formulating tenders to provoke more innovative proposals but it is silent as to how in the proposals received the innovative are to be distinguished from the disasters. In contrast Transport for London staffed itself not only to procure but also to assess innovative proposals. The DCLG call for "Eco-town" made much of proposals needing to showcase innovative technology, but as the Royal Academy of Engineering noted in its response it did not actually include any engineers on the proposal review panel. This is despite engineering failures of untested technologies playing an important role in the difficulties of many "third wave" New Towns in the 1970s.

16. There is a particular problem in the UK because Treasury often has a formative part in shaping as well as funding initiatives. While acknowledging the undoubted skill set of public sector economists, there is no reason to expect that they have much experience in either the risk management issues or the modality of operation of real world engineering enterprises. The Treasury Green Book used as the basis for policy appraisal does not distinguish engineering innovation issues at all. Treasury of course does not have a Chief Scientist.

Is it Different Abroad?

17. I have given advice on using scientific advice to policy making to Commonwealth Governments and the European Commission. It would seem that the tension between political and specialist advice is here to stay. Outsourcing of engineering advice is widespread. The European Commission retained a single consultant to inform its antitrust action against the might of Microsoft. But none, including the US, seem to have gone as far as the UK in the degree to which they have distanced engineering knowledge from the Centre. Almost all countries, including the European Commission, have at least retained some engineering research capability that can serve as a resource for staffing headquarters functions. The US has a much more flexible career relationship between private and public sectors at Federal and State level. The US National Academy of Engineering records 7% of its members as in the "government and not-for-profit" sector, in contrast to around 3% (my estimate of the NAE equivalent) in the Royal Academy of Engineering. In stark contrast the "Asian Tiger" Model has been to throw the throttle full on in the other direction with very strong technocratic administrations.

Training and Skills

18. If the public sector has forgotten about engineering, engineering education seems to have forgotten about work in the public sector. The much applauded Royal Academy of Engineering report on engineering education (Educating Engineers for the 21st Century 2007) makes no mention of training to acquire skills to work within Government and Agencies. Imperial and Cambridge, amongst the top five European engineering schools record less than 2% of their UK resident engineering graduates entering the whole public sector. I have not myself ever given much credibility to Civil Service "science and technology fast stream" entry. Its current undemanding first degree requirements underlie the point. In any case it is far more important to understand how engineers with real world experience are brought into the public sector, and how they are trained to work within public policy. Of the 16 specialist programmes at the National School of Government (NSG), none are designed for mature entry engineering specialists. The only NSG induction programme I have found was for economists. Indeed none of the six qualities highlighted by the Civil Service Commission Recruitment Gateway for "experienced professionals" entry seems to require actually knowing anything in any detail. There are more demanding entry requirements for "professionals" but none of these classes cover engineering or science in civil departments.

19. There well may be some "executive" induction training for new Chief Scientists. But I doubt the problem is at this high level. After all if Ministers were uncertain about a submission, the Private Office could always invite the President of the relevant engineering institution in for a chat! The difficulty is in the many more low profile decisions taking place across the whole civil side of the public sector.

Recommendations[19]

20. Based on past experience I doubt that procedural recommendations will have much real traction. The deployment of specialist resources within the Government on say legal services, or the economics service or press offices is not capricious. Departments have to combat citizens in the Courts, Treasury in the reviews of spending and rebut the Press on a daily basis. I believe it is no accident that the one area that has been robust to my own inquiries is the high profile area of incident investigation. From outside MoD appears to take more interest in its engineering, but then its decisions are tested on the modern battlefield. If Departments were to be held more effectively accountable for "winging it" on engineering, I am confident that resources would redeploy with great ingenuity and rapidity.

21. Unfortunately those able to spot the engineering errors can be represented in uninformed public debate as interested parties, or they have little incentive to correct reasoning because they are in a good position to be paid later for putting errors right. While our journalists are required to meet standards of professionalism and in the BBC's case, impartiality, this does not include, with some outstanding exceptions, actually understanding the substance on which they are reporting. A good technical press operates in a cognoscente's world of its own. All this is of course is the public interest rationale for Departments and Agencies having some internal mastery of what they are doing. For some reason blaming the contractor not the contract has become an accepted explanation for failure in delivery. *Caveat emptor* no longer applies. That itself brings new dubious rewards for the Executive to contract out what it does not understand.

22. If the Executive was minded to be more self-reflective on its engineering capabilities my guess is that it would rapidly devise a flexible employment contract suitable for employing engineering expertise that was not a life sentence. It would correctly address the induction needed to bring in experienced engineers to work in the public sector and identify appropriate competencies at career grade. It would create a proper service-wide career pool and a proper professional development programme appropriate to public service.

September 2008

Memorandum 171

Submission from Semta

Summary

1. Semta would like to see government use the Sector Skills Council (SSC) network more effectively when engaging with the engineering sector. We are happy to work with officials in any capacity which would enable government to address the needs of the sector more appropriately. We can offer expertise on all areas of the skills landscape, as well as facilitating direct government contact with employers.

2. We would like to see consultations, legislation, and other proposals scrutinised for their impact on engineering BEFORE they reach the public domain, as we are continually having to raise these issues at a late stage in the process. Semta would be happy to contribute at an earlier stage of the consultation process.

3. An engineering "Champion" in government would be welcome—a named, high profile, authoritative advocate of engineering to speak on behalf of the sector and work across departments to raise its profile. This individual could be supported by a group of civil servants who scrutinise activity across departments to raise issues where it will impact negatively on the sector.

Semta, the Sector Skills Council for Science, Engineering and Manufacturing Technologies

4. Industry owned and led, Semta aims to increase the impact of skilled people throughout the science, engineering and manufacturing technologies sectors.

5. We work with employers to determine their current and future skills needs and to provide short and long term skills solutions, whether that be training and skills development, or campaigning with government and other organisations to change things for the better. Through our labour market intelligence and insights from employers across our sectors, we identify change needed in education and skills policy and practice, and engage with key industry partners and partners in the education and training sector, to help increase productivity at all levels in the workforce.

6. The sectors we represent are: Aerospace; Automotive; Bioscience; Electrical; Electronics; Maintenance; Marine; Mathematics; Mechanical; Metals and Engineered Metal Products.

7. Semta is part of the Skills for Business network of 25 employer-led Sector Skills Councils.

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[19] In obtaining information through FOI requests I have been at pains not to burden Departments and Agencies. No doubt in preparing their own evidence they would devote more time to precision, and if there are any discrepancies I bow to their figures. In most cases the numbers are so bald that I cannot believe the differences would be significant to my conclusions.

Engineering Advice and Government Policy-making

Representation on skills

8. We feel that government currently does not effectively use the network of Sector Skills Councils to gather information and opinion before making decisions. Through SSCs, government can access expertise and experience on a range of skills-related issues, and bring employers effectively into the policy-making process. The network was created to be "the voice of its employers, yet SSCs sometimes feel that we are the last to be considered. Semta has processes in place which would enable government to access employers directly, to present their proposals and gain feedback.

9. Semta directly represents the views of its employers at all levels of government. This is done through a variety of routes, detailed as follows, together with Semta's view on their efficacy (or otherwise).

Face-to-face meetings with ministers and officials on particular issues and subjects

10. Semta is reasonably confident that it is able to arrange meetings with appropriate ministers and officials, both on its own behalf, and on behalf of its employers. We naturally only approach government and officials for meetings where there is a subject of substance for discussion. These meetings are sometimes initiated by Semta, and sometimes by government.

11. Our experience of these meetings is that ministers and officials are generally responsive to employer concerns, and sympathetic to their needs. However, their knowledge of engineering can be low, and understanding of some of the more complex issues facing companies can be simplistic. Of course, Semta (and our employers) are keen to address this, and ministers and officials often show great enthusiasm for learning more about the sector. We are not aware of any issues around the attitude of ministers and officials to engineering—they appear interested and engaged.

Formal responses to consultations

12. Semta submits responses to consultations as part of its policy representation. These consultations are usually compiled from direct employer input (where time permits). The number and frequency of consultations coming from government which are of relevance to the engineering sector means that it can be problematic to gather meaningful responses. Semta is also observing an increasing level of cynicism, and belief that the formal consultation process is not a serious attempt to gain feedback and establish the right direction, but rather a "final stage" before implementation.

Regular meetings as part of projects and programmes underdevelopment or activity underway

13. Semta meets with officials when working of specific projects and funded programmes, as part of the process of project management and delivery.

Indirect communication through others

14. This relies on the third party to accurately communicate our views to the right people in government. This can be problematic, and our experience suggests that, on occasion, the "message" is not relayed in the right way to the right person. For example, Semta is currently experiencing a great deal of difficulty around qualifications in our sector, and their incorporation into the new Qualifications and Credit Framework in England. Our concerns are being filtered through third parties (the regulatory bodies) to civil servants. We are not confident that these third parties and their civil servant partners are then reflecting our concerns upwards to the appropriate people. This can leave ministers and senior officials in an embarrassing position, as they are unaware of any problems until we are forced to contact them directly. A specific government "Champion" for engineering might enable the sector to have a more effective voice in government.

Example of policy decision-making to illustrate concerns

15. The current apprenticeships proposals are causing considerable concern for engineering employers, who feel that many of the proposals are being introduced to support and encourage non-traditional apprenticeship sectors. The proposals suggest a single approach across the economy to address the needs of non-traditional sectors (the creation of the National Apprenticeship Service, the move of "ownership" of the apprenticeship blueprint from SSCs to the NAS, etc). We expressed these concerns on behalf of our employers early in the consultation process, but received no reassurances. It was only a meeting with David Lammy, which Semta attended with employers, which began to address these issues, with confirmation that the proposals are designed to support non-traditional sectors, but will not be allowed to compromise existing good practice in traditional sectors. Even with the minister's assertions, Semta is still unsure as to whether officials, and those who will be implementing the proposals, are aware of the minister's views, and we will continue to speak strongly in this issue until the official documentation reflects our employers' concerns.

Engineering across government

16. The engineering sector would benefit from someone with authority in government to "speak up" for its requirements across all government departments, who led a group of civil servants tasked with protecting the interests of the sector. Perhaps it would be appropriate to take equal opportunities as a model—it is common practice to scrutinise proposals and ensure any implications in this area are known and addressed. A similar approach is needed for the engineering sector. If the government accepts that the sector is key to the future prosperity of UK plc, then officials working in areas such as taxation, company law, inward investment strategy, etc must consider the impact on engineering. This would require expertise within the civil service, and the authority to influence developments.

Current levels of knowledge about engineering

17. As stated previously, while enthusiasm to support the sector is not necessarily lacking, understanding of the sector can be deficient. We have sometimes observed a lack of clarity around the definitions of "manufacturing" and "engineering", which leads to confusion and lack of confidence. The needs of the two sectors are actually quite different in many areas, as they are at very different stages of their economic cycles, and are affected by different external drivers. Civil servants need to improve their understanding of these issues, and their appreciation of the complexity of the economic landscape.

In the devolved administrations

Wales

The experience of Semta in Wales is reflected in the comments made previously, but with the additional comment that the newly-formed Manufacturing Forum is likely to be very helpful in raising the profile of manufacturing (and engineering), as well as improving understanding. Semta is looking forward to playing its part in this welcome initiative.

Scotland

The experience of Semta in Scotland is reflected in some of the comments made previously. Government in Scotland is supportive of engineering, but could use the SSC network more effectively in its decision-making and policy formation. However, the Scottish government has made additional commitment to the engineering sector in areas such as adult apprenticeships, which suggest it has a strong understanding of the particular needs of the sector.

September 2008

Memorandum 172

Submission from the Royal Academy of Engineering

1. Introduction

1.1 The overriding messages of this response are that the Government must recognise the difference between scientific advice and engineering advice and ensure that policy is appropriately informed by engineering advice at all stages of development and delivery. Presently, the Government does not articulate a clear view of the role of engineering in society or in policy making. Too often, phrases such as "science and technology" or scientific "innovation" are fielded as a substitute for "engineering".

1.2 Engineering is concerned with the art and practice of changing the world in which we live. In doing this, engineers seek to achieve useful and beneficial outcomes in the physical world and in a business context. Much Government policy is delivered by means that require engineering solutions, which need to be developed, informed and tested by engineers as part of the policy development process.

1.3 As well as informing the delivery of policy, engineers can bring perspectives to policy formation that can enhance decision-making at all stages of the policy cycle. Engineers understand how to work with risk and uncertainty in project delivery, a key element of identifying and weighing options in policy formation. In articulating the engineering issues inherent in and raised by a policy, engineers can help identify potential barriers to implementation and ways of avoiding them.

1.4 A number of key policies fundamental to the long-term national well-being have suffered and been found wanting as a result of a lack of good engineering advice being taken at the formulation stage. The Climate Change Bill, Sustainability and Planning Bill and recent Energy Bills over the last five years failed to address engineering risks and reality in delivering the engineering assets required to enable policy to be realised and targets to be met.

1.5 Government should make better use of the expertise that resides in the engineering institutions and their overarching bodies to obtain engineering advice at all stages of the policy cycle. The Royal Academy of Engineering could act as a broker in the preparation, collation and submission of profession-wide[20] advice where and when it is required.

1.6 Government needs to be an intelligent customer for the engineering advice it receives. This means having civil service staff who are able to understand and evaluate engineering advice. With the focus strongly on evidence-based policy, the civil service should have amongst its staff engineers who are able to source and assess technical evidence. Evidence-based policy in key areas such as climate change, energy supply and low-carbon transport is only achievable with the input of policy advisers with an understanding of the required evidence—and that will include engineering evidence.

1.7 There always have been highly qualified engineers employed within Government, but because engineering has generally always been seen as a policy delivery issue rather than a policy development issue, those engineers have predominantly been employed in Agencies rather than Departments. As political ideas and imperatives are developed into policy within Departments, there is a need to embed engineering advice within them.

2. Recommendations

2.1 The response makes the following recommendations which appear here in the same order as they do in the text:

(a) Certain key Departments should have Chief Engineering Advisers, rather than or as well as Chief Scientific Advisers to reflect the increased importance of engineering to those Departments. Chief Engineering Advisers in these Departments are likely to be engineers by profession (as some DCSAs already are). This would allow them to articulate and address the engineering issues faced by those Departments and would ensure that the Government Chief Scientific Adviser has access to engineering advice within his or her team. Chief Scientific Advisors and Chief Engineering Advisors also require high quality staff support within their Departments if they are to provide a service with the required breadth.

(b) Effort should be made to recruit engineers with practical experience of large-scale projects to these posts. The required remuneration package and terms of employment to attract a senior engineer from industry to a DCSA post will be necessarily different from that offered to an academic engineer expected to maintain his or her post at a university and return to it after the term of office as a DCSA.

(c) The GCSA and the DCSAs should meet regularly with the engineering profession (through the Royal Academy of Engineering, the engineering Institutions and their overarching bodies) to communicate issues of current interest and discuss the sourcing of engineering advice.

(d) Engineering advice should be sought early in the policy development process even if the engineering aspect of a problem is not obvious to policy makers.

(e) Any large-scale project should be carried out with the advice of engineers—engineers have project management skills relevant to complex projects, especially those with a technical component.

(f) Advisory committees should be established in Government Departments which should be used to identify when engineering advice is needed and on what issues. The engineering community, through the engineering institutions and the Royal Academy of Engineering could advise on members for such committees.

(g) Open and formal processes for inviting engineering advice at the onset of policy consideration should be established.

(h) Recruitment of engineers through the Fast Stream should be increased, with more engineering graduates able to forge careers within the civil service, leading to senior positions, but with the opportunity to retain engineering as a specialism.

(i) Government should actively advertise the role for engineering graduates in the civil service for policy development functions as well as through delivery Agencies, so that it is perceived to be a viable career path.

(j) The Government should require the professional registration of both its technical staff and also the staff of its consultants and suppliers to ensure that it receives the best advice from fully qualified, up to date engineers.

(k) Government should be encouraged to consider the engineering community as a resource for informing policy at all stages as the US government does with the National Academies.

(l) An understanding should be developed of how Governments in other countries take engineering advice as part of the policy process.

[20] Engineering encompasses pure civil, electrical, process and mechanical engineering, of course, but also engineering directly related to building, transportation, ICT, materials, utilities, agriculture, healthcare, and mining.

2.2 In addition to making these recommendations, the professional engineering community offers:

(a) To continue to undertake policy studies that identify matters of importance to Government policymaking, provided there is a willing recipient for those reports.

(b) To respond, as a coordinated body, to requests to give advice on draft policy and to peer review research carried out for Government, when invited.

(c) To agree a process with Government whereby the professional engineering community can provide advice on key policy topics to support Government decision-making.

3. The Role and Effectiveness of the Government Office for Science and the Chief Scientific Advisers in providing Engineering advice across Government and Communicating Issues Relating to engineering in Government to the Public

3.1 The system of Departmental Chief Scientific Advisers (DCSAs) is new—the result of an initiative of the previous Governmental Chief Scientific Adviser (GCSA), Sir David King. At this stage, it is difficult to judge the effectiveness of the system. Some general comments can, however, be made.

3.2 Firstly, the role of the GCSA is broad, intended to encompass both science and engineering. This is not, however, reflected in the department's title (Government Office for Science), unless it is simply assumed that engineering is a sub-discipline of science. But engineering is a quite different discipline, pursued in a different manner towards different ends. Engineering is concerned with solving practical problems and in changing the physical world, using scientific, technical and business skills. Science, on the other hand, is principally about understanding the nature of the world. The practical nature of engineering means that engineering advice and expertise is of great value in developing policy and delivering projects. For example, the need for engineering advice is particularly pertinent in the area of climate change. The big challenge is no longer the search for evidence for climate change but rather the search for means of avoiding its advance and mitigating its effects, many of which will be matters of engineering and technology.

3.3 The impact of the GCSA depends to a large extent on the influence of the individual DCSAs within their Departments and the strong leadership provided by the GCSA ensuring the role of the DCSAs is appreciated and understood at Cabinet level. The recent GCSAs have done a very effective job of raising the profile of the scientific aspects of policy issues, especially in the arena of climate change. The status and impact of the DCSAs depend in part on how many opportunities they have to speak to ministers. The support they get in terms of staff is also an issue as most of the DCSAs are part-time positions. Building the influence of DCSAs within their Departments might be helped by making the posts full-time and ensuring that DCSAs have appropriate and effective staff resources within Departments.

3.4 There are some Departments in which it is important that an engineer fills the DCSA role—the DfT, the MoD and potentially BERR and DIUS. In these cases, it would make sense to call these advisers Chief Engineering Advisers, to reflect the kinds of expertise needed and the advice required. In the MoD for example, there is a Chief Scientist, and the Defence Science Advisory Board. The MoD is a Department where the budgetary spend on engineering is ten times that spent on science. Science advice in MOD is a combination of blue sky research, management of applied research, operational analysis and scrutiny of technical requirements and project approvals. Engineers are involved in this but are mainly engaged in delivering equipment projects. The CSA's role is an essential element of the checks and balances over billons of pounds of public expenditure on mainly high-tech projects. Although DSTL is an agency of the MOD (employing more engineers and scientists than any other Government agency), its expertise does appear to be used by the MOD in policy formation far more than any other agency in Government. In other Departments both scientific and engineering advice is needed—DEFRA is a clear example where the life sciences and engineering are both relevant, yet the current description of the role of its CSA does not include the provision of engineering advice.[21] In these Departments, it should be made clear in the job description and potentially in the job title that providing and assessing engineering advice is a core role. It is also important that the expertise of advisers is not limited to their own Department. Many issues and the successful delivery of many policies cut across Departmental boundaries and a free exchange of engineering advice across Departments is necessary. For example, a transport issue being considered by the DCSA for the DfT might impinge on local community issues addressed by the DCLG and environmental issues addressed by DEFRA.

3.5 Many of the current DCSAs are scientists and engineers working in academia who may not have current experience of delivering major industrial projects. This could result in the CSA service struggling to provide robust advice on practical application of scientific and technical knowledge and therefore in the successful delivery of policies even where they are based on robust scientific and technical evidence. The search for DCSAs should extend beyond the world of academic research into business and industry where there is a wealth of skill in finding appropriate, cost-effective solutions to practical problems. This experience would be invaluable in helping Departments to understand practicalities of rolling out technology at scale and understanding the breadth of engineering research in the private sector, research that the Government can stimulate and can gain from.

[21] See http://www.defra.gov.uk/science/how/adviser.htm

3.6 We recommend that:

3.6.1 Certain key Departments should have Chief Engineering Advisers, rather than or as well as Chief Scientific Advisers to reflect the increased importance of engineering to those Departments. Chief Engineering Advisers in these Departments are likely to be engineers by profession (as some DCSAs already are). This would allow them to articulate and address the engineering issues faced by those Departments and would ensure that the Government Chief Scientific Adviser has access to engineering advice within his or her team. Chief Scientific Advisors and Chief Engineering Advisors also require high quality staff support within their Departments if they are to provide a service with the required breadth.

3.6.2 Effort should be made to recruit engineers with practical experience of large-scale projects to these posts. The required remuneration package and terms of employment to attract a senior engineer from industry to a DCSA post will be necessarily different from that offered to an academic engineer expected to maintain his or her post at a university and return to it after the term of office as a DCSA.

3.6.3 The GCSA and the DCSAs should meet regularly with the engineering profession (through the Royal Academy of Engineering, the engineering Institutions and their overarching bodies) to communicate issues of current interest and discuss the sourcing of engineering advice.

4. The Use of Engineering Advice in Government Policy Making and Project Delivery, including examples of Policy Decisions or Project Delivery that have been or will be taken with or without Engineering Advice

4.1 Engineers are not sufficiently often invited to contribute to policy development—their role seems to be restricted to implementation and checking of policy after the fact. But the routine engineering practices of comparing solutions for cost-effectiveness, efficacy and public acceptability would be highly valuable in informing policy decision-making at the earliest stage. Engineers' skills in project management would also be useful in scrutinising complex policy delivery.

4.2 Recent energy policy is an area of policy development that appears to have suffered as a result of lack of engineering input at an early stage. We have been told privately by reliable sources that unrealistic estimates have been made about the contribution of non-fossil fuel sources to energy supply and CO_2 emissions reduction as well as the potential carbon emissions savings of various energy efficiency measures. A sound engineering insight would have given a clearer picture of the contributions of the different energy technologies, the timescales in which they could feasibly come on-stream and the measures necessary to mitigate risk—whether technical, political, commercial or otherwise. Engineers' views are also essential to identify barriers to certain policy solutions as well as ways to circumvent or overcome them. For example, while the use of microgeneration of electricity through wind power might be recommended, this recommendation is undermined by the fact that the electricity grid is not currently[22] designed to deal with the feeding back of large amounts of power into the grid—the distribution system is designed to be one-way.

4.3 Recent plans for developing Eco-towns were drawn up with the help of a steering committee (the Eco Towns Challenge Panel) which had no engineering input. The contribution of an engineer in this case would have been to look at the intended outcome—reducing domestic carbon emissions within the UK—and assessing whether this was the best means to meet that outcome. Engineers would have been highly likely to conclude that the outcome would be better served by retro-fitting existing housing to reduce its carbon emissions, a view that seems to be emerging through the consultation process.

4.4 Large IT systems are an area of Government procurement that has and continues to experience both bad press and implementation problems. Some would assert that specifications have been driven by political imperatives rather than being derived from operational requirements; a situation which would apply to both the ID Card project and the National IT Programme (Connecting for Health). It is possible that this approach has led to decisions about the architecture of systems being taken or assumed before detailed expert advice was taken. Here, a distinction needs to be made between the advice received by Government in the procurement of systems, which is often good and realistic, and the advice received in the development of policies which are delivered through the procurement of IT, which is often lacking.

4.5 The MoD has the Defence Science Advisory Council, but there are limited opportunities for inputting engineering advice through this structure. Advisors have said that they are unable to get close to the real engineering problems themselves, and have a somewhat distant role, being asked to comment on the scientific quality of advice received in terms of the bibliometric citation rate of the authors rather than addressing the real world problems the advice has been sought to address. Although the MoD continues to struggle to deliver projects to time, cost and performance, it appears more likely to take engineering advice than other Departments. The recent review of the Royal Navy procurement of two large aircraft carriers by Sir John Parker FREng was instigated at a late stage to give the Government comfort that the contract could be managed and delivered by industry. It is welcome that the Government should seek such advice, but it could be an integral part of the procurement process for difficult projects rather than a late stage add-on.

[22] Although, with some planning and investment, engineered solutions can be provided.

4.6 Although aspects of risk are routinely addressed in the assessment and development of policy, the specifics of engineering risk are more often than not entirely missed. As an engineering concept of risk is wide, including project risk as well as risk of failure or catastrophe, an appreciation of it in the policy development phase when implementation relies on engineering would be advisable. In many cases, particularly in energy policy, the financial risk that investors are expected to take on has been badly assessed, leading to financial incentive structures being put into place that can actually increase risk to investors.

4.7 We recommend that:

4.7.1 Engineering advice should be sought early in the policy development process even if the engineering aspect of a problem is not obvious to policy makers.

4.7.2 Any large-scale project should be carried out with the advice of engineers—engineers have project management skills relevant to complex projects, especially those with a technical component.

5. How Government Identifies the need for Engineering Advice and how Government Sources Engineering Advice

5.1 From the point of view of the profession, there are neither established means by which Government decides when engineering advice is required nor what advice specifically is needed. There is also no clear, open and formal process by which individuals or groups are invited to provide advice or proposals. This style of much policy making has led to some individual engineers and industrialists being called on to provide policy advice, however this advice is seldom peer reviewed. It would, however, be possible for Government to access a broader range of engineering advice by means of a more formal policy-making process that would call for advice and ideas at a much earlier stage than at present. The current formal consultation stage in policy-making, where open invitations for evidence are made, is generally at a late stage of policy development by which time the direction of travel is often already framed and the opportunities to explore alternative solutions are closed.

5.2 The Government often procures engineering advice from external consultants which is of variable quality. For instance, we understand that some reports produced for the DfT Low Carbon Cars strategy produced by third party consultants under extreme time pressures contained inaccuracies that would be obvious to an engineer with relevant expertise, but not necessarily to an official without that expertise or access to it. Engineering expertise is needed within Government Departments to ensure the quality of the procurement and quality control of that advice.

5.3 Advisory committees such as DSAC in the MoD and the interdisciplinary committee in the Home Office have great potential value in advising Departments on whether engineering advice would be valuable to inform policy development and planning policy implementation. There are engineers with the relevant experience on these committees to fulfill this role and it is the duty of the relevant Departments to engage them appropriately.

5.4 Greater use could also be made of university research, but there are obstacles to academic-Government interaction. As will be discussed in a forthcoming Council for Science and Technology (CST) report, there are disincentives for academics to carry out research for Government use. The results are often secret, or at least not published, so they cannot be used by the academic as examples of their work. Government Departments may offer little remuneration or may expect work to be carried out *pro bono*. Often the process of setting out what advice is needed is too extended, meaning that academics may have moved on to other projects between being invited to provide advice to Government and receiving the details of the arrangement. The Academy's experience of helping to place engineers on advisory panels for various Departments and Agencies is that remuneration or honoraria range from average to inadequate considering the amount of expertise and engagement requested.

5.5 The CST itself is a valuable source of advice on engineering. Although the title does not include "Engineering", the Council includes many engineers amongst its membership (with more Fellows of The Royal Academy of Engineering than of The Royal Society). But Government rarely proactively seeks advice from the CST and the reports produced by the CST are not always heeded. The CST's report Better use of personal information: opportunities and risks (November 2005), is a salient case in point that contained timely advice the Government would have done well to heed.

5.6 The issue of engineering advice also extends to advice about how to ensure an adequate supply of competent professional engineers and technicians. Here, the Royal Academy of Engineering and the engineering institutions have worked closely to respond to Government wish to clarify and strengthen careers advice. However, in the field of education, despite the importance of engineering to the economy, advice tends to be sought first from the Sector Skills Councils, and rarely specifically solicited from the profession. This can lead to short-sightedness on the part of Government on such issues as the Bologna Declaration, and the development of the new points-based immigration rules (which fail to recognise professional qualifications).

5.7 We recommend that:

5.7.1 Advisory committees should be established in Government Departments which should be used to identify when engineering advice is needed and on what issues. The engineering community, through the engineering institutions and the Royal Academy of Engineering could advise on members for such committees.

5.7.2 Open and formal processes for inviting engineering advice at the onset of policy consideration should be established.

6. The Status of Engineering and Engineers within the Civil Service, including Assessments of the Effectiveness of the Science and Engineering Fast Streams, and the Role and Career Prospects of Specialist Engineers in the Civil Service

6.1 The Fast Stream of the Civil Service encourages a culture of educated generalism. Fast streamers spend time in all parts of a Department to gain an understanding of all aspects—giving the ability to take a broader view. However, the focus on handling a new brief every two to three years and delivering ministerial advice pulls against the retention of specialist skills and knowledge. Within the Science and Engineering Fast Stream it may be possible for engineering graduates to specialise in engineering-related projects, but the numbers of graduates entering via this route is small—15 in 2007–08 compared with 190 recruited to central departments and 100 into the Economics Fast Stream. And of course, this number encompasses both science and engineering graduates and it is likely that the greater proportion is from science.

6.2 In Government, the focus is strongly on evidence-based policy, so it would seem important that it has amongst its staff engineers and scientists able to source and assess technical evidence. Evidence-based policy in key areas such as climate change, energy supply, low carbon transport and so on is only achievable with the input of policy advisers with an understanding of the required evidence—and that will include engineering and other technical evidence, whereas this is currently done by analysis professionals, usually with an economics background.

6.3 More engineers are needed within the civil service if Government is to be a genuinely intelligent customer of external advice, with sufficient expertise to be certain of knowing what questions to ask and to assess the accuracy of answers returned. The potential for establishing Government policy on incorrect evidence is of concern. For example, the errors in the reports on low carbon cars for the DfT could have been used to make policy decisions. There is therefore a pressing need for more engineers within the civil service, as lack of engineering expertise can lead to financially and politically costly errors. There must not only be a recognised career path for engineers within the civil service, but engineers must be recognised for their contribution to the policy making process and must not be perceived as career limited as compared to other professions within the civil service.

6.4 However it is not just a numbers game. The competence of those in post should not be taken for granted in such a fast moving profession. The engineering institutions exist, in part, to develop and maintain high professional standards in engineering. The institutions assess and register engineers to the standards agreed by ECuk and all require their members to comply with a professional code of conduct. Most provide information, continuing professional development and networking opportunities that enable engineers to stay up to date and competent. Whilst this may appear to be self promotion on the part of the engineering institutions, we contend that Government can only be confident with the advice it receives if it has been provided by a competent, assessed practitioner.

6.5 We recommend that:

6.5.1 Recruitment of engineers through the Fast Stream should be increased, with more engineering graduates able to forge careers within the civil service, leading to senior positions, but with the opportunity to retain engineering as a specialism.

6.5.2 Government should actively advertise the role for engineering graduates in the civil service for policy development functions as well as through delivery Agencies, so that it is perceived to be a viable career path.

6.5.3 The Government should require the professional registration of both its technical staff and also the staff of its consultants and suppliers to ensure that it receives the best advice from fully qualified, up to date engineers.

7. The Role and Effectiveness of Professional Engineers and the Engineering Community in Promoting Engineering and providing Engineering Advice to Government and the Civil Service

7.1 The professional engineering organisations have the potential to make a significant contribution to Government policy. The focus of the professions is the public good and the engineering profession seeks to improve quality of life through its work. Therefore, professional bodies have a duty to input to public policy processes. The engineering bodies have a greater interest in providing such advice than does industry which naturally focuses on growing a market, shareholder value, international competitiveness and so on. We support the advice of the erstwhile Science and Technology Committee in its 2006 report Scientific advice, risk and evidence-based policy making that Government should turn more readily to the profession and learned societies.

7.2 Individually and collectively, the engineering institutions offer what advice they can but recognise that this advice must be well co-ordinated and focused. The institutions, with The Royal Academy of Engineering acting as focal point, are, however, able to commit to provide Government with detailed, co-ordinated, professional advice. However, for this to work optimally, an agreed, clear mechanism for dialogue will be needed. A number of engineering institutions as well as the Academy already publish high quality policy advice to Government,[23] but better communication would ensure that this advice were more timely, constructive and informative.

7.3 The institutions and The Royal Academy of Engineering could help provide engineering advisory committees for key Government Departments to assist Departments in scoping questions for consultants and peer-reviewing the resulting work. Such committees could also comment on the feasibility of policies such as the national ID card plan to highlight strategic engineering and technical issues around their delivery. A positive example of such an undertaking is the engineering advisory group convened by BERR for the Severn Barrage feasibility study, comprising members of The Royal Academy of Engineering, the IET, IMechE, IChemE and the ICE.

7.4 However, there is always a limit on how quickly a group of professional engineers providing advice on a voluntary basis can produce the information needed by Government Departments. The engineering community should not be the sole source of engineering advice—there must also be competent engineers within Departments who can provide engineering expertise and assess the work of consultants. It is most important that engineering is embedded in the civil service so that policymakers are alive to the engineering aspects of policy and know when to ask for advice and how to use it.

7.5 A more structured process for the provision of advice, agreed by Government and the professional engineering community, would greatly improve the effectiveness of the provision of independent advice.

7.6 We offer:

7.6.1 To continue to undertake policy studies that identify matters of importance to Government policymaking, provided there is a willing recipient for those reports.

7.6.2 To respond, as a coordinated body, to requests to give advice on draft policy and to peer review research carried out for Government, when invited.

7.6.3 To agree a process with Government whereby the professional engineering community can provide advice on key policy topics to support Government decision-making.

8. International examples of how Engineers and Engineering advice are Embedded in Government

8.1 In the USA, there is a constitutional relationship between the Executive, the Legislature and the National Academies, with the Executive and Congress procuring research through the National Research Council (NRC). As a result, the US National Academy of Engineering (which stands in a similar relationship to the US engineering societies as The Royal Academy of Engineering does to the engineering institutions in the UK), is a large, well-staffed organisation that is able to be responsive to the needs of Government. Although the National Academies in the USA were established with this relationship intended from the outset, the engineering community in the UK, with The Royal Academy of Engineering as the co-ordinating body, could develop a similar role. This could become a two-way communications channel between the community and Government, with Government requesting advice and the community responding promptly. The collaboration between The Royal Academy of Engineering and the Royal Society on the Nanoscience and Nanotechnologies report, which was commissioned by Government, is very much in the US mould. Opportunities for similar projects that bring together experts from the engineering community should be sought by both Government and the engineering community. In summer 2007, an offer was made to the Treasury and BERR by the engineering community to produce a report on the engineering aspects of climate change. This was not taken up but would have been a substantial piece of work of great value in informing energy policy.

8.2 Another initiative to adopt from the USA might be the secondment of senior engineers to Government departments. In the USA engineers are seconded to departments such as Department of Defense and Department of Energy. This would be an effective way for Government to make use of the experience of engineers in industry.

8.3 In China the engineering professions and government have strong links. Obviously the political systems in this country differs significantly from that in China, but the close relationship between engineering and government and the status of engineers within government is something that the UK should

[23] Some recent examples are recent typical examples being the Flooding Report issued by the Institution of Civil Engineers in June 2008 http://www.ice.org.uk/downloads/2008_flooding.pdf, the IMechE Low Carbon Transport Report in March 2008 http://tinyurl.com/6bq2bm, and the Need for Domestic Air Services in the UK, published by the Royal Aeronautical Society in August 2008 http://tinyurl.com/5td67z

learn from. If it is possible to understand why engineers have this greater involvement and if it were possible to make some steps toward creating such a situation in the UK, it could have great benefit for the Government in being able to deal with engineering challenges.

8.4 The Australian Government is focusing effort on exploiting engineering expertise through the Prime Minister's Innovation, Science & Engineering Council. The title of the relevant senior position, held recently by former Institution of Chemical Engineers President Dr Robin Batterham FREng, was Chief Scientist; however the Council's scope clearly included engineering. The Australian government is also developing a body of experts on software systems engineering and looking for international expertise to populate it. It is essential that our Government recognises the need to use global engineering expertise as engineering challenges require the best thinkers from around the world.

8.5 We recommend that:

8.5.1. Government should be encouraged to consider the engineering community as a resource for informing policy at all stages as the US government does with the National Academies.

8.5.2 An understanding should be developed of how Governments in other countries take engineering advice as part of the policy process.

September 2008

This response has been prepared by The Royal Academy of Engineering with the input and support of a large body of organisations from across the engineering community, whose names are listed below:

Signatories

The British Computer Society;

The British Nuclear Engineering Society;

The Chartered Institution of Building Services Engineers;

The Engineering and Technology Board;

The Energy Institute;

Engineering Council UK;

The Institute of Acoustics;

The Institute of Healthcare Engineering and Estate Management;

The Institute of Highway Incorporated Engineers;

The Institute of Marine Engineering Science and Technology;

The Institute of Materials, Minerals and Mining;

The Institute of Measurement and Control;

The Institution of Agricultural Engineers;

The Institution of Civil Engineers;

The Institution of Chemical Engineers;

The Institution of Engineering and Technology;

The Institution of Engineering Designers;

The Institution of Lighting Engineers;

The Institution of Mechanical Engineers;

The Institution of Nuclear Engineers;

The Institution of Railway Signal Engineers;

The Institution of Royal Engineers;

The Institution of Structural Engineers;

The Institution of Water Officers;

The Royal Academy of Engineering;

The Royal Aeronautical Society;

The Royal Institution of Naval Architects;

The Society of Environmental Engineers; and

The Welding Institute.

Memorandum 173

Submission from the Institution of Engineering and Technology

1. Introduction

- The IET fully supports the evidence submitted jointly by the engineering institutions. We provide the following information as additional evidence from IET members.
- In general the IET considers that the Government's use of engineering advice and in particular its use of the engineering resource represented by the engineering institutions has been ad-hoc and uncoordinated in nature. Whilst the engineering profession might not fully appreciate the Government's position or its requirements, we would argue that the Government does not formally acknowledge the role of engineering in policy making and perhaps does not realise the resources available.
- We are confident that the profession, through the Institutions and engineering organisations, would welcome the opportunity to work with the Government to establish an engineering strategy for the UK.

2. The Status of Engineering and Engineers within the Civil Service, including Assessments of the Effectiveness of the Science and Engineering Fast Streams, and the Role and Career Prospects of Specialist Engineers in the Civil Service

2.1 As one might expect, the status of engineering varies from department to department. For example there are many engineers in the MoD, the DfT and particularly within their agencies. Evidence for policymaking in departments is gathered from the engineering experts, who are in turn expected to present their expertise in terms of policy options. The very nature of engineering can and does result in different experts presenting contrary advice, particularly where there is incomplete evidence available. In some circumstances, a generalist civil servant would have to weigh up the options and recommend one course of action to their Minister.

2.2 Other departments have seen a reduction in their engineering competence. For example, following Government's "arms length" approach to the liberalised energy market, we believe that the internal engineering expertise within BERR has reduced. For example, when Dr Peter Fenwick retired as Chief Engineering Inspector at BERR he was not replaced. That is not to say that the department does not seek relevant expertise, however the use of consultants and seconding engineers from industry may not provide the impartial advice that is required.

2.3 Where external engineering advice is obtained, there is some concern that there is often only low level management of these activities, which focuses on meeting the political drivers, with much of the complexity of the engineering challenges filtered out to in order to provide easily digestible "sound bites".

2.4 In some departments there is a poor understanding of science and engineering within the non specialist Civil Service (as within society as a whole). This leads not only to misunderstanding, but also to distrust as suspicions may arise that engineers and scientists are deliberately taking the debate outside of the non specialist's understanding for their own advantage.

2.5 There is a fear that there has been a general fall in the status of engineering and engineers with the central Civil Service, caused in part by the separation of policy execution from policy formation which takes the experts "away from the action". This may be an area the Committee may wish to investigate.

2.6 The Civil Service moves its senior staff regularly across departments; however in complex areas of policy such as energy, this does result in a damaging loss of understanding and continuity and ultimately adversely affects the credibility of the department. We contend that the length of the learning curve required in such department should be considered when placing and moving senior staff.

2.7 Information Technology is another area where the complexity of the issues requires greater technical understanding and which could benefit from independent, impartial advice. IT systems tend to be treated by government departments as purely technical projects, rather than business change programmes. Examples include the CSA, tax credits and the DfH's National Programme for IT. The engineering profession has proposed a procurement model for IT systems, but there seems little evidence that it will be accepted by government departments despite the successive failures of Government IT projects

2.8 Regarding Civil Service career paths, there used to be special complementary schemes within the Civil Service to reflect three things:

- a technical expert would normally be expected to become a manager at a middling level but there was still a need for out and out specialists;
- Special Merit permitted promoting an expert in post up to Grade 6 and was generally assumed to mean working on full time engineering duties with no administrative responsibilities; and

— Individual Merit Promotion took this even further and there was no limit: a central CSC committee assessed and promoted the very few who were seen as world class experts to be managed off complement and treated as special assets.

2.9 Making career progression possible without management responsibility is a common problem across the engineering profession. Many technical experts find themselves encouraged to leave "real engineering" and go into management positions in order to progress their careers. The Civil Service merit schemes provided the opportunity for individuals to retain their engineering focus and gain "promotion" whilst maintaining the corporate technical knowledge within departments. The Committee may wish to investigate if the current Professional Skills for Government framework allows expertise to be rewarded, nurtured and maintained.

3. International examples of how Engineers and Engineering Advice are Embedded in Government

3.1 The following evidence is the experience of some IET members in those countries.

3.2 *New Zealand*

3.3 The Institution of Professional Engineers of New Zealand (IPENZ) provides a central focus for government to seek advice. The size of the population and the less formal atmosphere allows for easier communication between organisations such as the IPENZ and policymakers.

3.4 *Italy*

3.5 The engineering profession is more formally controlled in Italy, with the National Council of Engineers (CNI) representing the profession at the national level. The CNI is regulated by law and gives its opinion on parliamentary bills and regulations relevant to the profession, including the setting of professional fees. The CNI performs a primary role of promoting, developing and enhancing engineers' activities to increase their incidence in the society where they operate. It has become more active in pursuing the development of the technical and cultural knowledge of engineers and in enhancing a higher social and political recognition of the leading role engineers have in the evolution and change processes. Unlike the UK, in Italy professional registration is compulsory, and is achieved through academic attainment and passing a State examination.

3.6 Despite this formal relationship, anecdotal evidence would suggest that the Italian Government seldom appoints individual expert engineers onto working groups and committees

3.7 *Hong Kong*

3.8 The Hong Kong Special Administrative Region (HKSAR) Government has two major Policy Bureaus—the Development Bureau and the Environment Bureau—that are formulating engineering-related policies and overseeing numerous departments and agencies responsible for the capital project works and everyday works covering water supplies, drainage, civil, structural, E&M, geotechnical, town planning, etc. The Permanent Secretary (Works) is normally a veteran engineer who advises the HKSAR Government at the Policy Bureau level. The Heads of Works Departments are, again, experienced engineers in respective disciplines.

3.9 The 60 member Legislative Council (LegCo), under Basic Law, has its main functions to enact laws; examine and approve budget; and monitor the works of the HKSAR Government. One half of the LegCo Members are directly elected while the remaining half represents functional constituencies including one seat from engineering. That particular LegCo Member is, by default, an engineer, elected by the professional registered engineers who are normally members of the Hong Kong Institution of Engineers (HKIE). This LegCo Member has a mandate to advise Government on the engineering-related policies with his voice representing engineers-at-large in Hong Kong.

3.10 As in the UK, from time to time, the HKSAR Government conducts public consultations to seek comments and views from the public, including the professional bodies as part and partial of their policy making process. It is up to the professional bodies to submit their views and opinions to HKSAR Government with a view to influencing the Chief Executive and Principal Officials on the matters of policy, budget allocations, and priorities settings.

September 2008

Memorandum 174

Submission from the Engineering and Technology Board

Summary

Engineering is vital not only to our economy but also to solving many of society's most pressing problems. Engineers are key to providing solutions to global challenges such as climate change, renewable energy and clean water. Consequently it is vital that the UK can access a ready supply of highly skilled engineers and technicians. Government, through its Science and Innovation policy and programmes, has a vital role to play in ensuring a well founded science and technology base. Within Government, whilst DIUS leads on Science, Innovation and Skills, the role and contribution of engineers, engineering and technology impact upon virtually all Government Departments.

The Engineering and Technology Board's (ETB) purpose is "to promote the vital role of engineers, engineering and technology in our society and to inspire people to pursue careers at all levels in engineering and technology".

Its strategic goals are:

- to improve the perception of engineers and engineering;
- to improve the supply of engineers; and
- to raise awareness and credibility of the ETB with key stakeholders.

The ETB partners business and industry, Government and the wider science and technology community: producing evidence on the state of engineering; sharing knowledge within engineering; and inspiring young people to choose a career in engineering, matching employers' demand for skills.

We recognise the crucial role that government plays in driving forwad the innovation agenda and specifically welcome its interest in harnessing enginering skills and technologies for UK plc through its Enginering Inquiry. The ETB has already responded to this major inquiry into engineering and supports the undertaking of this case study Engineering in Government. In this regard we would remind the committee that ETB-commissioned research, which quantifies the contribution of Science, Engineering and Technology (SET) to the UK economy, indicates that SET-intensive sectors produced £252.3 billion (27.3%) of the total UK gross value added (GVA) in 2002 and that the high SET-intensive sectors contributed 27.1% of the improvement in labour productivity over 1993 to 2000: science, engineering and technology are key drivers of productivity.

Additionally, there are about 2.5 million people in SET occupations in the UK, both within the SET intensive sectors and elsewhere, including services. SET skills are fundamental to our economy's success, yet among SET employers and occupations, women represent a significantly under-utilised resource. Also appropriate skills at the technician level are becoming scarce.

As well as the above general comment, the ETB also provides the following specific response to issues cited in the Engineering in Government case study.

1. The Role and Effectiveness of the Government Office for Science and the Chief Scientific Advisers in providing Engineering advice across Government and Communicating Issues relating to Engineering in Government to the Public

(a) We note that many of the science and technology issues facing Government are common to several Departments, so individual Chief Scientific Advisers (CSA) will be frequently called upon to advise on matters which have common technological foundations. We also note that the individual backgrounds of CSA's are diverse and complementary. Despite the formal job title, it should be recognised that some are distinguished engineers. The input for engineering from suitably qualified personnel must be maintained.

(b() We commend the coordinating initiatives of the Government Chief Scientific Adviser and groups of individual CSAs in tapping into their collective experience and the UK expert base through the Royal Society, the Royal Academy of Engineering and individual science and engineering institutions. This is particularly important in new and emerging areas of which sustainable systems engineering is a good example.

2. The use of Engineering Advice in Government Policy Making and Project Delivery, including examples of Policy Decisions or Project Delivery that have been or will be taken with or without Engineering Advice

(a) Science, engineering and technology have evolved into a continuum. Thus it is often difficult to separate their individual roles in providing solutions to the sorts of problems that impinge upon Government policy. Government is, therefore, unlikely to seek engineering advice in isolation but rather advice that is underpinned by mathematics, science engineering and technology. For example, dealing with the outbreak of Foot and Mouth depended upon the combined advice of mathematicians, chemists, biochemists and engineers. Similarly the risk management of flooding in the UK (post Hurricane Katrina) involved advice from across the spectrum of leading edge mathematical modelling to heavy civil engineering advice sourced from our Institutions.

3. How Government identifies the need for Engineering advice and how Government sources Engineering Advice

(a) Engineering professionals are members of Institutions and networks of peers. The Chief Scientific Advisers and their staff are well plugged into these networks so they are likely to be only one or two steps away from independent authoritative specialist advice.

(b) The vast majority of the UK's top engineers are Fellows of the Royal Society, the Royal Academy of Engineering and the major Professional Engineering Institutions. The Chief Scientific Advisers fall into this group themselves. The Fellows are, therefore, the group that are the source of expert engineering advice.

(c) The major challenge is for the Chief Scientific Adviser on behalf of the Government, to determine the nature of the advice that is currently needed and importantly identify future issues where early advice could be sought.

4. The Status of Engineering and Engineers within the Civil Service, including Assessments of the Effectiveness of the Science and Engineering Fast Streams, and the Role and Career Prospects of Specialist Engineers in the Civil Service

(a) In some Government Departments the term "engineer" was synonymous with "technician" so that professional engineers were described as "scientists". It is important that the civil service recognises and embraces the professionalism and contribution of its graduate scientists and engineers.

(b) The science and engineering institutions have professional competence-based grades of membership that have international currency.

(c) The ETB recommends that the effectiveness, status and career prospects of the science and engineering members the civil service, including fast streamers, would be greatly improved if they were encouraged to follow the initial and continuous professional development (IPD/ CPD) offered by a science or engineering institution.

(d) Governments Departments should pay the fees for such membership and professional development.

(e) We also note and welcome the recent announcement by DIUS through its current *A Vision for Science and Society* consultation para. 6.12. which states: Within government, the Government's Chief Scientific Adviser (GCSA) is leading work to strengthen the skills and raise the profile of the science and engineering community within the Civil Service, a major employer of scientifically skilled workers. Key to achieving this is the revitalisation of the HoSEP (Head of Science and Engineering Profession) network.

5. The Role and Effectiveness of Professional Engineers and the Engineering Community in promoting Engineering and providing Engineering Advice to Government and the Civil Service

(a) The role of the ETB is to promote the vital contribution of engineers, engineering and technology to our society. This includes their promotion to Government and the civil service.

(b) In this context "the ETB" means the Chairman, Chief Executive and the other fifteen members of the ETB Board.

(c) The ETB believes that with a newly constituted Board which is more representative of the broad engineering community coupled with a proactive partnership based engagement strategy the Government and the civil service will experience a step change in the effectiveness of the promotion of engineering.

6. International examples of how Engineers and Engineering Advice are imbedded in Government

(a) Generally, other nations do not have the multiplicity of engineering institutions (nor the rich science and technology base). In these cases, independent advice is achieved through the single professional institution/academy. In others, there are large Government funded agencies that provide expert advice. We would suggest that DIUS should look at these different national models with the view to extracting best practice that can be translated into the UK.

September 2008

Memorandum 175

Submission from the Engineering Council UK

1. The Engineering Council UK has contacts with many engineers' organisations around the world, both informally and through membership of the European association, FEANI (the European Federation of National Engineering Associations—www.feani.org) and worldwide through the International Engineering Alliance—www.ieagreements.org). ECUK used these contacts to canvas equivalent regulatory authorities around the world in order to provide an up to date response to this question. This paper is therefore directly based on their responses.

2. In the USA the Government largely interacts with engineering on policy matters and seeks advice through the National Academy of Engineering (equivalent to The Royal Academy of Engineering) and the National Research Council. On occasion, on a topical matter, they will interact with one of the engineering societies, of which there are several dozen. The Office of Science and Technology Policy (an office of the President) advises the President on science policy and seeks input from the science and engineering community from time to time. Government agencies have advisory boards, and *ad hoc* advisory panels to varying degrees.

3. However, on professional engineering and professional registration matters, the individual States work closely with the State Boards (statutory regulators) and the National Council for Examination of Engineering and Surveying.

4. The European Federation of National Engineering Associations (FEANI), of which ECUK is a leading member, has close links with the European Commission, in particular the Internal Market DG and the Employment, Social Affairs and Equal Opportunities DG. Typically, the Energy and Transport DG recently asked FEANI to collaborate by providing advice in an initiative reviewing shortages of nuclear engineers across Europe. FEANI is increasing its links with the European Parliament and as a result was the only professional association asked to present evidence at the European Parliament hearing on the European Institute of Technology.

5. Within Europe, the engineering profession in Germany has the loosest formal relationships with Government. These are mainly conducted through the joint technical and scientific organisation, the DVT (Deutscher Verband technisch-wissenschaftlicher Vereine). The DVT and the society of German engineers, VDI (Vereine Deutscher Ingeniuere) have good relations with governmental authorities, who regularly consult them on general engineering matters. Examples include the introduction of energy performance certification for buildings, and the Ingenieurgesetze der Lander (Engineering laws in the regional departments of Germany), which were drafted with the input of the VDI and DVT. At the official hearing of the Ministry concerned with the recent draft Energy Savings Order, VDI experts were able to demonstrate how the Bill could be improved. VDI is one of the largest organisations of its type, and includes many specialist divisions

6. In Italy and Greece, there are formal organisations that both regulate engineers and advise Government. In Italy, the Consiglio Nazionale degli Ingenieri (CNI—National Council of Engineers) is an association set up by public law for the purpose of overseeing the organisation of the engineering sector at a national level. It operates under the jurisdiction of the Ministry of Justice. CNI acts as a consultant to both Parliament and the Government on the practice of the profession and on general engineering issues.

7. The Technical Chamber of Greece (TEE) is the official advisor to the State on all technical matters (part 2 article 4 Law 1486/1984). All qualified engineers are members.

8. TEE contributes to Government permanent and special scientific committees and supervises six thematic offices that study scientific, technological and development issues that concern society. TEE also provides specifications and technical directives that facilitate the work of engineers and contribute to the quality improvement of services and products offered to society.

9. In Ireland, Government has an Office of Public Works, retaining considerable engineering expertise to advise them on infrastructure and utilities. The Government works closely with Engineers Ireland, the Irish equivalent of the Engineering Council and the professional engineering societies combined, co-funding their work to promote engineering, and their project to encourage greater take-up of continuing professional development (CPD) of engineers.

10. In the Far East the engineering profession is embedded in the legislative process. Hong Kong provides a place as of right for the engineering profession in their Legislative Council.

11. In Taiwan the Government has several high level offices and committees who provide engineering advice. The Office of the President has a Technology Advisory Committee as well as the Economic Development Advisory Committee. Members of these committees are senior academics or senior industry leaders. The following five offices govern national policy issues within the Executive Yuan (the Cabinet), under the premier:

- Public Construction Commission (the licensing body for professional engineers);
- Department of Engineering and Applied Sciences of the National Science Council;
- Advisory Office of the Ministry of Education; and

— National Energy Conference/Bureau of Energy, Ministry of Economic Affairs Council for Economic Planning and Development.

12. In both Hong Kong and Taiwan, professional engineering societies play key roles in shaping Government policies. Members of these societies are often invited by Government to offer professional advice on national projects, or in other related capacities.

13. In Japan, Government ministries that are responsible for matters related to science and technology retain engineering officials in their administrations. However, those who engage in policy making, planning legislation, project planning and management tasks related to science and technology are administrative officers with law and economics backgrounds. In most cases, engineering officials play a subsidiary role in these matters.

14. Besides their engineering officials, each government ministry has an associated research institute. In recent times most of them have become independent administrative corporations. These agencies (institutes) provide the controlling ministry with necessary supporting information for administrative activities. Administrative bodies that are in charge of public works employ many engineers in house.

15. In general, government decision making follows Basic Plans. However, for non-routine decision-making, advisory panels or commissions draw on academia and other experts to provide opinions and suggestions.

Conclusions

16. The responses received indicate a range of ways in which engineers inform overseas governments' policies and operation but the common feature is that there is a greater interaction, particularly in a structured way, than is the case in the UK.

17. The overseas organisations who replied have a variety of structures and remits so are not exactly parallel to the UK case. However, it does appear that national Governments' willingness to seek advice from the leading professional bodies has made them more cohesive and better able to respond quickly to policy development needs. It is possible to perceive a system in which the Royal Academy and the discipline-specific expertise of the UK professional engineering institutions would be used to inform engineering policy. ECUK's knowledge of the requirements for professional competence and academic qualifications (including their international benchmarks) could be used to inform government on engineers, particularly their education and training, recognition of competence and supply and demand.

Further Information

18. Further information can be provided through ECUK CEO Andrew Ramsay, Head of International Recognition Dr Jim Birch, or Chairman of the ECUK International Advisory Committee, David Long.

September 2008

Memorandum 176

Submission from Prospect

Introduction

1. Prospect is a trade union representing 102,000 scientific, technical, managerial and specialist staff in the Civil Service and related bodies and major companies. We represent engineers across a range of disciplines, functions and sectors. Prospect represents more professional engineers than any other UK union. Across government we represent 18,000 engineers and technical staff. However, the engineering community in government has declined significantly over the last ten years.

2. For example, the number of civilian personnel employed by the MoD fell from 133,000 in 1997 to 90,000 currently. The union believes that up to 7,000 more jobs will be cut as part of the Chancellor's pre-budget report in October. These new cuts will be in addition to the 7,000 or so job losses already in train and a significant proportion will be in engineering and technical functions, falling disproportionately on Army, Navy and RAF front line commands with a direct and immediate effect on support to military operations. This exercise typifies Prospect's concerns about Government's approach to management of specialist staff, including engineers, since there is no central knowledge of the location, functions or specialist expertise—and hence no clarity of what capability is being lost or whether retained capability will be sufficient to cope with future demands. A similarly short-sighted approach was evident during privatisation of the Property Services Agency 15 years ago and has since occurred with depressing regularity.

3. Prospect contributed evidence at an earlier stage of the Committee's inquiry, in March 2008, and this brief submission builds on that evidence. We are fortunate in being able to draw on the knowledge and first hand experience of our members to inform our views. Responses to the specific issues highlighted by the Select Committee are set out below.

The Role and Effectiveness of the Government Office for Science and the Chief Scientific Advisers in providing Engineering Advice across Government and Communicating Issues Relating to Engineering in Government to the Public

4. Prospect believes that the Government Office for Science has an important and significant role to play, though it is not well resourced to deal with a complex and wide-ranging engineering community. The initiative by the new Chief Scientific Adviser to establish a science and engineering community of interest is very welcome but, in practice, its impact will be limited because it depends on voluntary self-identification and is limited to core government departments and agencies. Prospect played an active role in promoting this initiative to our members, many of whom had not heard of it from their own employer. Others who wished to become involved were barred from doing so because they work outside the core civil service, despite the fact that this is where much of the Government's practical engineering work is undertaken.

5. At departmental level Chief Scientific Advisers and Heads of Science and Engineering Profession tend to be even less well resourced, and many combine this responsibility with other professional roles. Prospect did have high hopes that Government Skills, the Sector Skills Council for central government, would provide additional support to the network of scientific advisers. However, it is becoming increasingly evident that Government Skills' priorities lie elsewhere. This is of particular concern given that many of the key challenges for government, such as climate change and defence security, depend crucially on engineering and technical expertise. Indeed a recent initiative by the Ministry of Defence to review its current skills base was abandoned because it was, by their own assessment, "too difficult".

6. Although Prospect does closely monitor government policy advice, we would be very hard pressed to identify examples of either the Government Office for Science or Chief Scientific Advisers communicating issues relating to engineering to the public.

The use of Engineering Advice in Government Policy Making and Project Delivery, including examples of Policy Decisions or Project Delivery that have been or will be taken with or without Engineering Advice

7. Prospect members are concerned that, in part due to recruitment difficulties, Government's capacity as an "intelligent customer" of engineering projects has eroded. There is insufficient technical expertise both among Senior Civil Service policy and decision makers and at levels below Chief Scientific Adviser, resulting in increased use of external consultants without either contextual knowledge or "corporate memory". Thus, one member reported that administration managers are faced with answering questions on bridge design. Conversely in-house engineers can contribute to innovative solutions through intimate understanding of project requirements and partnering with other engineers, for example in universities, to develop value for money approaches that would not arise within the confines of a consultancy contract.

How Government identifies the need for Engineering Advice and how Government Sources Engineering Advice

8. Prospect members report examples where engineering advice feeds effectively through to policy makers, though often this is through informal means and dependent upon personal relationships with colleagues in policy teams. In effect, engineering advice is "loaned out" through the goodwill of individual engineers and their managers. Whilst this can work well, the informality of such arrangements means that consultation does not occur as a matter of course and so there are likely to be many instances where policy decisions are made without engineering input.

9. Too often engineering and scientific advice are called on simply in times of crisis and, on occasion, to rectify poor quality work done by external consultants.

The Status of Engineers and Engineering within the Civil Service, including Assessments of the Effectiveness of the Science and Engineering Fast Streams, and the Role and Career Prospects of Specialist Engineers in the Civil Service

10. Prospect recently conducted a survey of members in the Civil Service, attracting 5,300 responses of which around one fifth are from engineers and technical experts. The survey findings show the engineers' own frustration over the lack of status that engineering enjoys within the Civil Service as well as frustration over career prospects.

- Three quarters of engineers responding to the survey are more dissatisfied in their job now than they were a year ago. This level of dissatisfaction is higher than for civil servants as a whole, for which the dissatisfaction rating was 63%.
- 76% of engineers are either dissatisfied or very dissatisfied with their level of pay compared with 63% of all civil servants, and 79% are angry at the lack of pay progression compared with 74% of civil servants generally.
- Just one third of engineers are satisfied with training and development opportunities, reflecting the wider view of civil servants.

11. It is clear that there is considerable anger underlying these responses. For example, members have variously commented that:

> "Engineering in [department] is a joke".
>
> "With so few engineers available to give advice, the generalists will never see how valuable their contribution could be".
>
> "[Department] is by far the worst employer I have ever come across in my entire working life".
>
> "The structure of the Civil Service is such that it does not see engineers as playing an essential role in its policy-making decisions".
>
> "My advice to engineers is not to go within a million miles of government".
>
> "There is no real career opportunity for engineers unless we are willing to take a pay cut and move into a generalist post".

The Role and Effectiveness of Professional Engineers and the Engineering Community in Promoting Engineering and Providing Engineering advice to Government and the Civil Service

12. As previously indicated, many Prospect members are also members of professional engineering bodies, and Prospect seeks to work collaboratively with such bodies on projects of common interest. Initiatives such as WISE and UKRC provide valuable expertise and resources to enhance diversity, and Prospect has some involvement with both bodies. The engineering community faces major challenges to ensure an adequate skills base for the future, as highlighted in recent work both by the Department for Business, Enterprise and Regulatory Reform[24] and the Department for Environment, Food and Rural Affairs.[25] Sector Skills Councils are starting to address these challenges, albeit with varying degrees of enthusiasm, but Government itself needs to ensure a cross-sectoral and cross-departmental approach to resolving the engineering challenge. In Prospect's view, the Commission for Employment and Skills could play a valuable role in taking this work forward.

September 2008

Memorandum 177

Submission from The Royal Society

Summary of Key Points

- Two overarching considerations should underpin the provision and use of science and engineering advice by Government:
  - (a) Scientific advice to Government must be independent;
  - (b) All scientific research or evidence used by Government should be exposed to independent and rigorous peer review.
- In fulfilling their roles Chief Scientific Advisers (CSAs) act as conduits for scientific and engineering advice: by gathering, synthesising and communicating advice from experts. To deliver effective advice to Departments they therefore need to access and maintain extensive networks of contacts in the UK, Europe and the international scientific community.
- Where departmental CSAs have been appointed at a senior level from outside Government this has led to an improvement in the use of science (including engineering) across Departments and has assisted in the development of a clear strategy for science. However, it is vital that the CSA is involved in all the key strategic decisions within a Department.
- Some departments—for example, Defra and the Home Office—have created independent Science Advisory Councils to provide independent advice, support and challenge to the departmental CSA. We believe that to maximise effectiveness, there is scope for further sharing of best practice between departmental Science Advisory Councils. Departmental science advisory committees should be involved in all major policy issues involving scientific evidence.
- We welcome the designation of the Government Chief Scientific Adviser (GCSA) as the pan-governmental "Head of Profession" for science and engineering. This development, coupled with the creation of similar Head of Science and Engineering Profession (HoSEP) positions within each department, should make a positive difference to career prospects for scientists and engineers within the civil service. We are exploring ways in which we can support HoSEPs and the use of science across government, as we do with our scientist-civil servant pairing scheme (see paragraph 19).

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[24] Energy Skills—Opportunity and Challenge.
[25] Skills for a Low Carbon Resource Efficient Economy.

Introduction

1. The Royal Society welcomes the opportunity to contribute to the Committee's Engineering in Government case study. This submission has been approved by the Royal Society's Physical Secretary, on behalf of the Council of the Royal Society.

2. From its inception, the Society has used a broad definition of science which encompasses both engineering and medicine. Our responses to the Committee's questions draw on this wide perspective, meaning that where we use the term "science", we do so meaning all areas of the sciences, engineering, mathematics and medicine.

3. A number of important principles and observations have informed the Royal Society's response:

- We believe that policy decisions should be informed by the best available scientific advice and analysis; indeed it is the Society's objective to "influence policymaking with the best scientific advice".
- Many of the key challenges faced by the UK and other nations (such as demographic and socio-economic change, globalisation, climate and environmental change, global uncertainty, and technological change)[26] are characterised by their complexity and their far-reaching, often global, impacts. Scientific research and advice will play a major role in Governments' abilities to respond to these and other challenges. Given the nature and scale of these issues, government departments and agencies must be able to draw widely on the best available scientific expertise, wherever in the world it is to be found.
- The nature and complexity of these problems will require, in many cases, collaborative and multidisciplinary responses by research and policy communities. This means that Government must frequently draw on and integrate scientific advice of various kinds; eg advice from economists and social scientists as well as scientists and engineers. It is therefore important not to artificially separate science from engineering or to treat different sorts of information and advice in isolation.
- Two overarching considerations should underpin the provision and use of science and engineering advice by Government:
  - (a) Scientific advice to Government must be independent;
  - (b) All scientific research or evidence used by Government should be exposed to independent and rigorous peer review.

The Role and Effectiveness of the Government Office for Science and the Chief Scientific Advisers in providing Engineering Advice across Government and Communicating Issues Relating to Engineering in Government to the Public

4. In fulfilling their roles CSAs act as conduits for scientific advice: by gathering, synthesising and communicating advice from experts. To deliver effective advice to Departments they therefore need to access and maintain extensive networks of contacts in the UK, Europe and the international scientific community.

5. Where departmental CSAs have been appointed at a senior level from outside Government this has led to an improvement in the use of science across Departments and has assisted in the development of a clear strategy for science. However, it is vital that the CSA is involved in all the key strategic decisions within a Department.

6. The cross-departmental overview is a vital aspect of the Government Chief Scientific Adviser's work (GCSA). Work to bring together the departmental CSAs (for example the Government Chief Scientific Advisers Committee) and raise the profile of key cross-departmental issues, such as climate change and energy, has had positive impacts.

7. The Global Science and Innovation Forum (GSIF) provides an opportunity for CSAs to engage not only with each other, but also other important stakeholders from across Government. More active participation of CSAs in GSIF should ensure that it plays its proper role in the development of a coherent, strategic approach to science and innovation internationally.

8. These are valuable forums for the interchange of ideas and good practice which enable the CSAs to work together on cross-cutting issues. Though often private, these meetings can also provide good opportunities for CSAs and others to engage collectively with external parties on matters of scientific importance.

9. Input from public and wider stakeholder dialogue is important when forming policy responses to new developments in science and technology. While public engagement is not within the remit of the CSAs as we understand it, it is important for the CSAs to actively engage with the Science and Society Unit in the Department of Innovation, Universities and Skills and with other mechanisms that enable public dialogue on science and scientific issues, such as the Sciencewise Expert Resource Centre.

[26] *Long-term opportunities and challenges for the UK: analysis for the 2007 Comprehensive Spending Review*, HM Treasury, November 2006 see: http://www.hm-treasury.gov.uk/media/6/F/csr_longterm271106.pdf

10. It is important that public communication of science and technology issues emphasises the special position of the CSAs and GCSA who are required to maintain their professional independence while working as civil servants. This independence ensures that there is no political interference with the scientific advice given to Government and, as a result, gives the GCSA an autonomous media profile. It is important not only that the GCSA and departmental CSAs are independent, but that they are perceived as such by the public.

The use of Engineering Advice in Government Policy Making and Project Delivery, including examples of Policy Decisions or Project Delivery that have been or will be taken with or without Engineering Advice

11. Policy decisions should be informed by the best available scientific advice and analysis; indeed, it is the Society's objective to "influence policymaking with the best scientific advice". We need to be mindful of both our present and future science and engineering needs, in terms of practical expertise and policy analysis. For example, our response to the Committee's earlier inquiry on nuclear engineering (Royal Society 2008)[27] highlighted the fact that a lack of indigenous nuclear technical skills could mean that the UK lacks the expertise needed for future nuclear activity (including expansion, decommissioning etc). This lack of skills would also diminish the UK's ability to be an intelligent customer since policy advice and economic, technical and security judgements might be flawed.

How Government identifies the need for Engineering Advice and how Government Sources Engineering Advice

12. Our response to the House of Commons Science and Technology Select Committee's 2006 inquiry on scientific advice, risk and evidence included a suggestion that a panel (or, in some cases, panels) of independent experts should be available to each Government Department to support the use of science and engineering advice in decision making. We note that there are now approximately 80 Scientific Advisory Committees across government and welcome the revised Code of Practice for Scientific Advisory Committees published in December 2007.

13. We believe that these advisory committees should be involved in all major policy issues involving scientific evidence. They should include internationally recognised scientists (covering an appropriate range of disciplines) in addition to other stakeholders. External advice about the membership of such committees should be sought from learned societies and appropriate professional bodies. The chairperson should have access to ministers when appropriate.

14. Some departments—for example, Defra and the Home Office—have created independent Science Advisory Councils to provide independent advice, support and challenge to the departmental CSA. We believe that there is scope for further sharing of best practice between departmental Science Advisory Councils in order to maximise effectiveness.

The Status of Engineering and Engineers within the Civil Service, including Assessments of the Effectiveness of the Science and Engineering Fast Streams, and the Role and Career prospects of Specialist Engineers in the Civil Service

15. The departments and agencies of the UK Government are major employers of science and engineering graduates, including many who work in non-science and engineering posts. According to the Office for National Statistics there were 532,000 employees in the civil service in September 2007.[28] For those permanent employees where a profession was reported, 2,280 were employed in engineering posts and, separately, 2,930 were employed in science posts.

16. We welcome the designation of the GCSA as the pan-governmental "Head of Profession" for science and engineering. This development, coupled with the creation of similar Head of Science and Engineering Profession (HoSEP) positions within each department, should make a positive difference to career prospects for scientists and engineers within the civil service.

17. The creation of a network for HoSEPs, which provides an opportunity to meet regularly and share good practice, is especially welcome, as is the development of a Government wide 'community of interest' of scientists and engineers.

18. To encourage closer and more effective interaction, understanding and communication between professional scientists and engineers and the civil service, the Royal Society and the Government Office for Science (GO-Science) ran a pilot scheme in 2007 pairing scientists with civil servants working in relevant policy areas. The scientists and civil servants spent a week together in Whitehall and the civil servants also visited the scientists in return to find out more about the working environment of active researchers. Following the successful pilot, the scheme will be repeated annually by the Society and GO-Science.

[27] Royal Society response to the Innovation, Universities, Science and Skills Committee inquiry on nuclear engineering, March 2008 (RS Policy Document 12/08).
[28] Civil Service Statistics, September 2007 (July 2008, ONS) see: http://www.statistics.gov.uk/pdfdir/cs0708.pdf

The Role and Effectiveness of Professional Engineers and the Engineering Community in Promoting Engineering and Providing Engineering advice to Government and the Civil Service

19. The Society is supportive of the number and diversity of bodies representing engineering interests, but is concerned that, as with other areas of science, it can be confusing for those outside the community to navigate the various institutions, or to identify the key messages and consensus issues and to understand when views diverge. We recognise that, on occasion, it is necessary for the science and engineering community to speak with one voice.

20. A good example of a collaborative approach is the Advisory Committee on Mathematics Education (ACME), established in January 2002 and based at the Royal Society. ACME is an independent committee which acts as a single voice for the mathematical community, seeking to improve the quality of education in schools and colleges. It advises Government on issues such as the curriculum, assessment and the supply and training of mathematics teachers and was established by the Society and the Joint Mathematical Council of the UK with the explicit backing of all major mathematics organisations, and is supported by the Gatsby Charitable Foundation.

21. Another education partnership to which the Society belongs is SCORE (Science Community Representing Education). SCORE operates on a different model to ACME, but also seeks to bring a collective voice to science education. Although the Royal Academy of Engineering is not a member of SCORE, SCORE and the Royal Academy are actively seeking ways to work more closely together on education issues. In addition, the Royal Academy of Engineering has a representative on the Royal Society's Education Committee.

September 2008

Memorandum 178

Submission from Research Councils UK (RCUK)

Executive Summary

The Research Councils believe engineering is vital both to the UK economy and to society in general. We seek to support a full spectrum of research and postgraduate training within engineering and work to ensure that the research climate for engineering in the UK is vibrant. Connectivity between the research base and users across engineering is crucial and there is strong engagement between Councils and Government Departments on areas of mutual interest. Research Council have signed Memoranda of Understanding with a number of Government Departments and there are regular meetings to review strategic priorities and areas of mutual interest in addition to considerable ad hoc engagement. A number of research programmes have been developed relevant to engineering and all the Councils participate in the MoD joint grant scheme.

Each of the Research Councils engages with key stakeholders to identify new research opportunities and needs and examine the impact of our research and training programmes. Such engagement will include advice from key groups such as the Chief Scientific Advisors and both EPSRC and BBSRC have Chief Scientist representation on their Councils. In addition, there is representation on primary advisory bodies, for example EPSRC has representation from Government Departments on the Technical Opportunities Panel. BBSRC has representation from Government Departments on a number of its Research Committees and Strategy Panels. The opportunity to influence policy making extends back into Departments with engineers supported by Research Council funding as members of their advisory bodies. Research Council staff also directly engage with such bodies for example, the CEO of EPSRC is a member of the Health Innovation Council and is able to provide a view on behalf of all the Councils.

Research Councils support high quality basic, strategic and applied research and related postgraduate training. The development of individual research projects are primarily researcher led; however, larger programmes of research include advisory boards are able to provide external benchmarking and context. The funding of major research centres and consortia have provided an opportunity for departments such as the MoD, Home Office, BERR, DfID, and Defra to advise research programmes. It is also vital that the outputs from research inform government policy and that there is a direct route for the outputs of those programmes to inform departments. Such major consortia funding is also an area where more than one Council will work together with a department and possibly other funding bodies such as the Technology Strategy Board in delivering a research programme.

RCUK Introduction

1. Research Councils UK is a strategic partnership set up to champion the research supported by the seven UK Research Councils. RCUK was established in 2002 to enable the Councils to work together more effectively to enhance the overall impact and effectiveness of their research, training and innovation activities, contributing to the delivery of the Government's objectives for science and innovation. Further details are available at www.rcuk.ac.uk.

2. This evidence is submitted by RCUK on behalf of all Research Councils and represents their independent views. It does not include or necessarily reflect the views of the Science and Innovation Group in the Department for Innovation, Universities and Skills. Separate written and oral evidence has been provided by RCUK and EPSRC to the Committee's main inquiry into engineering and to related case studies. This submission is made on behalf of the following Councils:

- Biotechnology and Biological Sciences Research Council (BBSRC) Engineering and Physical Sciences Research Council (EPSRC);
- Medical Research Council (MRC); and
- Science and Technology Facilities Council (STFC).

Background

3. The spectrum of engineering research covered by this case study is as defined in the main RCUK submission. As highlighted in the main submission, the Research Councils believe engineering is vital to both the UK economy and to society in general. In supporting the full spectrum of research and postgraduate training, the Councils and the engineers supported have significant engagement with representatives across Government departments. The Research Councils engage with key departments in a variety of ways, to enable them to contribute to and influence the engineering research agenda, to access the engineering research portfolio, and to engage with the engineering research community. This case study has been structured around the primary mechanisms of engagement.

Working Agreements with Government Departments

4. The Research Councils and a number of departments work closely together on research and development issues of mutual interest with an emphasis on promoting wealth creation, quality of life and sustainable development. This level of engagement has been formalised through the agreement of a number of concordats. The concordat establishes a framework within which the two organisations can interact across areas where there is complementarity of roles and benefit can be gained from shared experience and cross-representation. Concordats are valuable in providing a clear statement of the respective roles of the two organisations to ensure that clear and open avenues of communication exist between the Department and the Council; and to ensure the effective and efficient management and operation of activities of mutual interest.

5. EPSRC has developed concordats with the former DOE, DOT, DETR, and DTLR. EPSRC and DfT have now built on these and have re-affirmed their intention to maintain and develop co-operation in science and research. In pursuing their common interests, both organisations have subscribed to *Guidelines 2000*[29] on the use of scientific advice in policy making. In September 2006 a concordat was also signed with Defra, to encourage effective working between both parties with the aim of promoting future joint activities; the concordat will be updated in September 2008. Initial discussions have also taken place between EPSRC and CLG to explore the possibility of developing such a concordat which builds on the previous concordat with the Office of the Deputy Prime Minister, where activities focused around the area of fire engineering.

6. BBSRC have developed Memoranda of Understanding with FSA, Defra, MoD; DfID and Scottish Government which aim to provide mechanisms to deliver joint strategic research in important policy areas. These have the potential to impact in areas such as engineering of: food processing, food transport and the prevention of disease transmission in the food chain; engineering processes underpinning sustainable agriculture or to improve farm animal health; technologies for detection of pathogens and biological agents; and bioremediation and bioenergy technology development. In addition, BBSRC research activities applicable to addressing Millennium Development Goals have been delivered through collaboration with DFID.

7. EPSRC, the Ministry of Defence, the Atomic Weapons Establishment, British Nuclear Fuels plc (now Nexia Solutions) and British Energy plc work together under a formal agreement in areas of common interest in research and training to sustain critical nuclear related capabilities. Future developments are discussed and areas highlighted for Research Council activity, addressing stakeholder need. The Health and Safety Executive and the Nuclear Decommissioning Authority are also involved in the discussions.

[29] http://www.berr.gov.uk/dius/science/page15432.html

Representation on Research Council Advisory Groups

8. All Council members are appointed by the Secretary of State for Innovation, Universities and Skills and are drawn from both the academic and stakeholder communities. The EPSRC Council includes the Ministry of Defence Chief Scientific Advisor, Professor Mark Welland; BBSRC Council includes the Department for Environment, Food and Rural Affairs Chief Scientific Advisor, Professor Robert Watson. Council meetings also include representation from the Department for Innovation, Universities and Skills. In addition, Professor Brian Collins, Chief Scientific Advisor for DfT and for BERR, is a member of the Advisory Board for Digital Economy Cross Council Programme, and is also on the EPSRC Technical Opportunities Panel.

9. The Office for Strategic Coordination of Health Research (OSCHR) has been jointly established as a Government office by the Department of Heath in England (DH) and the Department for Innovation, Universities and Skills (DIUS). OSCHR's focus is to develop a coherent strategy for translational medicine research. EPSRC's relationship with OSCHR has been developed through regular meetings and Liam O'Toole (Head of Office) is a member of EPSRC User Panel.

10. The Research Councils' Energy Programme Scientific Advisory Committee (SAC) has representatives drawn from the providers and users of research who have an interest in ensuring that we have access to pertinent advice and comment to inform decision making. Advice from the SAC helps define the Programme's approach to supporting research and training. There is DIUS, BERR and Defra representation on the advisory committee.

Jointly Commissioned Research Programmes

11. Strategic partnerships are formal arrangements between EPSRC and other organisations where we agree to jointly support research, training and other activities in UK universities. A partnership can involve one or several organisations, and gives a framework for supporting mutually-beneficial activities in areas of interest. Activities can include funding of research chairs, research grants and consortia and studentships. Such strategic partnerships have been developed between EPSRC and MoD, DSTL, DfT, which all have contributed to the development of engineering research activities. An example is the current activity with DSTL in the area of enhancing damage tolerance through materials science. This partnership is being taken forward with a new £2 million activity in signal processing.

12. Interdisciplinary Research Collaborations (IRCs) are centres of internationally-acknowledged scientific and technological excellence, with sufficient critical mass to make a real impact in areas of key future industrial relevance to the UK. In 2002 an £19.6 million investment funded jointly by BBSRC, EPSRC, MRC and the Ministry of Defence established two Interdisciplinary Research Collaborations in Nanotechnology:

12.1 The aim of the Bionanotechnology IRC which is led by the Department of Physics, University of Oxford, is to learn from nature—to understand the structure and function of biological devices and to utilise nature's solutions in advancing science and engineering in areas as diverse as biosensors, genomics, the discovery of new medicines, diagnostics and drug delivery.

12.2 The nanotechnology IRC is led by the Department of Engineering at the University of Cambridge and it aims to provide underpinning interdisciplinary activity in nanotechnology with the theme of understanding and controlling the physical properties of nanostructures and devices by fabrication at single molecule precision.

13. The LINK Programme was developed by DTI prior to the establishment of the Technology Programme as a means by which the Government encouraged collaborative research for innovative and industrially-relevant research to support its wealth creation and quality of life goals. Because of its relevance to industry and the collaborative nature of the work, the programme was supported by relevant Research Councils and other Government Departments.

14. The Bioremediation LINK Programme was launched in April 2001 to support the development of technologies that will provide UK industry with the multidisciplinary capability necessary to enable the commercial exploitation of biotechnology for the clean up of contaminated land, air and water. The core Programme sponsors were the Department of Trade and Industry (DTI), BBSRC, EPSRC and the Environment Agency (EA). Projects with engineering relevance include using microorganisms to clean up acidic mine waste and developing reactive barrier technologies for the bioremediation of cyanide.

15. Other examples include the following LINK programmes:

- Advanced Food Manufacturing LINK (jointly funded by Defra, Scottish Government, BBSRC and EPSRC) which encourage collaborative R&D that will strengthen and improve the UK industry's technical base in process design, process capabilities and operational efficiency through diagnostics and control.
- Food Quality and Innovation LINK (jointly funded by Defra, Scottish Government, BBSRC and EPSRC) which aims to increase industry's technical capability and performance in producing safe, high quality nutritious food and to provide necessary information and direction in terms of

ensuring these foods meet consumer expectations and needs. One BBSRC co-sponsored grant at the University of Leeds worked with engineers and the biscuit industry to optimise taste, colour and texture whilst reducing energy inpuys and the effect on the environment.

— Renewable Materials LINK (jointly funded by Defra and BBSRC) encourages investment in research and the exchange of knowledge between the private sector and the research base in furthering the non-food uses of renewable materials to support sustainable development. For example one grant to BBSRC's John Innes Centre looks at reducing the carbon footprint of lubricants by designing sustainable biological alternative to mineral oil; with basic biologist working with engineers to make sure the outputs can be integrated into UK industries.

— Horticulture LINK; Sustainable Livestock Production LINK; and Sustainable Arable LINK (jointly funded by BBSRC and government with ESRC involvement in SLP-LINK) all have objectives that include engineering solutions to improve agriculture production, adapt to and reduce the effect of climate change and lessen the effects of agriculture on the environment.

16. The Research Councils have been working with the Technology Strategy Board and the previous DTI technology programme since it started in 2004, and provide co-funding for academic partners. Through the Innovation Platforms two major research initiatives have been developed which involve direct partnership with Government Departments. The DTI, EPSRC and DfT came together to support research consortia in the area of Intelligent Transport Systems; the EPSRC and DTI invested a total of £9 million, with a further £3 million from industry. There has also been significant engagement with DfT through the Low Carbon Vehicles Innovation Platform. The TSB will invest £20 million in the programme; DfT and EPSRC will also each contribute at least £10 million. In addition the DfTs National Transport Innovation Incubator was co-funded by EPSRC.

17. EPSRC is set to announce grants through the "Integrated Risk Management Planning" initiative in collaboration with CLG. These grants were developed following a workshop hosted by CLG, which looked to identify ways in which IRMP can improve community safety, reduce the commercial, economic and social impact of fires and other emergency incidents (such as flooding and terrorism threats) and make a more productive use of Fire and Rescue Service resources to meet today's risks. Two grants were developed through this process: *"Multi-Objective Decision Making for the Fire & Rescue Services—A scoping study"* and *"Evaluation of prevention and protection activities on commercial, public and heritage buildings"*. EPSRC has invested £658k; CLG will be providing on going support through involvement on the steering committees and will provide over £1 million of in-kind support through involvement of staff and software access.

18. EPSRC has partnered with the Department for International Development (DfID) and a call has been issued looking to support research consortia in decentralised off grid electricity generation that will promote links between UK universities and developing country universities and facilitate the transfer of technologies that will help alleviate developing country poverty. EPSRC has allocated £3 million to this call with DfID co-funding proposals up to a level of matched funding.

19. EPSRC has partnered with the Home Office to develop and fund research consortia. This partnership developed through the supporting of grants funded through the five calls of the Crime and Security Programme. The original programme had a wide remit and specific workshops were subsequently developed on key areas of interest; Gun Crime, Ensuring Privacy and Consent, and Cargo Screening (details below). A similar partnership with the Department for Transport has led to the organisation of an IDEAS Factory sandpit (to take place November 08) focusing on reducing the environmental impacts of airports.

18.1 The Gun Crime workshop took place in September 2005 and explored long-term ideas preventing gun crime, protecting against gun crime and assisting in the detection of gun crime. Four proposals, including one network, arising from this were supported and include collaborations with a range of stakeholders including the Home Office, Forensic Science Service, Metropolitan Police, Association of Police Officers of England Wales and Northern Ireland, Greater Manchester Police, The Forensic Alliance Ltd and the National Firearms Centre.

18.2 The Ensuring Privacy and Consent workshop (November 2007) was developed in association with the Home Office (HO) and Identity and Passport Service (IPS) with the aim of delivering solutions on how the next generation of identity management infrastructures can offer assured privacy, and depend on truly informed consent. Three resulting multidisciplinary projects were jointly funded by The Technology Strategy Board's Network Security Innovation Platform, the Engineering and Physical Sciences Research Council (EPSRC) and the Economic and Social Research Council (ESRC), representing a total investment of £5.5 million.

18.3 The Cargo Screening workshop took place in December 2007 following identification of the problem in association with the Home Office Scientific Development Branch. The aim of the workshop was to develop an understanding of the current barriers to efficient and effective screening of cargo and to develop multidisciplinary research projects capable of developing technological solutions to help overcome these barriers. EPSRC subsequently funded five research projects and one network arising from the sandpit, at a total cost of £2.5 million.

Government Departments as Direct Collaborators on Research Grants

20. Across Engineering EPSRC currently has a research portfolio in excess of £100 million, which has collaboration with either Government departments or Executive Agencies. Their contributions to these grants can be in cash but more frequently involve in kind support with the specific partner. There has been direct co-funding of proposals related to engineering and the portfolio with the DfT is £6.8 million and Defra is currently £3.3 million. The Ministry of Defence has the specific mechanism of the joint grant scheme which has led to a portfolio of £27 million; however, in addition to this there has been an additional £2.5 million co-funding of engineering grants.

21. Two members of CLG, including the Chief Scientific Adviser, are members of the Steering Committee for an EPSRC Sustainable Urban Environment Knowledge Transfer consortium. CLG are also involved in the Local Authority Research Councils' Initiative (LARCI), which aims to bring local authorities and the Research Councils into closer partnership to enhance the transfer of Research Council funded research to practitioners.

22. The Multidisciplinary Assessment of Technology Centre for Healthcare (MATCH) supports the healthcare sector with: new methods for establishing clinical value, new methods for capturing user needs for early design and in-use upgrades, best practice research on production and decision-making processes and a forum to engage the regulators and seek better ways forward all concerned. MATCH academic partners include: Brunel University (hosting institution), University of Ulster, University of Nottingham, University of Birmingham and King's College London. MATCH Plus is an additional initiative to address user needs jointly funded by EPSRC and the Department of Health to the total value of £1.7 million over five years. The aim of this project is to provide a toolkit and training to aid in the translation of MATCH project to the health service. EPSRC is contributing funds to the DoH initiative: Healthcare Technology Cooperatives (HTC) pilot cooperatives focused on "Devices for Dignity" and "Bowel Function".

23. In October 2008, EPSRC will award a £1.2 million grant to establish a Centre of Excellence in Managing and Understanding Natural and Environmental Risk at Cranfield University. The Centre will be joint funded by a consortia which will include Defra, EPSRC and other research councils and will involve two-way knowledge flow between academia and Defra including secondment of Engineering researchers into Defra. A representative of EPSRC will sit with representatives of Defra on the Centre's advisory board.

24. BBSRC currently fund Government Partnership Awards (GPAs) which recognise the importance of basic research in underpinning policy development and regulation. Such partnerships have been developed with Defra and the Food Standards Agency, which support process engineering in food production. One award to Professor Peter Fryer, at University of Birmingham (value: £236k), seeks a better understanding of fouling in food processing plants by carrying out an interdisciplinary approach (process engineering and materials science) of the processes of cleaning, and to develop a model which can be used to study real problems.

Research Council Representation on Department Committees and Advisory Groups

25. EPSRC Chief Executive is a member of Health Innovation Council, and is able to provide a view on behalf of the research councils. EPSRC is also represented on a number of DoH panels including HTC, Healthcare Technology Devices (HTD), New and Emerging Applications of Technology (NEAT) and Invention for Innovation (i4i) programme.

Research Council funded Engineering Researchers on Government Advisory Groups and informing Government Policy

26. Engineering researchers funded through the Research Councils are directly involved in the development of policy through membership of Government advisory groups. Professor William Powrie, head of Southampton University's Civil Engineering Department, has a current portfolio of 11 EPSRC grants and is a member of the Defra Waste and Resources Research Advisory Group. Professor Peter Guthrie from Cambridge University, principal investigator on the £1.4 million EPSRC Sustainable Urban Environment "ISSUES" project is a member of Defra's Science Advisory Council.

27. The cross-Research Council's Towards a Sustainable Energy Economy programme established the UK Energy Research Centre, (UKERC) leading whole systems research. UKERC technology and policy assessments, for example on intermittency of supply, have informed government policy and UKERC modelling was used to shape the 2007 Energy White Paper. Professor Jim Skea, the UKERC Research Director, is a member of the Committee on Climate Change.

28. The Government's manufacturing strategy, Manufacturing: New Challenges, New Opportunities, published September 2008. In preparation of this BERR established a Ministerial Advisory Group on Manufacturing to provide advice during the Review. Membership included Prof Mike Gregory, Head of the Institute for Manufacturing and Director of one of the EPSRC Innovative Manufacturing Research Centres.

September 2008

Memorandum 179

Submission from the Campaign for Science and Engineering

Introduction

1. The Campaign for Science and Engineering (CaSE) is a pressure group aiming to improve the scientific and engineering health of the UK. Our objective is to communicate to Parliament and the nation as a whole the economic and cultural importance of science and engineering, and the vital need for its funding by government and industry. CaSE is supported by its members, which includes individuals, corporations, universities and learned societies.

2. CaSE has long been an advocate for improving the system of science and technical advice within Government. We strongly believe that government departments need appropriate research and development (R&D) budgets, internal scientific and engineering expertise, and systems to access independent external advice.

The Role and Effectiveness of the Government Office for Science and the Chief Scientific Advisers in Providing Engineering advice across Government and Communicating Issues Relating to Engineering in Government to the Public

3. The Government Office of Science (GO Science) and the Government Chief Scientific Adviser (GCSA) have important roles in providing engineering advice across government and for challenging departments to improve their scientific and engineering capabilities. Both GO Science and the GCSA have a cross-department responsibility for scientific and technical advice. However, it is critical that every department has their own internal capacity as well. Greater focus should be given to engineering and technical expertise within the scientific advisory system.

The use of Engineering Advice in Government Policy Making

4. Government departments need to have the same "intelligent customer" function for engineering advice as the need to for scientific advice. For this to happen they need senior civil servants and members of Scientific Advisory Committees with relevant engineering and technical backgrounds. It cannot be expected that each Departmental Chief Scientific Adviser will have expertise in all of the scientific and technical issues relevant to their department. However, consideration should be given to having a balance of scientific and technical expertise within the Committee of Chief Scientific Advisers.

5. The Sainsbury Review recommendation 8.4 was that a "more robust mechanism should be put in place to identify and protect departmental R&D budgets." CaSE supports the development of a "robust mechanism" so that R&D budgets are maintained and strengthened in order to improve departmental capacity to procure the evidence and innovation relevant to their functions.

The Status of Engineering and Engineers within the Civil Service

6. CaSE supports the science and engineering profession programme co-ordinated within the Government Office of Science. However, it is critical that each government department works to support their engineers. Each department and agency should have a head of profession for scientists and engineers. However, this is not yet the case. For example, even after numerous recommendation by various parliamentary and government reviews, the Department for Culture, Media and Sports still does not have a Departmental Chief Scientific Adviser, Scientific Advisory Committee or Head of Profession. As the lead Department responsible for the London Olympics and good design in the built environment, engineering expertise, as well as other scientific disciplines, should be better integrated into the DCMS by now.

7. As part of their work to improve the standing of engineers, departments need to provide the support, both in terms of finance and time, for membership and participation in professional engineering institutes relevant to their area of expertise.

8. CaSE strongly supports the need for a science and engineering fast stream into the civil service. Increasing the number of people within the civil service with engineering and technical skills should be a government priority. However, we are very concerned that there are very few opportunities available in the science and engineering fast stream. There were only 17 vacancies for the science and engineering fast track position in 2007. Nine out of the 249 successful candidates for the general fast stream, which includes the science and engineering fast stream, had an engineering degree.[30] CaSE recommends that the government recruit more individuals with an engineering background so that there is a better balance of skills within the civil service.

[30] Cabinet Office (2008) Civil Service Fast Stream Recruitment 2007: http://www.cabinetoffice.gov.uk/reports/faststream/

9. Secondments are another important route for improving engineering skills within government. Departments should support and facilitate both inward and outward secondments of engineers to improve the technical skills available.

10. As part of the Government's commitment to improving science and engineering skills, it should record the number of engineering specialists and secondments in each department. Departmental science reviews should examine if there is appropriate engineering and technical expertise within the department.

THE ROLE AND EFFECTIVENESS OF PROFESSIONAL ENGINEERS AND THE ENGINEERING COMMUNITY IN PROVIDING ENGINEERING ADVICE TO GOVERNMENT AND THE CIVIL SERVICE

11. The Royal Academy of Engineering has an important role in providing engineering advice to Government. Part of the Academy's Grant-in-Aid package from DIUS goes toward policy advice. The Academy produces important topical policy reports. However, it can be difficult to measure the effectiveness of reports and the Royal Academy of Engineering should strengthen its capacity for on-going dialogue and post-report follow-up to ensure the greatest impact on the policy process.

12. Professional engineering institutes also play an important role in facilitating the exchange of information between their respective communities and departments on relevant issues. Individual engineers also volunteer their time and expertise to sit on formal advisory committees, but there are also many contributions made through informal dialogue. Their important contribution to engineering advice to Government and the civil service should be supported, recognised and better facilitated.

INTERNATIONAL EXAMPLES OF HOW ENGINEERS AND ENGINEERING ADVICE ARE IMBEDDED IN GOVERNMENT

13. One example is the US Secretary of State's Science and Technology Adviser. Although the current incumbent is a biologist, the post provides both scientific and technical advice. The Foreign and Commonwealth Office should appointment a similar position to imbed scientific and engineering advice within the FCO. Many diplomatic issues have a scientific or technical component. The UK's diplomatic position on these issues would be strengthened by greater internal technical expertise.

September 2008

Memorandum 180

Submission from Professor Sir Martin Sweeting

Here are my comments:

— The government does not appear to recognise engineering in the same way that it does science or indeed business.

— Govt has good communications channels to the Royal Society (science) and CBI (industry) but weaker links to the Royal Academy of Engineering—although the RAEng is endeavouring to grow these.

— Government appears to understand "science" as the basis for knowledge and industry/business as the means for creating wealth—but under-estimates the role of engineering in providing the bridge or the link connecting science to exploitation and wealth creation.

— In the space sector, which admittedly is somewhat special, government has tended to see it as primarily "space science" funded via the STFC research council and "space engineering" has somewhat fallen between the cracks (or research councils!).

— To some extent understandably 30 years ago, space was perceived as an expensive "prestige club"—however the position has changed dramatically. Space is now fundamental to our national wealth, security of supply, transport, communications, banking, navigation and so on. If space were to be somehow "switched off", the UK economy and social order would rapidly collapse. This reliance of the UK on space technology and "engineering" has crept up un-noticed and largely unrecognised by HMG.

The recent appointment of Lord Drayson with responsibility of Science and Space with a seat at Cabinet is a very welcome development of which I hope the government will make full use.

November 2008

Memorandum 181

Submission from Richard Archer,[31] Managing Director, Two BC Ltd

Comments on the terms of Reference (particularly in respect of engineering in biotech/healthcare)

— Many of the world's best selling drugs were discovered, developed or manufactured in the USA using innovative technologies created by UK engineering companies. This is an example of where the failure to understand and adopt these engineering technologies first in the domestic market results in most of the true economic value from them being realised elsewhere.

— The role of engineering in healthcare is poorly understood and not well recognised. Both the medical and broader life science professions have a limited perception of the creative part engineering plays in taking a scientific or medical concept from an idea all the way through to a product that can be made consistently and to a price the NHS can afford. This problem will escalate as future therapies become more multi-disciplinary in the mix of skills required. The compartmentalised nature of UK science research funding bodies still does not fully encourage the necessary cross discipline working in healthcare.

— There is no shortage of "average" engineers in the UK—the issue is to have say 5,000 excellent ones graduating every year and then ensuring they all move into and progress in exciting engineering roles that encourage and exploit their talent. Too many of the best engineering graduates take their creative, analytical and project delivery skills to other sectors, such as finance or management consultancy, either on graduation or shortly after. This choice is mostly driven by adverse salary comparisons.

— The quality of engineering research in the UK is hampered by concentration on the peer review process for selection of academic research proposals. While this gives "safe" outcomes, it also mitigates against exploring the truly innovative idea, particularly where it is cross-disciplinary. Increasing use should be made of industrial advisory groups to ensure that academic engineering research is truly novel and challenging.

SUBMISSION

The Role Of Engineering in Healthcare

Engineering has traditionally played just a modest supporting role in the major healthcare industries, particularly in the pharmaceutical and biotechnology companies. Profit margins on their final products are high such that the drive for efficient and innovative manufacturing methods is small, and indeed unwelcome in many cases. However, as the ability of these companies to find yet further blockbuster drugs diminishes and the plethora of unmet medical needs in an ageing population grows, increasing emphasis will have to be placed on alternative strategies to improve healthcare. These will include personalised medicine, production of niche therapies, and the exploitation of stem cell and related basic research in the important emerging field of Regenerative Medicine. In all these examples, engineering has a leading role to play, both in creating innovative products and their related manufacturing processes, and in producing these products to cost targets that will be much more demanding in order to achieve prices society can afford. In essence healthcare has to move to the economic, efficiency, and rapid innovation models that have driven consumer electronics and automotive. The manufacturing of products that address these new healthcare product strategies will have to be highly innovative, complex and very responsive. However, if addressed now with a better mix of engineering and science skills, it gives the opportunity to create new high value manufacturing companies and healthcare industries that can grow in the UK and, more importantly, stay in the UK for the long term, for the combined benefits of health, wealth and employment.

The UK has a major world position in the areas of basic stem cell research and the related broader field of regenerative medicine. This arises from the current high levels of basic science funding in this area and political constraints on funding in countries such as the USA. There is a finite window of opportunity for the UK to exploit its current lead in basic research in regenerative medicine by focussed and rapid investment in the increasingly engineering related issues required to turn world class research outcomes into world class therapies, developed and manufactured in the UK. These novel regenerative medicine therapies will be complex and difficult to manufacture at scale. This is both the challenge and the opportunity though, as once successfully established in a UK base. there is little incentive to off-shore production of these therapies. Recognition of the leading role that engineering will have to play in achieving this will be essential if good basic UK research is not to be exploited elsewhere. This will also require some redirection of Government funding to ensure success before support from conventional funding becomes available.

[31] Executive Chairman of Axordia Ltd (A start up company exploiting stem cell research from Sheffield University, working on cures for blindness and organ rejection), Chair—remedi Project (A £9 million national research programme, partly funded by EPSRC, to explore all issues of establishing a Regenerative Medicine Industry in the UK)

Proposed specific actions are therefore:

— Increased emphasis on healthcare engineering as both an undergraduate and postgraduate training area.

— Increasing education for life scientists on engineering as a discipline.

— Further encouragement of, and funding for challenging cross-disciplinary research in healthcare engineering, with increased industry oversight.

— A cross-departmental agenda for Government in Regenerative Medicine to create a sustainable new industry in the UK.

January 2009

Memorandum 182

Supplementary memorandum from the Department for Innovation, Universities, Science and Skills

INFORMATION ON CIVIL SERVANTS WITH FIRST DEGREES IN ENGINEERING AND SCIENCE AND CHARTERED ENGINEERS

Overview

The data available at present from Government Departments by pay grade on how many civil servants: have a first degree in engineering; have a first degree in science; and/or are chartered engineers is presented, where currently available, in the data table below.

More widely, information existing on the first degrees and professional affiliations held by civil servants is variable across Government, and is often reliant on voluntary maintenance of HR records by staff as their careers progress. Implementation of the skills strategy for Government is expected to improve departments' HR records significantly by the end of 2009; this will include the data available on engineers and scientists.

January 2009

Data

Department	*Pay Grade*	*Numbers of civil servants with a:* First degree in Engineering	First degree in Science	*Number of Chartered Engineers*	*Comments*
Department for Business, Enterprise & Regulatory Reform (BERR)	all	n/k	n/k	n/k	BERR does not consistently record or retain data on how many civil servants in the Department have a first degree in engineering or science. BERR does have chartered engineers on its staff, who are very much valued for their professional skills and supported in maintaining chartered status but, their numbers are not recorded centrally. BERR is introducing a new online HR system during 2009, which will allow staff to record and maintain their qualification information (if they choose to).
Department for Children, Schools & Families (DCSF)	all	0	0	0	DCSF's HR system "Trent" holds information on qualifications, where employees have provided that information. Those records show that: no current employees have recorded a first degree in engineering or science, but there may be under-reporting. DCSF is not aware of any employees holding chartered engineer status. Although the department recently surveyed its employees on skills and professional qualifications, this did not cover engineering.
Department for Communities & Local Government (CLG)	all	n/k	n/k	n/k	CLG does not hold this information. Its HR system does not currently hold data on the qualifications and Professional grouping of individual staff members. However it has recently made changes so that this information can be captured in the future. CLG will be asking all staff to complete this information during 2009 in order to meet the targets set out by Government Skills in the Government Skills Strategy.
Department for Culture, Media & Sport (DCMS)	all	n/k	n/k	n/k	DCMS is unable to provide any accurate figures. The underpinning reasons for this are: — DCMS has operated a predominantly competence based recruitment process, so the number of qualifications featured in application forms is minimal; — Historically, there was no process for transferring details of qualifications from people's application forms onto a database that is searchable and which would provide this data; and — Self service entry of qualifications information by staff has been difficult due to the capability of the HR system, so information is patchy and unreliable at best. A project has been commissioned that will increase DCMS's capability in this regard.

Department	*Pay Grade*	*Numbers of civil servants with a:* *First degree in Engineering*	*First degree in Science*	*Number of Chartered Engineers*	*Comments*
Department of Energy and Climate Change (DECC)	all	n/k	n/k	n/k	Machinery of Government changes too recent for DECC to hold this information.
Department for Environment, Food & Rural Affairs (Defra)	all	n/k	n/k	n/k	Defra does not currently capture and hold data centrally on qualifications. However, it is working closely with the Cabinet Office to define what qualifications data are needed. A clear understanding of the requirement will be important here given the very long list of possible qualifications. Defra ensures that, before appointments to specific roles are made, its vacancy managers check that individual candidates have the required skills and, where appropriate, also hold formal qualifications or memberships of appropriate bodies (eg chartered through the Institution of Civil Engineers). To help ensure it gets the best people for each post, Defra has developed a new system called the Flexible Staff Resourcing system (FSR), which records top level skills, subject specialisms and competencies. All staff are required to complete their FSR profile. However, at present qualifications are not recorded systematically. Defra does not hold data on the number of staff who are chartered engineers. However, Defra's key engineering capability resides in its Water Directorate and it holds information on the qualifications and chartered status of engineering staff in this group. This is outlined below: *Grade 7*—two engineering posts: Two with first degree in Civil Engineering (both also have Masters degrees in an engineering discipline). Two Chartered Engineers, both chartered through the Institution of Civil Engineers (ICE). *SPTO*—three posts in total: Three with first degree in Civil Engineering (one of these also holds an MBA). Three Chartered Engineers, all chartered through the Institution of Civil Engineers (ICE). One is also a Grade 1 European Engineer (EurIng) through FEANI.

Department	Pay Grade	Numbers of civil servants with a: First degree in Engineering	First degree in Science	Number of Chartered Engineers	Comments
Department for Environment, Food & Rural Affairs (Defra)	all	n/k	n/k	n/k	Defra's Laboratory Agencies—Veterinary Laboratories Agency (VLA), Central Science Laboratory (CSL) and Centre for Environment, Fisheries and Aquaculture Science (CEFAS)—also have engineers. Defra does not hold data on qualifications and chartered status for agency staff either.
Department for International Development (DfID)	SCS-G5	3	9	n/k	The figures provided reflect information that has been provided by individuals on a voluntary basis through DfID's HR records system and therefore may be incomplete. The system does not record professional memberships or affiliations, so DfID have not been able to identify Chartered Engineers amongst their staff.
	A1	17	37	n/k	
	A2	14	64	n/k	The figures provided reflect civil servants that have identified themselves as having first degrees in science. Apart from those exceptions listed below, DfID have excluded all other classifications of degree because they could not specifically identify that they related to science or engineering. Figures provided therefore:
	A2(L)	2	8	n/k	
	B1-D (Fast Stream)	0	7	n/k	— include staff with a BSc or an MSc (if no lower degree is recorded);
	B1	1	15	n/k	— exclude any staff with a BSc in a social science qualification or those with a BSocSc;
	B2	8	22	n/k	— exclude any staff with a BSc if their qualification contained economics in the title, and those with an MSc (if their MSc qualification contained economics in the title and DfID could not identify that they had a first degree in science or engineering).
	C1	1	3	n/k	
					Where the grades are not shown this means that DfID did not have anyone providing information on a science/engineering degree on its HR system.
Department for Transport (DfT)	PB3 (EO/ SO/ PTO)	1		n/k	DfT does not hold this information at present. Plans are being developed, however, to collect more information on this in the future.
	PB4 (Fast Stream)	6			The data provided here is based on DfT responses to the recent GO-Science *Community of Interest* survey, which was voluntary; therefore figures are likely to be under-reported.

Department	*Pay Grade*	*Numbers of civil servants with a:* First degree in Engineering	First degree in Science	*Number of Chartered Engineers*	*Comments*
Department for Transport (DfT)	PB4 (HEO/ HSO/ HPTO)	9			In total there were 71 respondents: 30 indicated a science background, 35 an engineering background and 6 a joint science and engineering background.
	PB5 (SEO/ SSO/ SPTO)	21			43 people indicated that they were members of professional bodies, but this included science as well as engineering.
	PB6 (Grade 7)	25			
	PB7 (Grade 6)	6			
	SCS	2			
	Other (n/k)	1			
Department of Health	all	n/k	n/k	n/k	The Department of Health (DH) does not collate that information centrally, as it is not business critical. The Chief Scientist does, however, maintain a self-nominated list of staff who have science backgrounds and who wish to receive periodic information of interest to scientists.
Department for Innovation, Universities & Skills (DIUS)	EA	0	0	0	Figures relate to DIUS only, and exclude staff in its Executive Agencies.
	EO	0	2	0	The return is based on information that staff have made available voluntarily and therefore does not constitute comprehensive data.
	HEO	1	10	0	Given the lack of a clear definition of a science degree, there are likely to be some inconsistencies in the data provided.
	HEO (D)	0	5	0	Staff who have indicated that they are chartered engineers all have engineering degrees. Therefore each individual features in both lists.
	SEO	0	11	0	
	Grade 7	2	33	1	
	Grade 6	1	6	1	
	SCS PB1	2	8	2	
	SCS PB2	1	4	0	
	SCS PB3	0	1	0	
	Perm Sec	0	1	0	

Department	*Pay Grade*	*Numbers of civil servants with a: First degree in Engineering*	*First degree in Science*	*Number of Chartered Engineers*	*Comments*
Department for Work & Pensions (DWP)	all	n/k	n/k	n/k	DWP has one post where the post-holder is required to have a first degree in science, and both of the post-holders meet that requirement (one is on maternity leave). The post is graded Senior Scientific Officer, band E. DWP has no information on degrees held by other staff, which do not relate to the duties of their posts.
Forestry Commission (FC)	PB1	1	24	n/k	Engineering degrees include: BEng, BSc and MSc (eg BEng Civil Engineering, BSc Forest Engineering).
	PB2	5	80	n/k	Science degrees include: BA, BSc, MA and MSc (eg BA Physics, BSc Agriculture and Forestry).
	PB3	6	94	n/k	The figures provided reflect information that is updated by individuals on a voluntary basis as their careers progress. Therefore the Forestry Commission's (FC's) records may be incomplete. The system does not record professional memberships or affiliations, so FC has been unable to identify Chartered Engineers amongst their staff.
	PB4	8	149	n/k	
	PB5	1	78	n/k	
	PB5(OP)	2	153	n/k	
	PB6A	2	55	n/k	
	PB6A(OP)	–	48	n/k	
	PB6B	–	41	n/k	
	PB7	–	2	n/k	
	SSG1	–	6	n/k	
	SSG1A	–	4	n/k	
	SSG2	–	3	n/k	
	SSG3	–	1	n/k	
Foreign & Commonwealth Office (FCO)	all	n/k	n/k	n/k	FCO's HR database does not hold this information. There are 90 FTE posts in the Science & Innovation Network; a number of these staff will hold science or engineering degrees, as may other staff in the department.

<table>
<tr><th rowspan="2">Department</th><th rowspan="2">Pay Grade</th><th colspan="2">Numbers of civil servants with a:</th><th rowspan="2">Number of Chartered Engineers</th><th rowspan="2">Comments</th></tr>
<tr><th>First degree in Engineering</th><th>First degree in Science</th></tr>
<tr><td>Food Standards Agency (FSA)</td><td>UG5</td><td colspan="2">14</td><td>–</td><td>Figures for the FSA were assembled 18 months ago, but probably still give a good picture of breadth and depth of scientific expertise in the Agency. For posts up to and including UG5 (SCS), the proportion of staff with at least a first degree in science is 46%. Of these at least 67% have postgraduate experience and qualifications. For the SCS senior leadership team above UG5 (10 posts) there is a higher proportion with at least a first degree in science.

Figures include the natural and social sciences. FSA is unable to distinguish engineers from scientists in this analysis, but it is unlikely that these figures include many engineers.</td></tr>
<tr><td>HM Treasury</td><td>all</td><td>n/k</td><td>n/k</td><td>n/k</td><td>HM Treasury does not hold this information. No further explanation is currently available.</td></tr>
<tr><td>Home Office</td><td>SCS
Grade 6
Grade 7
HSO
HTTO
SPTO
HPTO
PTO
SSO
SO
AO</td><td>1
1
2
8
1
3
1
4
6
7
0</td><td>8
29
8
27
0
2
0
0
19
31
1</td><td>13</td><td>Figures relate to Home Office posts (by grade) which require physical science or engineering degrees. Whilst the Home Office Home Office IT systems do not hold information on the first degrees of individuals, the Department is confident that all those included in this table hold a degree in the relevant area.

While this information is as complete as possible it may be that there are a small number of posts which have not been included.

The figures do not include individuals who hold either engineering or physical science degrees which are not essential for their post.

Some areas of the Department hold more information than others: the Home Office has at least 13 Chartered Engineers and at least 25 Chartered Scientists, although this information is not exhaustive.</td></tr>
<tr><td>Health & Safety Executive (HSE)</td><td>all</td><td>594</td><td>395</td><td>135</td><td>The figures from HSE's e-HR system may under-estimate the number of degrees and chartered engineers because some staff have not entered all their qualifications or updated all of the chartered memberships onto the system.</td></tr>
</table>

<table>
<tr><th rowspan="2">Department</th><th rowspan="2">Pay Grade</th><th colspan="2">Numbers of civil servants with a:</th><th rowspan="2">Number of Chartered Engineers</th><th rowspan="2">Comments</th></tr>
<tr><th>First degree in Engineering</th><th>First degree in Science</th></tr>
<tr><td>Ministry of Defence (MoD)

Includes data on personnel who work for the Defence Science and Technology Laboratory (Dstl), which is a Trading Fund of MoD, but not its Defence Support Group (DSG), which is another Trading Fund</td><td>E2 (AA)</td><td colspan="2">11</td><td>~ 650</td><td>MoD's data has been extracted from its Human Resources Management System (HRMS). This is entered by individuals using self-service on a voluntary basis, so, although all members of staff are encouraged to enter details of their qualifications on HRMS, it is highly unlikely that this is the complete picture of science and engineering degrees held by civil servants in MoD.

At the end of Oct 2008, 44,500 out of the 65,000 MoD (not Trading Fund) staff did not have any qualifications listed on HRMS. Of the 22,500 people who had entered qualification data, 3500 indicated they had a first degree or higher (Level 6 in the National Qualifications Framework) and of these, 2000 had a first degree in engineering or science.

Individuals enter qualifications on HRMS under one of 22 "Broad Categories". One of these categories is "Engineering and Science" and because this category combines the two disciplines, it has not been possible to separate the data into first degrees in engineering and first degrees in science.

Because it is unclear where engineering and science could be taken to begin and end, these data also include the relevant degree subjects from the Health Professional, Corporate Support and Environment and Sustainability broad categories, which include psychology. Mathematics is not included.

At the end of 2007, as part of its future workforce planning initiatives, Dstl undertook a voluntary survey of the technical competencies of its staff, which included a request to identify qualifications. This was a non-mandatory information gathering activity and as such, the data from Dstl is also incomplete and yet to be verified.</td></tr>
</table>

Department	*Pay Grade*	*Numbers of civil servants with a:* First degree in Engineering	First degree in Science	*Number of Chartered Engineers*	*Comments*
Ministry of Defence (MoD) Includes data on personnel who work for the Defence Science and Technology Laboratory (Dstl), which is a Trading Fund of MoD, but not its Defence Support Group (DSG), which is another Trading Fund	E2 (AA)	11		~ 650	Information about an individual's chartered status and membership of professional institutions is also entered on HRMS on a voluntary basis, so it is again highly unlikely that this is the true number of Chartered Engineers within MoD. The MoD figure for the number of Chartered Engineers reflects the number of people who recorded their level of membership of one of the professional institutions who award the designation CEng as Chartered, but a breakdown by pay grade was not available. 47 people recorded Chartered Engineer as a qualification on HRMS; however, these people are not included in the above total as it could not be established if they had also recorded their membership of an institution as Chartered and would therefore be counted twice. Dstl provides a mentoring scheme to support staff seeking to achieve Chartership and Accreditation. As part of this process, Dstl is aware of 96 Chartered Engineers who are acting as mentors to others, but do not know the pay grade breakdown of these people. However, it is believed that there are other members of staff who have achieved Chartered status in their particular discipline who are not currently engaged as mentors within the formal Dstl Chartership scheme. Dstl currently has no central database of professional memberships or Charterships from which to provide specific information on the numbers.

AA—Admin Assistant
AO—Admin Officer
EA—Executive Assistant
EO—Executive Officer
FS—Fast Stream
HEO—Higher Executive Officer
HEO(D)—Higher Executive Office—Fast Stream
HSO—Higher Scientific Officer
HPTO—Higher Professional and Technical Officer
HR—Human Resources
n/k—not known
PB—Pay Band
SEO—Senior Executive Officer
SCS—Senior Civil Service
SO—Scientific Officer
SPTO—Senior Professional and Technical Officer
SSO—Senior Scientific Officer

Departments of State we do not yet have information for:

Ministry of Justice
Northern Ireland Office
Privy Council Office
Wales Office
Scotland Office
Cabinet Office
Office of the Leader of the House of Commons

IMPROVING DATA THROUGH THE SKILLS STRATEGY FOR GOVERNMENT—NOTE BY GOVERNMENT SKILLS

In January 2008, Permanent Secretaries agreed the skills strategy for *Government—Building Professional Skills for Government: A strategy for delivery*[32]. The strategy provides a central role for professions, encouraging them to look at the relevance and standing of the accredited qualifications appropriate to their own people, and work with business and HR Leaders to set expectations and shape career pathways linked to attainment of standards and qualifications. To support them in this work, departments are providing them with workforce data which will allow professions to understand trends in supply and demand within Government and in the wider market in order to facilitate better workforce planning. This workforce data will provide information on:

— The numbers and grades of the employees they have in their profession;
— The age and gender breakdown of their staff;
— The locations of their staff (departmentally and geographically);
— Joiners and leavers, to help assess turnover rates;
— Equality and diversity;
— Rewards; and
— Flexible working practices.

In addition, for the first time, departments have been asked to provide anonymous qualifications information, by profession, to enable professions to understand the numbers of their staff that hold relevant qualifications. This data should be available in the latter part of 2009 and will help professions to identify what skills, standards and qualifications are held at all levels within their profession, and inform work to develop new standards for attainment where necessary.

INTERNAL APPLICATION PROCESS

1. Complete the application form as fully as possible. You may find the guidance notes for completing internal application forms that is available on the Department of Resources (DoR) intranet site for House staff helpful. This can be found under recruitment.

2. Ask your manager to complete the reference form and to return it to you before the closing date. Attach the completed reference to your application form. Guidance is also available on the DoR intranet site on how to complete references.

3. Complete and return the equal opportunities monitoring form in a deal envelope marked “confidential” to: The Diversity Manager, DoR, 3rd floor, 7 Millbank. Please ensure that you include your name and the number of the vacancy on the monitoring form.

Do not enclose your completed equal opportunities form with your application form.

Send your completed application form and completed reference to your DEO unless you are in one of the following departments, in which case send it to:

Department	*Send To*
Department of Facilities	Patricia Welch/Alex George (former SAA)
	Jo Regan (former RD)
PICT	Kerry Stee—Development Directorate
	Elizabeth Rousou—Operations Directorate
	Sam Holliday—Resources Directorate
Department of Resources	Sarah Jane Robbie

[32] http://www.government-skills.gov.uk/documents/research-publications/skills-strategy-2008.pdf

You should give your completed form to the relevant contact at least two days before the closing date.

Your DEO or departmental human resources officer will forward the relevant paperwork to the Human Resource Management & Development Directorate. You will be informed of the outcome of your application as soon as possible after the closing date.

Committee Staff note on E-Consultation with engineering employers "Engineering in the UK"

The Innovation, Universities, Science and Skills Committee hosted two web fora during the course of its inquiry into Engineering. The first forum, entitled "Engineering in the UK" was aimed at engineering employers. The Committee was able to engage with employers who might not otherwise have contributed to the inquiry, particularly those running small engineering businesses, to identify the issues that really affect those on the ground.

The forum was launched on 17 September 2008 and ran until 24 October 2008. Moderation was carried out by the Committee Staff, although the forum was designed and operated by the Parliamentary Web Centre. The discussion rules were altered slightly from those normally used. This allowed users to divulge their full names and details of their company, should they wish to. This information was useful in that it provided more contextual information about the posts.

Publicity

Publicity was provided using a press notice and A5 postcards which were distributed at a number of events organised by various Engineering Institutions. Parliamentary Outreach workers distributed postcards to relevant groups in the field. In addition, a number of websites were involved in publicising the forum.

The Questions and Participants

The forum attracted 97 posts from 56 unique contributors. It also received over 5000 views:

Topic	*Posts*	*Views*
1. Are you optimistic about the future of engineering in the UK?	19	1,116
2. What one thing could the Government do to help engineering employers?	42	1,816
3. What are the biggest challenges and opportunities facing engineering companies?	19	1,125
4. How easy is it to recruit the engineering staff you need?	17	1,213

Summary of Responses

Out of necessity, the following summaries do not reproduce all of the posts on the forum. They are intended to be a summary of the major arguments, illustrated with selected posts. Some posts have been moved between threads where this was appropriate. The full list of contributions can still be viewed online at http://forums.parliament.uk/uk-engineering.

1. *How easy is it to recruit the engineering staff you need?*

Discussion of the recruitment and retention of engineering staff was frequently included in contributions to the other threads (discussed here). Posts generally identified a difficulty in recruiting engineering staff.

Numbers

One widespread observation was that there is a shortage of engineers. Contributors identified the cause as both the insufficient numbers of students taking engineering courses and the fact that a significant proportion of engineers choose an alternative career.

> *One contributor stated that: as engineering populations age and vacancies are "booming" worldwide, the result is the visibility of the shortfall of young people entering the engineering profession. The result for many companies is a true shortage of engineers that is (and will continue) to endanger their growth and in some cases their existence.*

One contribution offered a positive view of recruitment of graduate engineers and apprentices but stressed that this was a result of promoting engineering careers through "the relationships we have built up with schools and universities we work with" and participation in "the DTI funded Science, Technology, Engineering or Mathematics (STEM) programme".

Many posts suggested reasons for the shortage of engineers. For some it was a problem of remuneration, "Employers seem to think we should work for low salaries because of 'job satisfaction'", although another post pointed out that "salaries have improved over the last few years". Other contributors suggested another reason for the shortage of engineers was that the public image and status of the engineering profession was poor, influenced for example by "high profile company collapses like MG Rover" and misrepresentations of what an engineer is, "the unfortunate tendency of newspapers to describe people who maintain railway tracks as 'engineers'—they are really semi-skilled labourers". One post suggested that teachers had a very poor perception of engineering as a career path—"picture an engineer as a man in a cloth cap, carrying a spanner and oil can"—and that for them, engineering was certainly not a career for a woman. It was suggested that many teachers seemed to have the view that an apprenticeship was the route for a failed university entrant, not a positive career choice.

It was suggested that there is a particular difficulty in recruiting and retaining experienced staff and in provision of continuing professional development:

> *Deep expertise in the marketplace difficult to find.*
> *Many people working as professional engineers within the UK are not members of any institute and consider CPD as, quite literally, a joke.*

Some posts therefore described an alternative approach to recruitment. The head of a small engineering team described how: "In order to meet this skills shortfall we have decided to 'grow our own' engineers by recruiting from our own work force, then putting them through modern apprenticeships".

Quality

As well as a shortfall in numbers, posts identified problems with the quality of some candidates. Contributors suggested that candidates often do not live up to their CVs, "I am of the opinion that many of the candidates are more skilled at CV writing than engineering " or are too impatient to develop experience, finding it hard to adapt to the workplace.

> *The main problems appear to be a combination of poor education [. . .] a non-existent work ethic, a belief that because they've spent a year in a government sponsored training school they know all about engineering, CV's that look very nice but are largely works of fiction, as for higher end jobs I won't mention meaningless degrees, wonderful 3D cad drawings when 2D technical drawing would be far more practical. I would rather see a handwritten factual CV, a good basic education suited to the job, a willing attitude (VERY important) and simple courtesy and manners when dealing with people.*

Discussions across all threads featured suggestions that improvements were needed to the education system. However, not all posts were negative about the education system, "I think the Scottish modern apprenticeship is an excellent scheme which produces high calibre engineering employees at all levels".

2. *Are you optimistic about the future of engineering in the UK?*

A number of posts expressed the opinion that the sector is healthy. One Managing Director described that "the Engineering sector is buoyant, there is no shortage of work. In fact our company growth is mainly constrained by lack of professionally qualified staff". Other posts saw engineering as key to the problems of the future.

> *Engineering will be central to the delivery of solutions for many of the pressing challenges facing the nation. Whilst, particularly in these turbulent economic times, focus has shifted from these engineering solutions to economic considerations mitigating and adapting to climate change, securing the UK's future energy supply and the renewal of inadequate infrastructure are still with us and will not go away. All of these challenges will require engineering knowledge and skills to be deployed on a massive scale.*
>
> *I am optimistic that true engineering skills will remain, whether licensed, recognised, professionally recorded or not they seem to be an intrinsic part of our national character (fortunately). I am optimistic that our young people if properly exposed to engineering and nurtured when they express interest can form generations of engineering talent to fill the years to come. I am optimistic about the opportunities that engineering has, we have so much infrastructure to replace and enhance, so many innovations and technologies available to explore and refine to do those jobs with and so many opportunities to apply engineering skills across all sectors. Engineers solve problems, and we like a challenge.*

However, a significant number of posts were not optimistic in tone. Posts stated that UK engineering is losing out to overseas competition, with one warning that "Engineering in this country is dying a death". Many posts cited a decline in manufacturing industry in the UK as a reason for pessimism with one contributor stating that "no government since Harold Wilson has made any serious attempt to improve British industry. They have all been content to believe that the growing service and finance industries would replace manufacturing".

One post suggested that the future of the engineering sector depends on developing an intellectual property culture.

> *The UK needs an intellectual property culture [. . .] Unless we change, our only engineering opportunities will be installing new equipment from abroad and occasionally fixing it when it breaks down, traditionally the technicians job and not very inspiring for our new engineers [. . .] I am not at all optimistic that an IP culture needing the additional skills of the non-engineering types, especially legal, can be achieved in the UK; we have such a legacy of arrogance and contempt in these fields, a total inability to grasp basic physics and an almost allergic reaction to grubby engineers.*

3. *What are the biggest challenges and opportunities facing engineering companies?*

A number of posts saw human resource issues as the biggest challenge for the sector:

> *The biggest challenges and opportunities are about people. As a nation we need to increase the number and quality of young people coming in to the industry, having benefited from inspirational STEM teaching at school, career guidance at critical points in their education and having received a higher engineering education which prepares them adequately for taking their place in the industry. The opportunity is that young people are becoming more aware of the contribution engineers can make to the world, particularly to the challenges posed by climate change and energy. Having recruited them we need to keep them—by challenging them with early responsibility on exciting projects, by CPD [. . .] paying them properly, providing a lifestyle comparable to other professions (working hours and mobility are issues here) and offering a career structure which satisfies ambitions (too many young engineers still feel that engineering is just a springboard to other career paths). All this is within our gift as an industry—the opportunity.*

Other posts described the challenge of tackling the negative image of engineers, or reversing their negative depiction in the media:

> *Real talented engineers in the UK are de-motivated by the media (engineers in this country are regarded as second class citizens), a long term process may recover this anti-productive historical attitude.*

Others saw Government attitudes as a particular challenge:

> *The biggest challenge facing my engineering company and, I suspect, may other, is to survive against the continuing indifference of goverenment (not just this one).*

A number of posts saw a challenge in the attitudes of those in the sector and their clients, as well as the influence of Health and Safety considerations:

> *A further challenge is the lack of demand for innovation from clients, leading to a culture where it is more likely that organisations develop competitive advantage via cost efficiency rather than innovation.*

> *[T]the dreaded Health and Safety departments find endless reasons why existing slow and tedious manual methods must be retained. My cat is perfectly capable of making Risk Assessments on her own, without reference to any manual, just relying on experience and judgment, why can't our workers be permitted the same freedom of thought?*

One post addressed the challenge of competing with low-wage economies:

> *To produce high added value, high quality products that get us away from direct competition with low-wage economies. If we want to produce mass market goods—handy for employing lots of people—we need to build great brands that differentiate us clearly in the marketplace.*

4. *What one thing could the Government do to help engineering employers?*

The following were suggested:

- A number of posts requested that the term "engineer" should be protected or that a new term should be used to describe "engineers". Others suggested a licensing approach.
- Celebrate engineering and engineers and raise their status and profile.
- Pay engineers more.
- Challenge the engineering institutions to do more to promote engineering.

- Changes to the education system to:
  - increase teaching quality in science;
  - promote science in schools;
  - promote physics in particular in schools;
  - expand the curriculum;
  - reduce the impact of Health and Safety legislation in schools and thereby encourage practical work;
  - increase time for practical work;
  - increase educational standards; and
  - include visits to engineering environments.
- Listen to real employers about their problems, not advisers and analysts.
- More engineers in Government.
- A more co-ordinated approach to infrastructure spending by the Government and implementation of the BERR Committee's Report "Construction Matters". Continued Government investment in infrastructure.
- Use Government procurement. Revisit the terms and conditions of engagement for businesses, for example, the unlimited liability carried by businesses under contracts.
- Re-establish the manufacturing base. Create a competitive manufacturing environment in the UK.
- Join the Euro to allow manufacturing industry to compete on level terms with European competition.
- Harness those leaving the armed forces with technical training.
- Tackle the loss of jobs to abroad and foreign workers in the UK.
- More help for small and medium-sized enterprises.
- Nothing. The Government cannot help/the profession, who understand the industry, must act.

January 2009

Committee Staff note on e-Consultation with young engineers

The Innovation, Universities, Science and Skills Committee set up a web forum to find out what young engineers thought about engineering as a profession and to find out why they went, or are thinking of going, into engineering. The web forum ran for six weeks from 28 October and closed on 9 December 2008. The forum asked for views on four topics and each received a substantial number of replies (or posts) and each topic was viewed over a thousand times and in one case over two thousand times.

Topic	*Posts*	*Views*
1. What would you do to improve engineering in the UK?	52	1,823
2. Has your education prepared you for engineering?	36	1,273
3. Is engineering a good career choice?	50	2,160
4. What or who inspired you to consider engineering as a career?	31	1,097

This has been the most successful e-consultation carried out by the Committee. Moderators found the consultation easy to manage with a steady stream of postings and only a handful of posts rejected—obscene usernames, promotion of organisations' activities and inclusion of personal information identifying the person posting (though in the latter case posts were usually accepted with small excisions).

Because the e-forum invited views from young people arrangements were put in place to ensure that the identity of those under 18 was fully protected. In the event this proved largely unnecessary as, from the internal evidence in the posts, two under 18s posted. (This of itself could be evidence that those under 18 are unaware of the possibility of pursuing engineering as a career.) From the same evidence it appears that the bulk of those posting were in their 20s.

When considering another e-forum the Committee may like to examine ways of promoting the forum. Although respondents were not asked to comment on how they found out about the forum, there were no indications that the launch event in the Lambeth Academy, the flyers distributed by Members and to school parties visiting the Palace of Westminster or electronic links through other organisations generated the posts.

1. *What would you do to improve engineering in the UK?*

Respondents identified three issues that needed to be addressed: first, attracting young people to engineering; second, the training provided to engineers, which is examined at topic 2; and, third, retaining those who train as engineers in the profession.

There was criticism of the quality of mathematics and science teachers in schools. Several respondents criticised careers advice in schools pointing out that schools preferred to encourage young people—especially the most able—to study pure science rather than engineering. One respondent suggested that this was in part because of "the prestige element" but mainly because there has been insufficient effort on the part of professional and governmental organisations to inform careers advisors about the possibility. He added that this was compounded by the increasing burden of student debt, and the likelihood of an MEng being a four year degree, which put young people off choosing to study engineering.

Another respondent pointed out that schools were unaware of engineering scholarships, opportunities to do A-Levels at engineering schools and "Year in Industry" schemes, which allowed individuals to work at an engineering firm for a year before going to university, "giving the individual some experience in the field and the opportunity to make some money to pay for University, even the possibility of some sponsorship". Several respondents suggested that schools needed to persuade engineers in industry to come into schools to "hold 'fun', hands-on engineering and science" days.

> One respondent explained: *It would be helpful if we could attract pupils to evening events organised by the various institutions. It seems almost impossible to get teachers to bring pupils to any event not directly related to the national curriculum. It ought to be part of their wider education. It would be especially sensible for it to be part of the new diploma courses.*

One under 18-year-old commented that his school had new equipment and machinery and he considered that the Government "could help some schools by giving them some machinery to work with so they could build more different things which they couldn't before".

Respondents suggested that the engineering institutions and universities needed to merge to form a collaborative team to promote engineering and that too often attempts to promote engineering were dissipated if only one aspect was being promoted.

> A student commented: *Since I have started university, I have been devastated about how much effort and hot air is wasted attempting to run engineering promotion and the lack of attempts made to show what Maths and science can get you to do.*
>
> *Engineering needs to be repackaged for joe the plumber and when that is done, we will be in a much better position. Much of this can be achieved by the institutions and not government legislation. It's just support (and some money) that will get this going.*

Another respondent argued that the professional engineering institutions needed reform and to amalgamate, and suggested that they acted like "like old boys' networks, rather than representing and upholding the profession as a whole".

On retention, the point was made that a degree provided only part of the training necessary to become an engineer and that a fully-formed engineer needed practical experience before he or she had was fully qualified. Although salaries appeared generous they failed to take account of the volume of work required to become an engineer.

> One student commented: *The salary is really not equal to the work you put in during your degree, and this adds to the [. . .] problem. A pertinent example would be at my university (Bath). The 55 Civil Engineers in my year, can expect on average to start on something around £26–30k if they achieve a 2:1 or 1st, but below that the wages drop closer to £20,000. For a BBA (Bachelors of business and administration) the starting wage for that same 1st or 2:1 student could well be the same, despite having done a far easier degree both time-wise and syllabus wise. In addition after five years their projected salary will be far greater than the equivalent civil engineer, again, despite the difference in difficulty of the degree. The trend continues throughout the careers, with engineers earning less. Why should I do engineering if this is the case?*

One Chartered Engineer said that career progression was though management. He explained that of his degree peers that he had kept in touch with approximately 30% were still in engineering. He said that half the people who were not engineers any longer were in "management", mainly because they could work up the career path to higher wages faster in management.

A theme running through this topic (and others) was whether the title engineer had been devalued since the 19th century and whether it should require accreditation—for example, as chartered engineers by recognised institutions—and be legally protected. Such a step was seen as enhancing the status of engineers.

The suggestion was made that companies should, as a first step, be encouraged only to employ registered engineers at a senior engineering level by, for example, publicising the commercial or legal advantages. Eventually this could become mandatory and the UK could have a fully regulated profession.

One respondent explained: *I am not bothered about salary, prestige, education, whether or not I am arrogant, equal to a doctor or a lawyer.*

Just copy the system they have in Germany, and many others for that matter, for their engineer's accreditation—that will do. The rest will follow.

A contrary view—apparently from a journalist covering science for 40 years—saw the argument about "label" and status" as a distraction. He argued as follows:

A better solution [. . .] would be for engineers to stop whining and to celebrate their subject in public. Point out to young people the engineers are the ones who will solve the problems of climate change and energy shortages. Remind them that engineers created their iPods and the football stadiums they love to visit. Oh, and add that engineers are pretty well paid, despite the whingeing letters that occasional sneak into the newspapers.

For that to happen, engineers have to become better communicators. Don't leave it to the particular physicists to claim the glory from the Large Hadron Collider. Learn how to talk to ordinary people, and not just fellow engineers.

There has been a revolution in science communication over the past 20 years. Sadly, the engineers have missed the boat, perhaps because their institutions are too busy competing with one another when they should be collaborating on this important aspect of their profession.

Finally, one respondent suggested that the Government should appoint a "Chief Engineer" along similar lines to the "Chief Scientist", who would be responsible for advising on technical issues such as infrastructure investment and flood management and also for promoting the profession amongst politicians and the public. Another commented on the absence in the UK of a centre from engineering excellence.

2. *Has your education prepared you for engineering?*

Many respondents made the point that academic courses were an essential part of engineering education to provide the theoretical "tools to solve engineering problems". But the qualification was made frequently that theory had to be tempered with practical experience. One respondent pointed out that, although he was excellent at maths and could pass examinations, this did not "prepare you for the real world application of engineering science". Contracting engineers considered that many designers had no appreciation of the practicalities and problems faced during construction and that the way degree programs were taught prepared engineers for consultancy design work but not contracting. Several advocated compulsory industry experience as part of a degree course, particularly, "on-site 'in the rain and mud' experience".

Two posts illustrate the contrasting views:

(A) I am [. . .] studying Electrical and Electronic Engineering [and] I think that it is far too theoretical. I am currently on a one year placement and I have found that from the two years I have spent at University most of it is irrelevant to industry. Mathematically I am well prepared but the university creates no awareness of industry. I have spoken to many other graduates where I work and elsewhere, including some who have a PhD and have been working in industry for nearly 20 years, and they all said that what they where taught at university was nearly all useless and they have not used most of what they studied in all the years they have been in industry. I think that the teachers have no idea what industry is about, or if they do they do not give the students an appreciation of what is involved. Overall I think that graduates are ill prepared for work in industry.

(B) If you are involved in the creation of new ideas, new ways of doing things, and are going to be doing demanding engineering, an academic degree is a necessity. You need the theory as a basis for doing new things. Those who say they forget it all within a few weeks of graduating aren't in a job that requires it, but many people are. If you're not involved in development, then perhaps an academic degree is more inappropriate. The problem is; how do people know this when they make educational and career choices?

Some have entered engineering through apprenticeships—in some cases, because of concerns about the cost of courses and building up debt—and a number of those who entered via a degree considered that it to a significant extent irrelevant and that a placement or apprenticeship, BTEC National Certificate or an NVQ level 3, would have been better. It was noted that the status of apprenticeships was improving. One post mentioned that the Engineering Diploma positively and pointed out that "we need a broad range of skills from Engineers—both hands on and analytical and management based"—and considered that once the Diploma was fully established there would be a "full compliment of routes available to create a strong Engineering Industry".

A few commented on the subjects taught at schools. One chemical engineer, having worked in industry for several years and currently in a role bridging the public sector to industry, considered that he would have obtained more value doing a "Double Science" A-level (if it existed) because of the opportunities arising in industry were frequently "in cross-sector areas". Others commented that the mathematics and science subjects needed to have a greater engineering flavour to encourage young people to consider engineering. But one respondent warned against "clogging up secondary schools with fads" and said that having "advanced knowledge of electronics or computer programming is nice if you went to a good school, but not a necessity".

Some found shortcomings with the teaching of engineering in higher education institutions. Lecturers lacked experience of industry and many were interested in research rather than teaching. Several pointed out that an engineering degree needed to provide a wider range of skills—for example, communications and project management—to ensure graduates had a successful career.

> A mechanical engineer with a degree commented: *I found my degree to be severely lacking in the teaching of communications skills, something most engineers will need to work on if they want to succeed in industry. It was also very short on applying the theory to real engineering problems. Finally, it taught very little about the various sectors of engineering and hence I had to start from absolute grass roots basics when I started my role in the industry I am now a part of.*

3. *Is engineering a good career choice?*

Opinions were divided but the preponderant view was that pay and conditions were reasonable and the work satisfying. Some questioned, however, whether the level of remuneration adequately matched the training and skills required to become an engineer and some pointed out that increases in salary could only be achieved by moving company. The view was expressed that smaller companies offered "relatively few opportunities to graduates, particularly the experience and mentoring to become chartered" engineers. Several commented on travel: for a few a drawback but for many an opportunity, and as one respondent commented, "With experience and qualifications you can work anywhere in the world".

As to the future, there was some feeling that engineers in older traditional industries such as manufacturing may face redundancy as jobs moved to low wage economies overseas but others pointed out that civil engineering projects in the UK could not relocate—though there was a risk that skills' shortages would be filled from overseas—but there was some apprehension that after the Olympics and Crossrail had been completed there would a surplus of engineers. But many saw opportunities for engineers in new areas such as low carbon technologies and there was a strong vein of optimism that only engineers could provide solutions to the challenges of the 21st century.

> One respondent explained: *For me engineering was the ONLY career choice.*
>
> *However it has bought me numerous job changes through redundancies, project closure, take-overs, lousy management, and the list goes on and on.*
>
> *I have had to go back to university for a harder hitting qualification in the job market—which has worked. It has also bought me: International travel—23 countries; speaking at conferences; and asked to lecture to young students on a career in engineering.*
>
> *I see friends working in finance/accountancy permanently bored out of their minds, others working in IT seeing their salaries and contract rates slashed [. . .].*
>
> *With the demand for greener technologies, change in transportation, vast quantities of new power stations of one description or another and the demise of oil—it can only get better.*

Management emerged as a two-sided issue. Some considered that companies failed to manger or appreciate engineers adequately, often treating them as "technicians" and below other professions requiring essentially the same skills and expertise such as architects. While some engineers recognised that taking on management responsibility was a route to promotion, many wanted to keep hands-on experience and one wanted "career structures that enable their best talent to progress in a technical role". A new entrant to engineering commented that "my best chance for career progression is to go into a non-engineering, management role".

> One respondent explained: *Many people don't want to be managers. Indeed there is a body of management literature out there that identifies many engineers hitting a "ceiling" of poor performance once they get into management, whilst their technical skills wither and go out of date. These people would prefer to specialise in some technical area (that is why a lot of people go into the*

> *profession), but surprisingly in many (most) UK companies this isn't allowed. A placement company I worked for used the "motorola" approach whereby you can choose to develop as a technical specialist or a manager or a mixture, depending on personal preference. Motorola pay their technical experts more than their senior management in some cases.*

On the public perception and status of engineers, the debate ran along the lines of the one in the previous topic. While one respondent commented that if "you go into it purely for the status, you're in it for the wrong reason", the debate focussed on the public misunderstanding that engineers were "people think that we fix cars or washing machines" and on whether the title "engineer" should be restricted to professionally qualified engineers. One change suggested was to give greater status to "chartered engineers". On respondent pointed out that upon becoming chartered there was "a massive change in the way your employers view you, simply because they can now charge you out at a higher rate as those few letters at the end of your name demand".

> A young engineer explained: *There is clearly a problem of perception of engineers and whilst some of this may be snobbery there is clearly an issue with some companies calling some staff engineers who aren't. It is however difficult to draw a line on who is and who isn't an engineer. There is however a clearer definition of Chartered Engineer (which includes people who don't have a degree) but I suspect few people outside engineering understand what being a Chartered Engineer means.*

4. *What or who inspired you to consider engineering as a career?*

Two themes emerged from the posts. First, schools and careers guidance did not give sufficient encouragement to young people to become engineers. Engineering was not taught as a subject in schools and several commented on the absence of systematic arrangements to encourage young people to consider it as a career. Careers advice focussed on science careers rather than engineering. Second, several respondents said that there had been "good" at mathematics, physics and chemistry and enjoyed solving problems but only became interested in engineering when an event/often extra-curricular or external such as a visit or a television programme/focussed their interest.

> One respondent explained: *I fell into engineering without much thought really, which goes to show how much more publicity engineering needs. I was studying the right kind of subjects and had grandparents who were engineers and yet I'd never considered a career in it until my school offered me a place on the Engineering Education Scheme (EES) totally by chance because a friend had turned down her place. I enjoyed the project we worked on so much that I decided to study Civil Engineering at university.*
>
> *I was never told about engineering by careers advisors or teachers and I think this is due to a lack of education on their part.*

In contradiction of the cited example, several respondents commented that, in the absence information about engineering at school, having a family member who was an engineer opened their eyes to the potential of the profession. The family member provided not only information but a role model. One respondent commented on the need for a public face for engineering to do what Jamie Oliver had done for Cooking and Simon Schama for History. The other problem was that lack of knowledge about the disciplines within engineering. Even among engineers themselves there was ignorance of what, for example, a chemical engineer did.

The way best way to tackle these problems was better careers information and demonstrations of what engineering. One respondent suggested approaching local firms for a placement, which had the added benefit of practical experience when applying for courses. Several respondents made the point that that they had a predisposition towards practical activities—taking things apart to see how they worked or building machines or computers—and they once they got some hands-on experience they found their metier.

> A young engineer explained: *I don't think there's actually enough awareness of what engineering is, a lot of people seem to think it's mechanics (as in fixing cars) for some strange reason.*
>
> *Most people only ever hear about the architects and know little about the fact that engineers are the ones that make it possible. I first heard about engineering when I did work experience in an architect's office, and Civil Engineering has been the career path I've moved towards ever since.*
>
> *I was also lucky that I had a talk back at Secondary School by the WiTEC [Women in Science, Engineering and Technology], they inspired me to do something which was away from what traditional Chinese families consider as a profession (with doctors, bankers and lawyers being the most common). During the talk they emphasised the fact that everything we see and use has been*

engineered. From bus networks that we take in the mornings to PCs we use in the classroom, they have all been brought about by engineering in one form or another.

There definitely needs to be more promotion about engineering as a career path to children at a younger age. Teenagers tend to be quite inquisitive, and if you tell them how clever some of the solutions that engineers have come up with are, they'll be intrigued.

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