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The Economics of Climate Change

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NOTE:

The Report of the Committee is published in Volume I, HL Paper No. 12-I
The Evidence of the Committee is published in Volume II, HL Paper No. 12-II

ABSTRACT

The Committee, having considered various aspects of the economics of climate change, calls on the Government to give HM Treasury a more extensive role, both in examining the costs and benefits of climate change policy and presenting them to the United Kingdom public, and in the work of the Intergovernmental Panel on Climate Change (IPCC).

We have some concerns about the objectivity of the IPCC process, with some of its emissions scenarios and summary documentation apparently influenced by political considerations.

There are significant doubts about some aspects of the IPCC's emissions scenario exercise, in particular, the high emissions scenarios. The Government should press the IPCC to change their approach.

There are some positive aspects to global warming and these appear to have been played down in the IPCC reports; the Government should press the IPCC to reflect in a more balanced way the costs and benefits of climate change.

The Government should press the IPCC for better estimates of the monetary costs of global warming damage and for explicit monetary comparisons between the costs of measures to control warming and their benefits.

Since warming will continue, regardless of action now, due to the lengthy time lags in climate systems, and since there is a risk that international negotiations will not secure large-scale and effective mitigation action, a more balanced approach to the relative merits of adaptation and mitigation is needed, with far more attention paid to adaptation measures.

We are concerned that UK energy and climate policy appears to be based on dubious assumptions about the roles of renewable energy and energy efficiency and that the costs to the UK of achieving its objectives have been poorly documented. We look to the Government, with much stronger Treasury involvement, to review and substantiate the cost estimates and to convey them in transparent form to the public.

We think that current nuclear power capacity, before further decommissioning occurs, should be retained.

We urge the Government to replace the present Climate Change Levy with a carbon tax as soon as possible.

We are concerned that the international negotiations on climate change reduction will be ineffective because of the preoccupation with setting emissions targets. The Kyoto Protocol makes little difference to rates of warming, and has a naïve compliance mechanism which can only deter countries from signing up to subsequent tighter emissions targets. We urge the Government to take a lead in exploring alternative "architectures" for future Protocols, based perhaps on agreements on technology and its diffusion.

The Economics of Climate Change

CHAPTER 1: INTRODUCTION

1. Sir David King, the Government's Chief Scientific Adviser, has stated that "climate change is the most severe problem that we are facing today—more serious even than the threat of terrorism"[1]. Much of the debate about global warming—its reality, causes and the urgency of finding solutions—has been driven by the science of climate change. Despite a huge literature on the economic implications of warming, the costs of tackling it, and the role of economic policy instruments in the control of greenhouse gas emissions, economic arguments have not been to the fore in the public presentations on the issue. Many people may, therefore, be ignorant of key issues highlighted by an economic perspective—for example: the close linkages between world economic performance, the man-made forces influencing climate change, and the role of technological change in reducing greenhouse gas emissions; the considerable time lags between taking action and the effects of those actions; the costs that must be borne now for benefits that will not accrue to this generation; and the cost in terms of opportunities forgone by spending resources on climate change control rather than on, for example, addressing issues of global poverty now.

2. The economics is important. Indeed, the Chancellor of the Exchequer has declared that "climate change is an issue for finance and economic ministries as much as for energy and environmental ones"[2]. **We welcome this recognition of the central role of economics. It is the driving force behind our inquiry. But we believe that the Chancellor needs to broaden the scope of the Government's interests, and the Treasury's interests in particular, in aspects of the climate change debate that we feel have not yet been given sufficient emphasis.** Both the science and the economics of climate change are explored in the publications of the Intergovernmental Panel on Climate Change (IPCC). **We are concerned that the links between projected economic change in the world economy and climate change have not been as rigorously explored as they should have been by the IPCC. We believe the complex interactions between world economic growth and climate change need additional scrutiny at the international level, and that the United Kingdom Government has a role to play in ensuring that this happens. We are also concerned that clearer messages should be conveyed to the public about the likely costs and benefits of climate change control, who will bear those costs and benefits, and when.** Since the science of human-induced warming remains uncertain, the issue is how to behave in the face of that uncertainty. Uncertainty does not dictate doing nothing: none of the concerns we raise constitutes a reason for not tackling climate change. Rather, uncertainty dictates caution and the taking

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1 Sir David King, Climate change science: Adapt, mitigate, or ignore? *Science*. 303. 176-7, 2004.

2 Speech by The Rt Hon Gordon Brown, Energy and Environment Ministerial Roundtable, 15 March 2005.

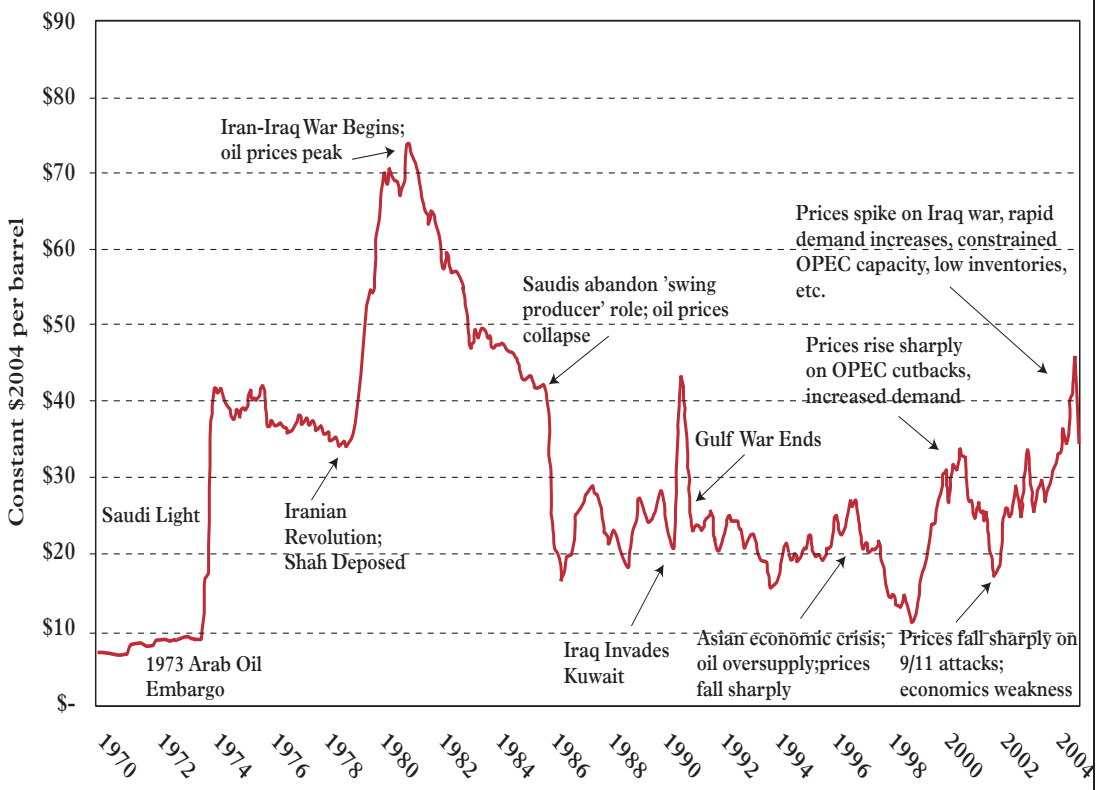
out of insurance against the worst risks. But, like insurance against any other risk, insurance costs money. It is important that the costs of such precaution are better understood, and the risk-cost trade-offs are better appreciated.

3. We believe there is an educative role to be played by a more frank and open discussion of the economic issues involved in tackling climate change, and that the public deserves to be better informed about them. We do not believe, for example, that many people are aware that the international efforts made so far—The Framework Convention on Climate Change (1992) and its first Protocol, the Kyoto Protocol (negotiated in 1997 and brought into force in 2005)—will make little difference to future rates of warming, even if implemented in full. It must be emphasised that these international agreements will have to be supplemented with far more telling initiatives if climate change is to be tackled in any significant way. Ultimately, a public that is not adequately informed may react adversely to the discovery that more and more cost burdens will fall on them, and on their children, in the name of warming control. The fuel protests of 1999-2000 are testimony to the sensitivity of the public to even modestly rising energy prices. Substantial increases in energy prices must be an integral part of any policy for reducing carbon emissions. Box 1 shows the time-profile of oil prices from 1970 to the present day. In real terms, oil prices today are about half of their peak price in 1981 at the time of the Iran-Iraq war. In nominal terms, prices are about the same. To encourage reductions in carbon emissions, real prices need to rise further, and by significant amounts. **We are not convinced that there is sufficient public awareness of this issue. Any public misperception on these issues could threaten the political feasibility of getting plans of action put into effect. If climate change is as serious as most scientists claim, and as the Government accepts, then it is important to convey the complementary message that the action to tackle it will also have to be serious and potentially life-changing. It is better to be honest now than to shield the public from the economic realities inherent in the more pessimistic forecasts.**

BOX 1

The path of oil prices 1970 to the present

The chart shows the evolution of real oil prices (i.e. oil prices with inflation netted out) expressed in constant 2005 US dollars. While nominal prices (inclusive of inflation) are about the same today as they were at the peak of oil prices in 1981, the real price is about one-half. If there is to be a major reduction in carbon emissions, energy prices, as typified by the price of oil, will have to rise significantly in real terms.



Source: US Department of Energy

4. The Committee decided to restrict the scope of its investigation to certain aspects of the economics of climate change. We have done so because we are aware that the subject is potentially very wide-ranging. In addition, other Parliamentary committees have also investigated some of the issues[3]. The Committee decided to focus on (a) the way in which scenarios of the future changes in the world economy affect the projections of warming; (b) issues relating to the costs and benefits of tackling climate change; and (c) the profile of economics in the governmental and inter-governmental processes relating to climate change science and control. We have not systematically investigated the important issues of choosing policy instruments for tackling climate change—the role of carbon and energy taxes, the EU emissions trading scheme and other measures. Nonetheless, our inquiry strayed into these areas and we have some comments to make.

[3] For example, the House of Commons Environmental Audit Committee has looked at the international agreements and the role of the UK in international negotiations: *The International Challenge of Climate Change: UK Leadership in the G8 and EU*. (2004-05, HC 105). See also House of Lords European Union Committee: *The EU and Climate Change*. (2003-04, HL 179).

CHAPTER 2: THE UNCERTAIN SCIENCE OF CLIMATE CHANGE

The greenhouse effect

5. Our dominant concern is with certain aspects of the economics of climate change, but clearly, any investigation must begin with the underlying science.

6. The Earth's surface is warmed by the sun. This incoming solar radiation is fairly constant—it does not vary with time. The Earth's temperature is controlled by the balancing between this incoming short-wave radiation, which warms the Earth, and the loss of this energy as it is bounced back into space. The re-radiated energy cools the Earth. Energy-out balances energy-in, and the Earth maintains a constant global temperature. Without this balance, the Earth would become steadily hotter and life would cease. Of the incoming solar radiation, roughly 30% bounces back into space from clouds, atmospheric aerosols and bright, reflective areas of the Earth's surface, such as deserts. That leaves 70% of the incoming radiation to be absorbed, mostly by land areas and the oceans. But even this 70% cannot stay permanently absorbed, otherwise the Earth would again continually warm up and life would not be possible. It is re-emitted primarily as long-wave, infra-red radiation back into space. But some of this re-radiated energy is absorbed by water vapour and by "greenhouse gases" which exist in the atmosphere. The principal greenhouse gas is carbon dioxide, but the principal absorbing agent is overwhelmingly water vapour. The effect of this absorption of the re-radiated energy is to produce another round of re-radiation, this time back to the Earth's surface, where it is absorbed once again. This is the "greenhouse effect". This re-absorption process is natural: it is what maintains the Earth's average temperature at +15°C rather than at levels below freezing[4].

[4] The effect is actually to warm the Earth by around 35°C, i.e. to +15°C rather than the approximate -20°C that would otherwise prevail.

BOX 2

The greenhouse gases

The main greenhouse gases are carbon dioxide (CO_2) which is emitted by the use of fossil fuels and by the burning of forests; methane (CH_4) which comes from decaying degradable matter, e.g. in landfill sites, and from livestock; nitrous oxides (N_2O) from fertilisers, industrial processes, and fossil fuel burning; and a group of other gases, such as perfluoromethane (CF_4) and perfluoroethane (C_2F_6) used in aluminium production, and sulphur hexafluoride (SF_6) from dielectric fluids. Other gases, such as carbon monoxide (CO) and nitrogen oxides (NO_X), have indirect effects on greenhouse warming through various chemical reactions.

The power of the main greenhouse gases to "force" temperature rises varies substantially. The conventional way of expressing these forcings is the "Global Warming Potential" (GWP). The GWP for carbon dioxide is set equal to 1. Then the other forcings are as follows:

Carbon dioxide	= 1
Methane	= 23
Nitrous oxide	= 296
Hydroflurocarbons	= 12 to 12000 depending on the gas
Perfluorocarbons	= 5000 to 12000
Sulphur hexafluoride	= 22200

However, CO_2 remains the most important gas because of the quantities in which it is emitted.

7. It is not this natural greenhouse effect that gives rise to concern. It is the fact that the relatively short period in the world's history since the Industrial Revolution has seen significant increases in the emissions of the greenhouse gases, especially carbon dioxide and methane. These greenhouse gases add to the concentrations already in the atmosphere. Moreover, they accumulate and stay in the atmosphere for decades (their "atmospheric residence time"). While they get generally mixed in the atmosphere, it is common in pictorial terms to show these increased concentrations as a "blanket" that traps the outgoing long-wave radiation and returns it to Earth. It is this accelerated or enhanced greenhouse effect that causes the concern, since the effect is to warm the Earth's surface even more than the level achieved naturally. In effect, what is happening is that the greenhouse gases are upsetting the natural energy balance in such a way that "something has to give" to restore the balance, and it is surface warming that is bringing about the adjustment.

8. Evidence from Antarctic ice cores suggests that atmospheric concentrations of CO_2 were fairly constant over 1000 years until the Industrial Revolution[5]. In the year 1000 (measured by ice core samples), concentrations were 280 ppm (parts per million), and the concentrations were the same around 1800, whereas today they are some 375 ppm. Currently, concentrations are growing at some 1.5 ppm every year, as recorded by the Mauna Loa observatory in Hawaii, which has been monitoring concentrations since 1959. A similar picture, but with more variability over time, emerges for N_2O, at around 270 ppb (parts per billion) between 1000 and 1700, rising to 310 ppb in 2000. Methane, CH_4, is also fairly constant between 1000 and 1750 at 750 ppb, rising to over 1600 ppb in 2000[6]. Longer historical records from ice cores also suggest that carbon dioxide and methane concentrations are now at their highest levels for the past 400,000 years[7].

Negative forcing

9. Not all greenhouse gases—gases that contribute in some way to the enhanced greenhouse effect—create "positive forcing", i.e. warm the atmosphere[8]. Some have a cooling effect. Aerosols—tiny particles of liquid or dust in the atmosphere, such as soot, volcanic ash and dust—give rise to cooling effects. Clouds can have a cooling effect as well, reflecting radiation back into space. The level of understanding of the behaviour of clouds and aerosols is unfortunately far less than the level of understanding for the main warming greenhouse gases. An important cooling aerosol is sulphate which comes from sulphur dioxide (when mixed with oxygen), which in turn comes from sulphur-bearing fossil fuels such as coal. These sulphate aerosols reflect sunlight and hence produce a cooling or "dimming" effect. In the rich world, substantial controls exist over sulphur emissions because of damage caused by local air pollution and transboundary acid rain. As a result, sulphur emissions are declining. But in the poorer world, there are still considerable pressures to burn fuels such as coal and lignite, and sulphur emissions are rising. The scenarios of future warming therefore depend in part on what happens to this balance of sulphur emissions.

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5 Sir John Houghton, *Global Warming: the Complete Briefing*. Cambridge University Press. 3rd Edition. 2005, p32. Ice cores can also be used to construct temperature and CO_2 records going back over 400,000 years (and, most recently, cores have been extracted that go back 900,000 years). As snow fell, the air in the snow became trapped in the ice that subsequently formed, so that greenhouse gas concentrations in the trapped air bubbles can be measured. This gives the CO_2 record for the whole period. Examination of the oxygen and hydrogen isotopes in the ice core also permits temperature readings. The two time-series—temperature and CO_2—appear to show a very close correlation, suggesting that the two are closely linked. Ice ages had low levels of CO_2 (about 210 ppm) and warm periods had high levels of CO_2 (around 270 ppm). See J. Petit et al. Climate and atmospheric history in the past 420,000 years from the Vostok ice core in Antarctica. *Nature*, 399, June 3, 429-436, 1999. While correlation is not causation, and there remains some dispute over the nature of the linkage, there is also evidence that CO_2 concentrations "lead" temperature rather than the other way round. See M. Maslin, *Global Warming: A Very Short Introduction*. Oxford University Press, 2004, p.60.

6 R. Watson et al., op.cit. p.47.

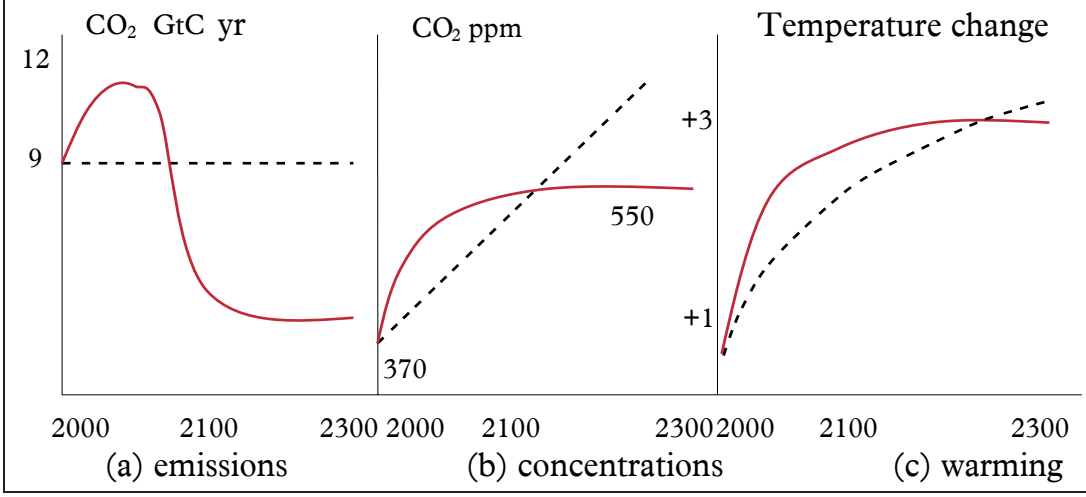
7 J. Weier, *Global Warming*, Earth Observatory, NASA, Washington DC. 8 April 2002.

8 "Radiative forcing" refers to the amount of energy trapped by the atmosphere and is measured in watts per metre squared (Wm^{-2}).

BOX 3

The basic linkages in climate change

Emissions of greenhouse gases (GHGs) cumulate in the atmosphere because the rate at which they diffuse in the atmosphere exceeds the rate at which they decay naturally, allowing also for the fact that they reside for various "lifetimes" in the atmosphere. Thus atmospheric concentrations of GHGs have risen steadily over time. In turn, because of the accelerated greenhouse effects, the increasing concentrations translate into radiative forcing which raises the mean surface temperature of the Earth. The exact relationships between emissions, concentrations, forcing and temperature change are not known with certainty. The diagrams below show a stylised picture of a situation in which global annual CO_2 emissions (the main GHG) stay constant at current levels for the next 300 years (the dashed lines), and an alternative scenario in which emissions grow from now until 2050 and then decline dramatically (the continuous line). Panel (a) shows the emissions trajectories. Panel (b) shows the resulting atmospheric concentrations, and panel (c) shows the resulting temperature profiles. While the dashed line is unrealistic—it assumes immediate cessation of the growth in CO_2 emissions—it serves to show that such a cessation would still result in steadily rising temperatures over the next few hundred years, illustrating the time lags and non-linearities in the climate system. The continuous line is consistent with radical action now, but emissions would nonetheless continue to rise for around 50 years, after which actions taken now and in the near future would dramatically cut emissions. The radical scenario achieves a 550 ppm concentration target by around 2100, a target that is widely being regarded as the long-term goal that might realistically be achieved. Again because of the lags in the system, stabilisation at this level in 2100 still results in rising temperatures thereafter, but temperature is stabilised at around +2.5°C in 2300. In practice, CO_2 emissions are still rising, although they are currently rising at a decreasing rate. The dashed line is therefore increasing rather than staying constant, underlining what many climate scientists regard as the urgency of early action.



Temperature change

10. Box 3 shows that the growth of emissions of greenhouse gases is linked to global temperature changes after some considerable time-lags. Since

greenhouse gas emissions, especially carbon dioxide, increased with the onset of the Industrial Revolution, current temperatures should have responded to these past emissions. The recent historical record of global temperature change is not disputed. Instrumental records (using thermometers) for temperatures in the Earth's Northern Hemisphere do not really begin until around 1860[9]. "Global" (i.e. Northern Hemisphere) average temperatures show marked fluctuations around a rising trend[10]. The (approximate) observed cycles are upwards for 1860 to 1875, downwards to 1890, up to 1900, down to 1915, up to 1942, down to 1970 and upwards since then. A more "smoothed" series would suggest a reasonably constant temperature to 1920, upwards to around 1940, downwards to 1970 and upwards since then. Since 1860, the mean temperature change has been around 0.6°C.

11. Any test of the link between temperature change and greenhouse gases must therefore account for these cycles. Mathematical models that try to explain temperature change are known as general circulation models (GCMs). These models attempt to mimic the forces at work that change the Earth's climate. If they can "explain the past", then they can be used to predict the future, assuming we have a reasonable idea of how the various determining factors (e.g. the greenhouse gases themselves) will behave in the future. GCMs tend to be very complex and have to run on powerful computers.

Scientific consensus and scientific doubt

12. Testing the validity of climate models is obviously difficult. In so far as the models predict climate change, the predictions can easily be in error and only the passage of time can validate the predictions. But if the science of climate change as embodied in IPCC reports is correct, the option of "waiting and seeing" may be risky because of the manner in which current emissions of greenhouse gases add to the stock of gases in the atmosphere. Once cumulated, the decay processes are very long term and hence the gases cannot be "decumulated" in short periods of time. Other tests are therefore needed. These tend to comprise (a) ensuring the internal consistency of the models—i.e. the extent to which they are consistent with received theory, and (b) the extent to which they "predict the past". In case (b) two historical tests are used. The first looks at the detailed temperature record since the mid-19th century, when instrumental records become widespread, and the second looks at the extremely long run record embodied in ice cores, tree rings and other "proxy" data going back hundreds of thousands of years.

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9 A unique series exists for Central England from 1659 and can be accessed at www.met-office.gov.uk/research/hadleycentre/CR_data/Annual/cet.gif .

10 It is important to understand how temperature changes are computed and portrayed. Temperature can obviously be measured daily and even hourly, so there are huge numbers of observations from the instrumental record. These are made more manageable by a process of averaging through time. A "moving average" of, say, 5 years, would take the average over the first 5 years 1 to 5, then the average of the 5 year period from years 2 to 6, and so on. The larger the averaging period, say 50 years instead of 5 years, the "smoother" the resulting trend line becomes. Turning points in this moving average therefore tend to change with the averaging period. In the climate science literature the difference between this moving average trend line and the actual temperature is known as an "anomaly". To test whether temperature and a greenhouse gas like CO_2 are correlated, it is the anomalies in temperature that are compared to CO_2 concentrations. This allows the correlation not to be unduly influenced by the time trends in the series.

BOX 4

The main IPCC publications

THE FIRST ASSESSMENT				
Year	**Working Group 1**	**Working Group 2**	**Working Group 3**	**Other**
1991	Volume 1 The IPCC Climate Assessment	Volume 2 The IPCC Impacts Assessment	Volume 3 The IPCC Response Assessment	Emission Scenarios
1992	Supplementary Report to the Scientific Assessment	Supplementary Report to the Impacts Assessment		Climate Change: The IPCC 1990 and 1992 Assessments
1995				Climate Change 1994 – Radiative Forcing of Climate Change and the Evaluation of the IS92 Emission Scenarios
THE SECOND ASSESSMENT				
1996	Climate change 1995 – The Science of Climate Change	Climate Change 1995 – Impacts, Adaptations and Mitigation of Climate Change	Climate Change 1995 – Economic and Social Dimensions of Climate Change	Climate Change 1995 – IPCC Second Assessment Synthesis of Scientific-Technical Information
2000				Emission Scenarios – IPCC Special Report
THE THIRD ASSESSMENT				
2002	Climate Change – The Scientific Basis	Climate Change 2001 – Impacts, Adaptation and Vulnerability Climate Change 2001 - Mitigation		Climate Change 2001 – Synthesis Report
2007	**THE FOURTH ASSESSMENT**			

13. The Committee heard from several scientific witnesses on the theory. No one disputes the fact of temperature rise in the last 100 years or so. No one disputes that carbon dioxide is a greenhouse gas and few dispute that it has an enhanced "greenhouse effect". What is disputed, albeit by a minority of scientists, is the scale of this effect. In the view of Professor Richard Lindzen of MIT, current climate models would have predicted a substantially greater increase in the past temperature than has been observed in the past 150 years, perhaps +3°C compared to the +0.6°C we have witnessed. In his view, this suggests that the models are biased upwards and that, while warming will occur, it is the lower end of the IPCC spectrum that is relevant, not the upper limits, which he regarded as "alarmist"[11]. Our understanding of the scientific response to this apparent anomaly is that (a) cooling effects, including those from sulphates, have masked the expected rise in warming,

[11] Evidence from R. Lindzen (Vol II, pp 44-55)

and (b) only climate models that combine natural variability and anthropogenic forcings "fit" the past data[12], as outlined in paragraph 15.

14. We recognise that there is a strong majority view on climate change. Majorities do not necessarily embody the truth, but we note that major associations of scientists have adopted similar positions. The IPCC tends to be the focus of the majority view which has been confirmed by the Royal Society[13], and by the US National Academy of Sciences, the American Meteorological Society, the American Geophysical Union and the American Association for the Advancement of Science. Despite this, it is a concern that the IPCC has not always sought to ensure that dissenting voices are given a full hearing. We document these concerns later in the Report.

15. As far as the recent temperature record is concerned, as noted above, the temperature record is not one of consistent warming. Indeed, there was a distinct "cooling period" in the 1960s and 1970s—see Box 5. The conventional explanation of this phenomenon is, first, that this period was associated with substantial sulphur emissions in North America and Europe, with sulphates having a cooling effect. As sulphur emissions came to be controlled, the underlying upward trend in warming resumed. Second, there was a natural variation in temperature in this cooling period due to changed sunspot activity. The IPCC is clear that GCMs that contain only anthropogenic temperature forcing predict more temperature change than has been observed in the 20th century. It claims that GCMs that embody only natural variation understate the temperature rise of the past 30 years or so. Only when anthropogenic and natural forcings are combined is the temperature record accurately simulated[14].

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12 On (a) see Sir John Houghton, *Global Warming: The Complete Briefing*. Cambridge University Press, 2005. p.103. On (b) see R. Watson et al., op.cit., p.198.

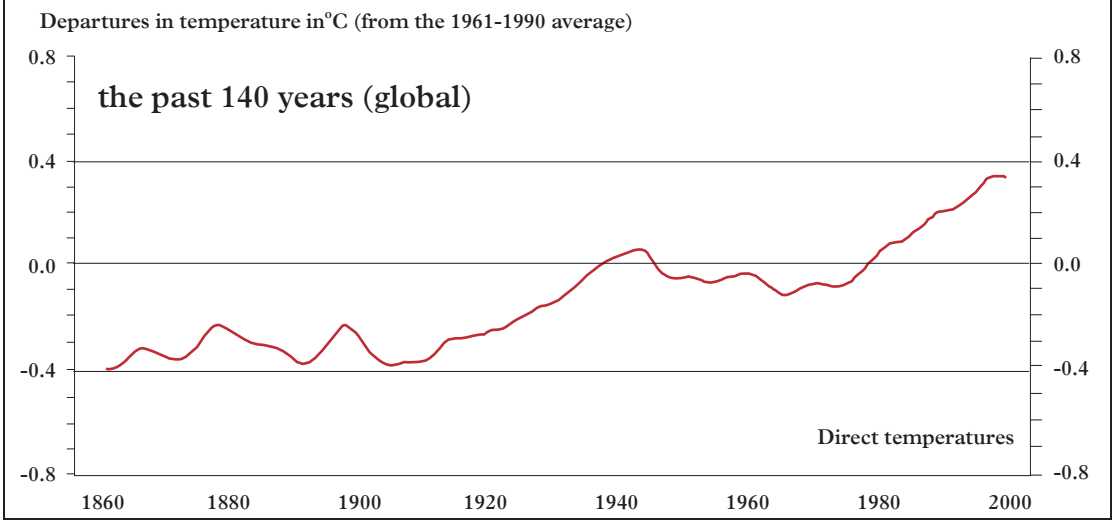
13 Evidence from the Royal Society (Vol II, pp 293-306)

14 R. Watson et al., op.cit. p.198

BOX 5

Recent temperature change

It is customary to show temperature in terms of deviations from the average of 1961-1990 temperatures. "Decomposing" the chart into approximate time periods, there is roughly a 0.6°C increase from 1860 to 2000. There appears to be no trend increase or decrease, i.e. temperature is fairly constant, in the period 1860 to 1920. There is continuous warming from 1920 to 1945, followed by a period of "cooling" from 1945 to 1965, in turn followed by continuous warming from 1965 to the present.



16. In his evidence to us, Sir David King drew attention to recent research which, it is claimed, shows that changes in ocean temperatures have been accurately predicted by the GCMs, further validating the models[15].

17. Apart from the issue of explaining the divergence between actual and expected recent past warming, we heard doubts expressed about other features of the accepted science. These include:

- concerns that changes in ice-core record CO_2 concentrations might have followed temperature rise rather than the other way round;
- the poor nature of the data used to compute the long run historical record, or alleged misinterpretation of the long-run historical temperature record;
- the GCMs fail to "reconstruct" the long term historical record;
- the view of some that the relative importance of the natural factors affecting climate variability, e.g. variation in solar output, is underplayed in the IPCC assessments;
- apparent divergences between land-based temperature records and satellite-based measurements, the latter showing some cooling rather than warming in recent years;
- the manner in which the GCMs are adjusted until they align with the observed data;

[15] Evidence from Sir D. King (Vol II, pp 96-106)

- the uncertain role of cloud cover. Professor Lindzen argued that clouds generate a negative feedback effect (cooling) rather than the positive feedback effect assumed in the GCMs; and that
- the models fail to predict sudden weather events.

18. We do not propose to evaluate these doubts, nor are we qualified to do so. We are also aware that climate scientists who adhere to the human-induced warming hypothesis have responses to most of these sources of doubt[16]. But the science of climate change remains debatable. We heard from witnesses who seemed in no doubt at all about the science, while others expressed one or more of the above concerns. **That makes it clear that the scientific context is one of uncertainty, although as the science progresses these uncertainties might be expected to diminish and be resolved, one way or the other. Hence it is important that the Government continues to take a leading role in supporting climate science, and encourages a dispassionate evidence-based approach to debate and decision making.**

19. In terms of policy on climate mitigation and adaptation, the issue becomes one of how to behave in the face of uncertainty. Given this uncertainty, the effective irreversibility of climate change, and the potential for large-scale damage, a precautionary approach is called for. But precaution cannot be the right option at any cost. We return to this issue later.

A note on the "hockey stick" debate

20. While we have not entered into the scientific debate in any detail, we received a significant amount of evidence on the so-called "hockey stick" debate and hence feel we should comment on this issue.

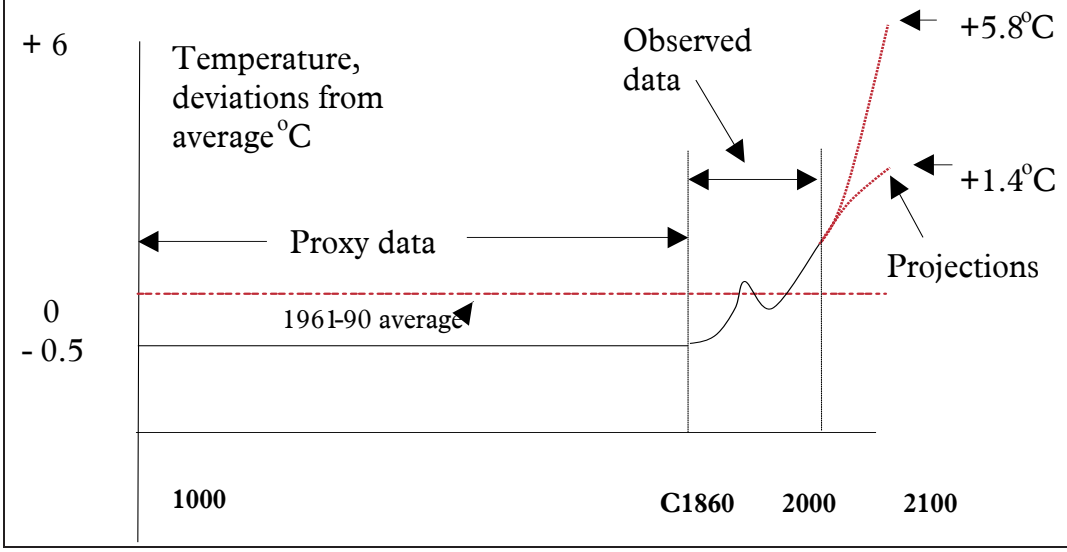
21. The hockey stick refers to the shape of the long-run time series curve of temperature change—see Box 6. This appears to show gently declining global (actually Northern Hemisphere) temperature from at least 1000 until about 1700, with a rise from then until the present. Most importantly, the recent past shows a sharp upturn such that the later part of the 20th century is warmer than any previous period. Thus the series resembles a hockey stick with the blade facing upwards—see Box 6. We noted earlier that a similar graph is suggested for carbon dioxide concentrations. The importance of the hockey stick shape is that the upturns in both temperature and CO_2 coincide and both are relatively recent phenomena, i.e. in the last 150 years or so. The hockey stick thus appears to be persuasive visual evidence that the recent temperature change is human-induced.

[16] An excellent description of most of these debates is to be found in M. Maslin, *Global Warming: A Very Short Introduction*. Oxford: Oxford University Press, 2004.

BOX 6

The "hockey stick"

According to the hockey stick literature, the time-profile of temperature in the Northern Hemisphere has the shape shown in the stylised diagram below. Temperatures before the mid-19th century tend to be inferred from ice-core and tree-ring data ("proxy" data). The implication is that natural climate variability has not generated temperature variations that compare with the temperature change witnessed since the onset of industrial times. Hence the temperature change of the last few centuries must be due to human-induced factors. The historical evidence is debated. Several studies have found fairly long periods in the last millennium in which variations of up to +1°C may have occurred[17]. In their evidence to us, the Royal Society drew attention to these papers but argued that natural variation alone cannot explain recent warming[18]. In a separate critique, Dr McIntyre and Professor McKitrick of Canada argue that one of the prominent hockey stick series is consistent with marked increases in temperatures between 1400 and 1500.



Source: P. Jones and M. Mann, Climate over past millennia. *Reviews of Geophysics*, 2004. 42: 1-42.

22. Some critics argue that the experience of the last few hundred years is too short a period for the climate models to determine the balance of natural and man-made factors in temperature change. This is why considerable attention has been paid to the longer run temperatures and the "hockey stick". One attempt to reconstruct a long-term temperature record is that of Professor Michael Mann of the University of Virginia[19]. The picture that emerged for

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17 H. von Storch et al. Reconstructing past climate from noisy data. *Science*. 2004.306:679-682; A. Moberg et al. Highly variable Northern Hemisphere temperatures reconstructed from low-and-high resolution proxy data. *Nature*. 2005. 433: 613-7.

18 Evidence from the Royal Society (Vol II, pp 293-306).

19 M. Mann, R. Bradley and M. Hughes. Global-scale temperature patterns and climate forcing over the past six centuries. *Nature*. 392, 1998. 779-787. 1999. M. Mann, R. Bradley and M. Hughes. Northern hemisphere temperatures during the past millennium: inferences, uncertainties and limitations. *Geophysical Research Letters*. 26. 1999. 759-762. M. Mann, R. Bradley and M. Hughes. Global-scale temperature patterns and climate forcing over the past six centuries: Corrigendum. *Nature*. 430. 2004. 105. The 1998 paper by Mann et al. is for the period 1400-1980. The 1999 paper expands the historical coverage back to 1000.

the period 1000–1980 is very much the hockey stick shape. The Mann hockey stick appeared in the IPCC Climate Change Assessment of 2001, thus achieving, as one journalist put it, "iconic status"[20]. In an analysis of Mann's et al data, Dr Stephen McIntyre and Professor Ross McKitrick of the University of Guelph in Canada claim that the analysis involves "collation errors, unjustifiable truncation or extrapolation of source data, obsolete data, geographical location errors" and other defects[21]. Their reconstructed series shows close correlation with Mann's series from 1550 to 1980 but shows temperatures higher between 1400 and 1500 than any of the 20th century temperatures. If correct, the late 20th century is no longer historically unprecedented and the "hockey stick" does not exist. We sought evidence that refuted the claims of McIntyre and McKitrick, but have not come across any detailed rebuttal. One curious feature of the debate over Professor Mann's time series is that the critics appear to ignore other studies which secure similar hockey stick pictures[22].

23. We are in no position to determine who is right and who is wrong in the growing debate on the hockey stick. If there are historical periods of marked temperature increase, it seems to us it is important to know why these occurred. Overall, we can only urge that the issue is pursued in the next IPCC Assessment.

On past scares

24. Some of our witnesses drew attention to previous environmental and resource exhaustion scares. The implication is that since these scares did not materialise, neither might accelerated global warming. While forecasters do seem to indulge periodically in "end of the world" stories, there is no guarantee that if they were wrong before they will be wrong again. More importantly, the science of global warming has advanced following substantial expenditures on research. Previous alarms, such as the 1970's *Limits to Growth* debates (which have not, in any event, gone away), earlier fears of global cooling (rather than warming), and even the fear in the 19th century over exhaustion of coal supplies, were based on more limited scientific investigation. **We do not believe that today's scientists are "crying wolf": they may turn out to have been wrong in some respects, but the arguments on which they base their case are better researched than in earlier cases. That said, this Chapter has sought to highlight some pressing issues which we believe deserve a further response from the scientific community in order to enhance understanding and resolve current controversies.**

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20 D. Appell. Behind the hockey stick. *Scientific American*. March 2005.

21 Evidence from R. McKitrick (Vol II, pp 262-266). See also S. McIntyre and R. McKitrick. Corrections to the Manne et al. (1998) proxy data base and Northern Hemisphere average temperature series. *Energy and Environment*. 14. 6.2003. 751-771. S. McIntyre and R. McKitrick. *The IPCC, the Hockey Stick Curve and the Illusion of Experience*. Washington DC: The George C Marshall Institute. S. McIntyre and R. McKitrick. Verification of multi-proxy paleoclimatic studies: a case study. Accepted Abstract. American Geophysical Union Meetings, Paper PP53A-1580, December 2004.

22 K. Briffa et al. Low frequency temperature variations from a northern tree ring density network. *Journal of Geophysical Research*, 106, (D3), 2001, 2929-41.

CHAPTER 3: THE FUTURE IMPACTS OF THE ENHANCED GREENHOUSE EFFECT

The nature of temperature change

25. Much of the global warming literature suggests that warming will be associated with many detrimental, and some positive, effects on human wellbeing and natural environments[23]. By and large, the greater the temperature rise, the larger the effects are likely to be. The IPCC's 2001 Report suggests a range of mean temperature changes of 1.4°C to 5.8°C by 2100[24]. We consider shortly how realistic this range is. These are mean global temperatures. Temperature changes in different continents will vary around this mean, some will be markedly higher, some lower. There will therefore be a spatial variation in temperature change. The lower end of the IPCC global temperature range appears modest. The problem arises because not only is there a problem arising from the trend increase in global temperature, but that trend rate masks substantial increased variability in temperature and probably in precipitation and weather events generally.

26. Measuring the impacts of global warming is obviously fraught with difficulty. Indeed, one of the Committee's witnesses went as far as to question whether predicting impacts 100 years and more hence has any value at all[25]. There are certainly profound problems involved in peering so far into the future. Nonetheless, it is hard to see the alternative. The problem lies in the time-lags that are endemic in the climate system. Present emissions of greenhouse gases do not have immediate impacts. Warming now is caused by greenhouse gases, emitted decades ago. This is because the emissions cumulate in the atmosphere and what damage is done arises from this concentration of gases, not from the current emissions themselves. Each greenhouse gas resides in the atmosphere before decaying naturally: CO_2 persists for 2 to 200 years, methane for 12 years, nitrous oxide for 114 years, and in the case of perfluoromethane upwards of 50,000 years[26]. It follows that action now to reduce emissions will have no immediate short-run effects. Any beneficial results will not accrue for decades to come[27]. By implication, climate policy is about reducing impacts in the decades and centuries to come; therefore, if impacts in 2100 are to be mitigated, action has to be taken sooner rather than later.

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23 Detailed assessments of the likely impacts can be found in Inter Governmental Panel on Climate Change, *Climate Change 2001: Impacts, Adaptation, and Vulnerability*. Cambridge: Cambridge University Press, 2001.

24 J. Houghton et al. *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge: Cambridge University Press. 2001. The benchmark for these temperature increases is not always clear, but is usually the "pre-industrial" period, i.e. around 1750. Thus, a projected rise of, say, 2.6°C would imply warming of about 2°C compared to the present day. Some of the scientific opinion at the conference convened in Exeter early in 2005 considered that the IPCC 2001 Assessment understates likely temperature change.

25 Evidence of Professor Colin Robinson (Vol II, pp 1-14)

26 R. Watson et al. op.cit. p.182

27 In many cases, reducing greenhouse gas emissions also reduces other pollutants, such as particulate matter. For example, any reduced road transport would have this effect since particulates and CO_2 are emitted from vehicles. The benefits of reducing particulates would, however, be fairly immediate. This joint effect is known as "ancillary benefits" in the literature. However, if the pollutant reduced is sulphur, then reduced sulphur emissions may actually increase warming—see the section on "negative forcing".

Impacts: a thumbnail sketch

27. **Whatever the validity of the temperature projections, the science of measuring impacts remains speculative.** Arguably, the most certain effect is sea level rise (SLR) due, in the main, to the thermal expansion of the oceans. The IPCC projects a mean global SLR of 20 to 88 cms by 2100. There will be local variations around this range. SLR clearly threatens low lying islands and deltaic regions in countries such as Bangladesh and Egypt. Some of these regions have additional problems of sinking due to rapid extraction of freshwater or diverted sediments (which offset erosion). **Many of the adverse effects can be offset by adaptation and we believe that the economic and social returns from investing in adaptation should be properly weighed against the cost of mitigation**. A notable example of such adaptation is the discussion already taking place on plans to extend and enhance the flood defences for London. But we acknowledge that foresight of this kind is a luxury that many poor countries cannot today afford from their own resources. International assistance will be required to help finance the adaptation that is needed. However, in the timescale before major adjustment needs to occur, projected economic growth in the developing countries should enable them to finance greater shares of the measures needed.

28. Rapid warming, which is what the IPCC's central projections suggest is the case, may be associated with increased weather variability and hence with the incidence or severity of weather events such as storms and monsoons. Despite a popular literature suggesting that cyclones and hurricanes will also increase, the climate models appear to be undecided on these effects. Similarly, often-repeated graphs of rising money costs of extreme weather events can be misleading since money value of damage is partly a function of the intensity of property development (and hence financial value of the assets) in addition to the severity of the weather event. Put another way, weather events could be constant in their severity but damage costs would still rise. Nonetheless, the facts are that more property and more lives are now at risk from major weather events. The IPCC provides evidence that global insured and uninsured property losses currently amount to over $40 billion per annum compared to just $4 billion per annum (all in real terms) some 50 years ago[28].

29. Impacts on human health are also open to some debate. Deaths associated with abnormally high summertime temperatures may well rise. By contrast, deaths may be reduced due to warming winters. Several of the Committee's witnesses referred to the European heatwave of summer 2003 and it was suggested that current warming (due to past emissions of greenhouse gases) accounted for the abnormal number of premature deaths at that time. A carefully researched study in *Nature* concluded that:

    "It is an ill-posed question whether the 2003 heatwave was caused, in a simple deterministic sense, by a modification of the external influences on climate—for example, increasing concentrations of greenhouse gases in the atmosphere—because almost any such weather event might have occurred by chance in an unmodified climate"[29].

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28 R. Watson et al. op.cit. p.256

29 P. Stott, D. Stone and M. Allen, Human contribution to the European heatwave of 2003. *Nature*, 432, 2 December 2004, 610-613.

30. But the authors do conclude that, relative to a temperature threshold that was exceeded in 2003 but in no other year since records began in the mid-19th century, "it is very likely (confidence level > 90%) that human influence has at least doubled the risk of a heatwave exceeding this threshold magnitude". The experience of 2003 may therefore not augur well for the future, although we are conscious again of the need to be careful about the policy implications. It will be sensible to manage exposure of vulnerable people to such heatwaves—a relatively simple task—rather than focus solely on emissions reductions to reduce the chance that they will occur again with more regularity.

31. Mortality and morbidity due to changes in the availability of drinking water are more likely with future warming. Higher temperatures, coupled with rising population growth, and hence growing demand for water, will decrease water availability in some parts of the world. Saline intrusion will affect freshwater supplies in some coastal areas, and water pollution can be expected to increase. The same issues of adaptation versus mitigation arise: much water is wasted, even in poor countries, and better water management policies may be better investments than attempts to reduce warming. This will be especially true if policies to reduce emissions have a limited chance of success, an issue we return to later.

32. It is also widely argued that vector-borne diseases will increase as regions warm, especially malaria. **However, we noted evidence from Professor Paul Reiter of the Institut Pasteur in Paris, which strongly disputed the IPCC's arguments on the likely spread of malaria**[30]. Professor Reiter argues that malaria is not a "tropical" disease and that it was widespread during the "little ice age" from mid-15th century to mid-18th century when temperatures were lower than today. Warmth is a factor in the transmission of the disease, but a number of location-specific factors are more important. Professor Reiter's cautions underline the fact that even the IPCC conclusions, based on a scientific process with many hundreds of experts, still need to be treated with care. We return to Professor Reiter's evidence later when we consider the reliability of some of the IPCC evidence.

33. Global warming will bring about ecosystem change and hence changes in the populations of species. The IPCC cites particular ecosystems at risk: glaciers, coral reefs and atolls, mangroves, boreal and tropical forests, polar and alpine ecosystems, prairie wetlands and remnant native grasslands[31]. A case in point is the coral reefs where the evidence suggests that coral bleaching will increase as oceans become warmer, an effect already identified with El Niño events. Since the reefs embody a great deal of marine biodiversity, the diversity of species is itself under threat. The threats from warming need to be placed in context. There are many other threats to coral reefs: over-fishing, destructive fishing techniques, pollution run-off, oil spills, even tourism. Nonetheless, the impacts of warming cannot be controlled as readily as these other man-made threats. For example, in contrast to some other impacts, it is difficult to see what adaptive measures could be taken to protect reefs from ocean surface warming. There are some offsetting factors. Some species will "relocate": a warmer North Sea, for example, has already

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[30] Evidence of P. Reiter: The IPCC and Technical Information. Example: Impacts on Human Health (Vol II pp 284-288)

[31] See R. Watson et al. op.cit. p.223. In his evidence to us (Vol II, pp 96-106), Sir David King was clear that current evidence suggests glaciers are in retreat for the first time in the current warming period.

experienced increases in a number of species, including large shoals of squid, followed by their predators—species of dolphins and whales that would normally be expected to inhabit more southerly waters[32]. But the available evidence suggests that any benefits to ecosystems are likely to be confined to the lower end of the projected temperature changes. Impacts on other vulnerable ecosystems will also be difficult, or impossible, to reverse, although, again, it has to be recognised that human influence over land use change, brought on by population growth and the extension of agriculture, is the major determinant of ecosystem and species loss.

34. Impacts of warming on agriculture are debated. The evidence suggests that some regions could gain from a warmer climate and the fact that higher levels of CO_2 enhance crop growth. But some regions, notably the poorer ones, will lose because of changes in precipitation and higher temperatures. Many other factors affect agricultural yields and IPCC concludes that it will be difficult to distinguish the impacts of modest climate change from the "noise" in these other factors. Moreover, at the lower end of the projected temperature increases there will be scope for adaptation. Provided the resources are available, farmers will not stand by and watch crops being ruined if there are alternatives available. But, to the extent that it is needed in the short term, adaptation in the poor regions of the world is clearly limited without outside help. At the higher end of the temperature increase spectrum the scope for adaptation is further reduced. Food security issues appear particularly problematic in Africa[33]. Dr Martin Parry has suggested that the positive effects of warming on crop yields would disappear at +1°C for India and perhaps 1.5°C for Southern Europe[34].

35. The impact literature also refers to "socially contingent impacts" which in turn relate mainly to the prospects of wholesale forced migrations of populations in seriously affected regions. The IPCC acknowledges that these effects, if they occur, must be uncertain.

Extreme events

36. The term extreme events tends to be reserved for weather events such as cyclones, hurricanes, tornadoes, ice storms, blizzards, rain storms, and heatwaves. The IPCC believes that many of these events will increase with warming. Sir John Houghton has declared that "these probably constitute the most important element in climate change impacts"[35]. For obvious reasons, the insurance industry tracks extreme events. Data from Munich Re indicate a more than five-fold increase in the number of weather-related extreme events in the 1990s compared to the 1950s. The economic losses from these events need to be distinguished from the number of events because economic damages will also be influenced by the scale of property at risk. These losses are estimated to have risen by a factor of 10 in the same period (at constant prices)[36]. Dr Madhav Khandekar, a Canadian consulting meteorologist, has

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32 *The Guardian*, 2 April 2005, reporting evidence from Dove Marine Laboratory, Newcastle University.

33 R. Watson et al. op.cit. p.231

34 M. Parry et al. Viewpoint. Millions at risk: defining critical climate change threats and targets. *Global Environmental Change*. 11, 2001. 181-3

35 Sir John Houghton, *Global Warming: The Complete Briefing*. Third Edition. 2005. Cambridge: Cambridge University Press. P179.

36 R. Watson et al. op.cit. p256.

challenged the IPCC findings in work he submitted to us[37]. Dr Khandekar cites studies which find no increasing trends for thunderstorms, intense tornadoes, hurricanes or tropical cyclones in the USA, although extreme precipitation events have increased. He finds no evidence for increasing trends of extreme events elsewhere that could be associated with warming rather than natural events like the El Niño Southern Oscillation, which remain, in themselves, unpredictable.

37. We are in no position to evaluate these contrasting views. **We do draw attention to the fact that, if extreme events are indeed to be considered the most important impacts from climate change, there is uncertainty and controversy about the underlying data required to substantiate this claim.**

Large scale one-off changes

38. Some of our witnesses placed considerable emphasis on the role of global warming in generating "surprises", or what IPCC refers to as "large-scale singular events". The GCMs generate results which suggest that, as radiative forcing increases, so climatic change increases in a fairly orderly manner. This result is fairly reassuring in the context of policy since it implies that, while climate change continues unabated during the policy-making period, there is time to adjust and introduce the required changes in policy and practice. But if change is non-linear and abrupt, then that reassurance largely disappears, and there are many examples of non-linear behaviour and thresholds in Earth's climate system[38]. Several GCMs suggest that some of these major events could arise at high levels of warming. One reason for being concerned about surprises, apart from their potential for large scale impacts, is that evidence suggests that some past climate change has occurred within very short periods of time[39]. The kinds of surprises that are prominent in the discussion are:

    - reversal (or "shut down") of the ocean thermohaline circulation (THC). The THC refers to deep-ocean currents that move heat and freshwater between the world's oceans. A major influence on these currents in the past has been the freshwater released from ice melts in the North Atlantic. The Gulf Stream brings warm surface water from the Gulf of Mexico to the North East Atlantic and returns cold deep water to the South Atlantic. The Gulf Stream maintains Europe's temperatures at about 8°C higher than they would otherwise be. It relies on salty and cooling surface water sinking downwards, and the fear is that additions of substantial amounts of fresh surface water will reverse or "switch off" this vertical change in the ocean's waters. Such fresh water additions could come from melting ice in the Arctic and Greenland. European summers would heat up and winters would become very much colder[40];

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37 M. Khandekar . Are climate model projections reliable enough for climate policy? *Energy and Environment*, 15 March 2004

38 For an overview of these features see J. Rial et al. Nonlinearities, feedbacks and critical thresholds within the Earth's climate system. *Climatic Change*. 65. 2004. 11-38.

39 See M. Maslin, *Global Warming: a Very Short Introduction*. Oxford: Oxford University Press. 2004.

40 In his evidence to us (Vol II, pp 96-106), Sir David King thought this shut-down process might take only a decade and that the temperature fall might be -20°C.

- disintegration of the West Antarctic ice caps which would alter the South Atlantic ocean circulation and produce sea level rise on a more dramatic scale than the increase due solely to thermal expansion, with increases of several metres;
- melting of the permafrost. Methane gas mixed with water, in solidified form, exists in very large quantities in soils beneath the permafrost[41]. High levels of temperature change could release the methane, a powerful greenhouse gas, producing a "runaway" acceleration of warming, in addition to considerable destruction of property that is built on top of these soils;
- acidification of the oceans, changing ocean life dramatically; and
- major regional effects that are likely to have global consequences. These include: a lengthening of the dry season in Amazonia, destroying the balance of wet (long) and dry (short) seasons that maintain the Amazon rainforest as we know it today; desertification of large parts of Africa; and major changes to the Indian monsoon.

39. **How such catastrophic threats should influence decision-making depends on the scale of the effects, their probability of occurrence, and when they might occur. The scale of these events is clearly very large.** The probability of their occurrence appears not to be known. Changes in the THC are not at all likely to occur, as we understand it, in the next 100 years, but might thereafter. Sir David King suggested to us that the important time benchmark is the point at which the Greenland ice sheet begins to melt. He told us that some of the GCMs suggest this could happen with +2°C, well below his own personal belief that, without serious action, the world would be heading for +3°C.

40. How seriously these risks should be taken clearly depends on many factors, at the very least on the commitment of the current generation to future generations, the degree of credibility in forecasts and projections hundreds of years ahead, and the speed at which technology will change. We recognise that the ways in which these risks can be integrated into decision-making procedures are only now being advanced. **If cataclysmic events which threaten the viability of existing societies are even remote possibilities, it is important that policy makers construct frameworks for analysing and debating probability and risks, since the threats associated with such "doomsday" scenarios are fundamental elements in driving the international discourse.** We acknowledge that the evidence on all these risks is continually being monitored and it is clearly important to reappraise the risks at regular intervals. There is a balance to be struck.

Summary indicators of warming damage

41. The detrimental impacts of climate change are likely to manifest many different types of effect. Moreover, the size of the global temperature change matters: low levels of temperature increase may be associated with some beneficial effects on agricultural yields and even ecosystem productivity. For

[41] These gas hydrates also exist in vast reserves below the world's oceans. There is a scientific debate about the extent to which high warming levels could also begin to release these hydrates, something that does appear to have happened many millions of years ago.

this reason, the Committee sought firmer guidance on the likelihood of the different temperature projections made by IPCC, since IPCC does not currently attach any probabilities to the temperatures within the range they suggest. Of course, even if low temperature increases are benign, doing nothing about climate change may still not be an option: warming does not stop automatically once a given temperature increase has been experienced. But if the lower projections are more likely, there could be more time to devise better strategies for mitigating and adapting to climate change. **We think it is a matter of some importance that IPCC moves towards clearer judgements on the probabilities of the projected temperature increases.** We return to this issue in Chapter 4.

42. Getting a concise picture of warming impacts is difficult, not least because the science of impact assessment is uncertain, probably more uncertain than the science of climate change itself. It is for this reason that the Committee sought evidence on summary indicators of climate change damage. Two presented themselves: (a) some indication of global and regional populations at risk now and in the future, and (b) monetary measures of damage which can be benchmarked on world and regional Gross Domestic Product (GDP). Dr Martin Parry has produced estimates of the former[42]. These are summarised in Box 7. (We defer consideration of the measures of economic damage to Chapter 6.) We acknowledge, however, that neither measure accounts adequately for large scale singular events.

[42] M. Parry et al. op.cit.

BOX 7

Populations at risk from global warming

We note and agree with the view that, while listing the many potential impacts of climate change is important, the end result is a confusing mix of effects, some of which may be very important and others far less so. There is a need for a "reductionist" measure of impact that can be readily understood. In Chapter 6 we look at the available monetary measures of impact. Dr Martin Parry and his colleagues have suggested a measure of climate change impact based on the numbers of people at risk. The measures are located in time in the 2050s and the 2080s. The results are summarised in broad terms below. They vary according to the level of temperature increase which, in turn, corresponds to atmospheric concentrations. Here we show how the impacts vary with temperature increase. The study estimates those at risk from hunger, malaria, coastal flooding and water shortage. We illustrate the malaria and water impacts only, for ease of presentation. (Since the source shows charts only, some error may also be involved in inferring absolute magnitude.)

Temperature increase	Additional people (millions) at risk from Malaria (M) and water shortage (W)			
	2050s		2080s	
	M	W	M	W
+1°C	160-230	1250-2250	-	-
+2 °C	200-260	2100-3000	225-280	2750-3250
+3 °C	-	-	270-340	3000-3500

The more alarming numbers relate to water shortages, the suggestion being that an additional three billion people would face water problems, or perhaps 40%of the world's population at the time. These are "business as usual" estimates, i.e. there is no climate mitigation and no adaptation. The latter is obviously very questionable, as we argue in this report. We also draw attention in the main body of this report to some serious questions about the estimates for malaria.

Source: M. Parry et al. op.cit.

Positive effects of warming

43. The Committee noted that the scientific literature tended to focus on the negative impacts of climate change. This is understandable given that some of these effects are thought to be catastrophic, and because individuals tend to be more averse to a loss than they are in favour of an equivalent gain[43]. But a rigorous appraisal of climate change does need to include positive effects. The beneficial effects of CO_2 "fertilisation" on crops was noted above. But there will also be gains in amenity across large areas. Several studies were presented to us which indicated the nature of some of these amenity gains: increased opportunities for tourism, for example, but also the fact that many people simply prefer to live in mild climates. In his evidence, Professor Mendelsohn of Yale University argued that regions have "optimal" climates: regions that are "too cold" gain from warming, while those that are

[43] This phenomenon of "loss aversion" is well documented in the psychological and economics literature.

"too hot" will lose[44]. Dr David Maddison of University College London and Ms Katrin Rehdanz of Hamburg University argue that impacts at the level of the household will be the most profound, yet little is known about how households perceive climate change. Like Professor Mendelsohn, they invoke the notion of an optimal climate but at the household level, with households moving towards or away from that optimum as climate change occurs[45]. The research suggests that people will accept lower wages to work in areas of "better" climate typified by lower rainfall, lower mid-summer temperatures (in countries such as Italy) and lower cloud cover. Similarly, house prices tend to be higher in regions with preferred climates. Household expenditures also change with climate. Finally, individuals' own ratings of their "happiness" have been shown to vary directly with income and climate[46]. Overall, there appear to be distinct amenity gains for the countries of Northern Europe, with generally neutral effects in Southern Europe. Once the focus moves to Asia there are serious household losses, confirming the general picture that it is the poorer parts of the world that suffer most from warming. **We are clear that fuller consideration needs to be given to the literature on the positive effects of warming.**

44. We draw attention to this literature for several reasons. First, we heard little about the positive effects of warming from the scientific witnesses. Second, we observe that this category of benefit is mentioned only in passing in the IPCC Working Group II assessment of impacts, where it is noted that economic impact studies "may have overlooked" positive impacts[47]. **We conclude that there are weaknesses in the way the scientific community, and the IPCC in particular, treats the impacts of climate change. We call for a more balanced approach and look to the Government to take an active role in securing that balance of research and appraisal.**

Adaptation versus mitigation

45. The IPCC 2001 Reports make explicit reference to adaptation to climate change. Adaptation can take various forms. The IPCC reports distinguish "autonomous" and "planned" adaptation. First, market forces and natural behaviour will lead to some "natural" adaptation to climate change, e.g. by changing crop strains so that crops are more tolerant of dry conditions. Second, conscious and deliberate policies and investments will also be needed to encourage further adaptation. We understand the IPCC cautions on adaptation: it is easy to see that reliance on adaptation alone would be risky since it may not be possible to adapt to major risks. But it also seems to us that nearly all of the public debate on global warming is about mitigation—reducing emissions—rather than about adapting to climate change and, assisting the most vulnerable societies in the world to adapt to the risk they may face.

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44 Evidence from R. Mendelsohn (Vol II, pp 266-269). See also R. Mendelsohn and M. Schlesinger, Climate response functions. *Ambio*, 28, 1999, 362-6

45 Evidence from D. Maddison (Vol II, pp 256-262).

46 K. Rehdanz and D. Maddison. Climate change and happiness. *Ecological Economics*. 52. 2005. 111-125.

47 There is no chapter or sub-section of the IPCC Working Group II 2001 Report dealing with positive impacts. Chapter 19 lists positive effects in the agricultural sector and possible reductions in winter mortality but makes no mention of amenity effects.

46. In evidence to us, Dr Indur Goklany of the US Department of the Interior argued that mitigation can do little to reduce many of the impacts from warming, whereas investment in adaptation now would both reduce the baseline risks that will occur even without any warming, and the warming impacts as well. His estimates suggest that warming could add substantially to the population at risk, notably from hunger, water shortage and coastal flooding. Those at risk from additional water shortage could, however, be offset by those who benefit because of warming-induced water gains[48].

47. **The issue is clearly one of balance. Most adaptation expenditures would be local, while mitigation requires action on a global scale. Few would suggest doing nothing by way of mitigation, and few would suggest no adaptation expenditures at all. But the policy literature seems to us to be overly focussed on mitigation. We therefore urge the Government to ensure that greater efforts are made to understand the relative costs and benefits of adaptation compared to those of mitigation.**

48 Evidence from I. Goklany (Vol II, pp 217-225).

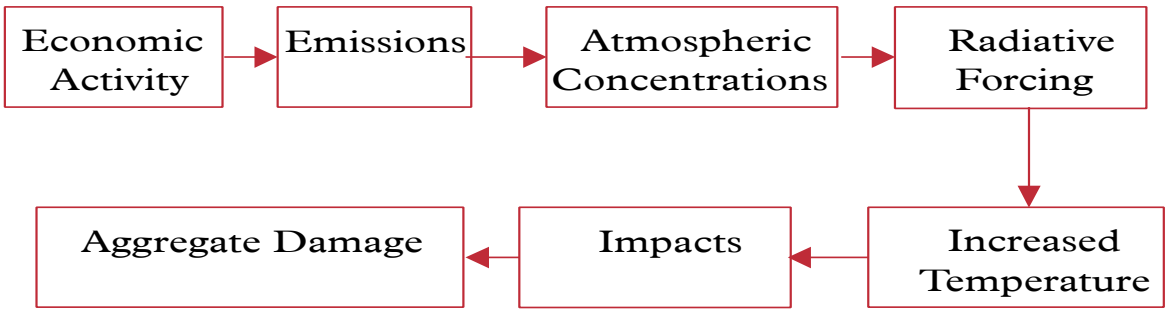
CHAPTER 4: FORECASTING GREENHOUSE GAS EMISSIONS AND TEMPERATURE CHANGE

The climate—economics linkages

48. This chapter focuses on an issue that was instrumental in launching our inquiry: the IPCC emissions scenarios. The IPCC has a separate set of experts whose task it is to develop greenhouse gas emissions scenarios. There are 40 such scenarios and six separate models are used to quantify them. The IPCC is concerned to argue that these scenarios are not forecasts as such, but "pictures" of "what would happen if" certain driving forces were in place. But once the scenarios are translated into the policy context, the distinction between "scenario outcomes", "projections" and "forecasts" seems to us to be fuzzy. Denying that the scenarios embody forecasts may have the effect of avoiding criticism of their realism, but the fact is that the resulting temperature projections are presented as conditional forecasts, changes that will come about if a certain combination of circumstances prevails.

49. Box 8 summarises the scenarios as they are described in the 2000 Special Report on Emissions Scenarios (SRES). The earliest reports on the scenarios were issued in 1990. They were revised in 1992, and the latest is dated 2000[49].

50. The role that emissions projections play in projections of warming and hence damage is, inescapably, complex. The sequence is as follows:



51. Each of the linkages between the components of the diagram above involve complex factors. For example, the link between economic activity and emissions involves population change, rates of economic growth, the stage of economic development (e.g. reliant on heavy industry versus a service-based economy), the type of energy used to "fuel" the economy, energy efficiency (the amount of energy used to produce a unit of GNP changes as economies develop), and technology. In addition, it is affected by the way global incomes are added up across countries—the "aggregation" debate (see below). Hence, emissions do not have any simple proportional relationship to economic activity. As far as the links from emissions to atmospheric concentrations of greenhouse gases and from concentrations to temperature change are concerned, what matters is the stock of greenhouse gases in the atmosphere. Annual emissions do not therefore have any simple proportional

[49] They can be found on-line at http://sres.ciesin.org. 52 people are listed as the SRES "Writing Team"

link to concentrations. Annual emissions add to the stock and the stored emissions (the atmospheric concentration) also "decay" at various rates. Most importantly, it is the stock that helps to determine temperature change. Even here the link is complex because the change in "radiative forcing" is not proportional to concentrations. The link from temperature change to economic damage depends on a further set of factors: how economies adapt to temperature change, how vulnerable some economies are, how rapid warming is and whether there are abrupt changes in temperature and weather events.

BOX 8

The IPCC emissions scenarios

The IPCC *Special Report on Emissions Scenarios* (SRES) for 2000 groups "alternative futures" into four "families", A1, A2, B1 and B2. Within these families there are variations in assumptions about the underlying driving forces, especially technological change, so that, in all, there are 40 scenarios. While they are given different names, the basic differentiating features are:

- A1 has rapid economic growth and rapid technological change, with population peaking in the mid-21st century and declining thereafter. There is strong convergence of per capita incomes between rich and poor countries.
- A2 has slower economic growth and technological change.
- B1 has the same population assumptions as A1, strong convergence, and strong reductions in energy and materials intensity.
- B2 has rising population growth, "intermediate" economic growth, and slower technological change than A1 and B1.

The scenarios are associated with a range of temperature changes: each sub-scenario within the A1 scenarios, for example, has a range of temperature changes, and the range across the sub-scenarios tends to be quite wide, especially for A1 scenarios.

None of the scenarios includes explicit policies directed at controlling climate change. Summary statistics for the scenarios are given below:

Scenario	Population 2050 (billion)	2100	World GDP 2050 trillion $ 1990	2100	Convergence rich/poor 2100 (1990 = 16.1)	GDP growth rate 1990 - 2100 (% p.a.)	Cumulative Emissions 1990 - 2100 (GtC)
A1	8.7	7.0-7.1	164/ 187	525/ 550	1.5 – 1.6	3.0	1068-2189
A2	11.3	15.1	82	243	4.2	2.2	1862
B1	8.7	7.0	136	328	1.8	2.5	983
B2	9.3	10.4	110	235	3.0	2.2	1164

The range of temperature increases corresponding to these scenarios is 2.1 to 6.1°C for A1 by 2100, 3.0 to 5.2 °C for A2, 1.7 to 3.0 °C for B1 and 2.1 to 3.9 °C for B2

Source: adapted from data in N. Nakicenovic et el. *Emissions Scenarios.* Cambridge: Cambridge University Press. 2000. Note: these ratios are computed using MERs, not PPPs.

The Henderson—Castles critique

52. Professor David Henderson and Mr Ian Castles have published several critiques of the IPCC SRES[50]. Essentially, their criticism is that the IPCC scenarios are built on projections of economic change that involve adding up economic activity across countries using market exchange rates (MER). If, instead, one uses the "purchasing power parity" (PPP) approach, the projected economic growth rates for developing countries (LDCs) will be lower[51]. The reason it may matter is that the IPCC SRES assumes there will be a substantial degree of convergence of real per capita incomes between rich and poor countries by about 2100. Hence economic growth rates in developing countries are assumed to be higher than in rich countries. Current PPP comparisons of incomes per capita show a ratio of rich to poor incomes of about 7, compared to 16 with the MER. But if the gap between rich and poor now is narrower, then LDCs have less "catching up" to do. Their growth rates will be lower (compared to what would happen with the MER assumption) and hence emissions growth will be lower, other things being equal. But if emissions are exaggerated in the IPCC SRES, then so may rates of warming be exaggerated. As noted above, there is no simple relationship between emissions and warming—the linkage is not a linear one—so it cannot be assumed that an error of X% in emissions translates into an error of X% in warming. Nonetheless, the Henderson-Castles critique pointed to a potentially significant source of error in the IPCC work, led to a somewhat heated exchange with the IPCC[52], and attracted both academic and media attention[53].

53. While the IPCC SRES does indeed make some use of PPP conversions, the IPCC acknowledges that it has used MER conversions in its main work, and it insists on the "methodological soundness of the use of MER for developing long-term emissions scenarios"[54]. We found no support for the use of MER

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50 See evidence from P.D. Henderson (Vol II, pp 36-44) and I. Castles (Vol II, pp 207-211) See also I. Castles and P.D. Henderson. The IPCC emissions scenarios: an economic-statistical critique. *Energy and Environment*. 14:2 and 3. 2003. 159-186. I. Castles and P.D. Henderson, Economics, emissions scenarios and the work of the IPCC. *Energy and Environment*, 14: 4, 2003, 415-435. I. Castles and P.D. Henderson, International comparisons of GDP: Issues of theory and practice, *World Economics* (forthcoming). P.D. Henderson, The Treatment of Economic Issues by the Intergovernmental Panel on Climate Change (*mimeo*). P.D. Henderson, *SRES and IPCC: The Treatment of Economic issues*. Address to Joint Meeting of the American Enterprise Institute and The Economist, Washington DC, November 2004.

51 Market exchange rates are the exchange rates we are all familiar with when changing foreign currency. PPP, on the other hand, compares the values of a given bundle of goods across countries allowing for the ratios of the actual prices of each component of the bundle. The "purchasing power equivalent" for any one good is the ratio of the price of that good in country A divided by the price of that good in country B. These price ratios are applied to average quantities of the selected goods to build up a picture for the purchasing power equivalent for the whole bundle of goods which usually amounts to extending it to GDP as a whole. Extending the analysis to many countries is far more complex. The most widely used procedure is to compute world prices so that each country's prices are expressed relative to these world prices. Even this procedure can involve error.

52 See N. Nakicenovic et al. IPCC SRES revisited: A response. *Energy and Environment*. 14:2 and 3. 2003, 187-214, and A. Grübler et al. Emissions scenarios: A final response. *Energy and Environment*.

53 The academic debate has only partially appeared in the journals. See especially J. Ryten, MERs, PPPs and IPCCs: Illusions and reality, *Energy and Environment*. 15:3. 2004, 363-367; W. McKibbin et al. Can the IPCC SRES be improved? *Energy and Environment*. 15:3. 2004, 351-362. We refer to other important contributions in the rest of this chapter. On the media attention see *The Economist*, 15 February 2003 and November 2003. W. McKibbin, Flaws in climate-change research need fixing. *Weekend Australian Financial Review*, July 24-5, 2004.

54 A. Grübler et al. Emissions scenarios: A final response. *Energy and Environment,* 15 (1), 2004, 11-24.

in such exercises, other than from Dr Nakicenovic of the IPCC. We consider that Professor Henderson and Mr Castles were right to raise the issue. In so doing, they have helped to generate a valuable literature that calls into question a whole series of issues relating to the IPCC SRES, not just the issue of MER versus PPP. It has emerged that the PPP versus MER issue is far more complex than perhaps anyone thought initially. Indeed, Professor Henderson has modified his own position, whilst retaining his very firm view that the IPCC SRES process embodies many confusions.[55] It seems unlikely that the debate over the emissions scenarios would have occurred at all had Professor Henderson and Mr Castles not persisted in their views. We consider that they have performed a public service.

54. The issues that have now emerged are:

- the credibility of IPCC's insistence that no one scenario is any more likely than any other;
- the compatibility of the economic growth assumptions embodied in the scenarios with historical experience, and the credibility of the world economic growth rates embodied in the scenarios in a resource-limited world;
- the assumption in the IPCC scenarios of "convergence" or, more strictly, "conditional convergence" of per capita incomes between rich and poor countries;
- the MER versus PPP debate itself;
- the compatibility of IPCC's overall emissions and concentration trajectories with past experience;
- the credibility of the population projections in the scenarios; and
- the role played by sulphur emissions (which have a cooling effect) in the scenarios.

We take each issue in turn.

Are the IPCC emissions scenarios equally plausible?

55. The IPCC takes the view that its emissions scenarios "reflect a wide range of future possibilities that characterize our current understanding of the uncertainties of the drivers of future emissions patterns". They say that "The SRES was designed to provide insights on uncertainty from a range of plausible scenarios, and not to assign likelihood to any of the alternative futures described by the set of 40 scenarios"[56]. This is indeed the standard procedure in scenario building, as it is practised in the world of business. But, while this may have been the purpose of the scenario exercise, the reasonableness of constraining the exercise in this way must be brought into question. Whatever the intent of the IPCC, the public perception of the scenario exercise is often that each scenario is equally plausible: by not assigning levels of significance—quantitative or qualitative—to the scenarios, the impression given is that each has the same probability of occurrence. One of the salient features of the Henderson-Castles critique was that the high-

[55] P.D. Henderson, SRES, IPCC and the treatment of economic issues: what has emerged? Westminster Business School, London. May 2005. *Mimeo.*

[56] A. Grübler et al. op.cit.

emission scenarios rest on assumptions that are not credible. We were therefore concerned to hear from Dr Nakicenovic that IPCC had no intention of undertaking any significant reappraisal of the SRES for the IPCC Fourth Assessment exercise (AR4) for 2007[57]. It seems to us that there is an urgent need for a wholesale reappraisal of the emissions scenario exercise.

56. One of our witnesses, Professor Richard Tol of Hamburg University, has assessed the relative likelihood of each of the IPCC scenarios[58]. One important feature of Professor Tol's work is that he has sought to validate the scenarios using long term historical data, something that the SRES did not do, and an issue raised in the original Henderson-Castles critique. On the underlying assumptions, Professor Tol finds: (a) the population projections are credible, although the A1 and B1 scenarios unaccountably have the same populations; (b) the per capita income growth for developed economies is credible; (c) the per capita income growth for the developing countries diverges from long-term (though not more recent) historical precedent, and for Africa there is a clear break with the past; (d) the assumption of convergence of per capita incomes is not consistent with much of the longer term past record; (e) projections of energy intensity are only partially confirmed by history. Professor Tol concludes on scenario assumptions that:

"The [previous observations] suggest that the SRES modellers know a lot about the supply side of the energy system, but less about the demand for energy. Their knowledge of economic development is lacking".

57. As to which scenarios are more likely, Professor Tol argues that the A2 scenario "is by far the most realistic" and

"The SRES scenarios do not accord with past trends. On the one hand, this makes for interesting scenarios. On the other hand, it is odd that all SRES scenarios break with past trends at the same time, and that this trend break is sometimes at the point where data end and scenarios start".

58. The A2 scenario is, however, one of the scenarios with high cumulative CO_2 emissions—see Box 4. The high emissions result from the population projection of 15 billion people in 2100, a projection not borne out by any of the population forecasts made elsewhere.

59. We find Professor Tol's analysis telling. He suggests that many of the likely errors in the scenarios cancel out, and he suggests that the scenarios do result in emissions that are within the range of "not implausible" futures. But the shortcomings in the scenarios identified by Professor Tol do further underline our call for their thorough reassessment.

60. **In short, serious questions have been raised about the IPCC emissions scenarios, and—as we have already noted—a reappraisal of the scenarios exercise is urgently needed.**

Are the economic growth assumptions credible?

61. Table 1 indicates that world GDP is expected to grow at 2.2 to 3.0% p.a. in the IPCC scenarios. In his evidence to us, Professor Angus Maddison, a

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57 Evidence from N. Nakicenovic (Vol II, pp 131-137)

58 Evidence from R. Tol (Vol II, pp 66-77). See also R. Tol. *How Likely are the SRES Scenarios?* Hamburg University, 15 January 2005, mimeo.

leading expert on the historical record of the world economy, produced estimates of expected growth in the world economy up to 2030 which are consistent with a 3% growth rate. and with the historical record from 1900 to 1990[59]. However, we were interested to hear from Paul Johnson of HM Treasury that he found the high economic growth scenarios "relatively unlikely" and that "the 3% a year growth for 100 years is certainly extremely unprecedented"[60]. Table 1 shows data for historical growth rates taken from the work of Professor Maddison.

TABLE 1

Past economic growth rates for world and world regions

	1500 - 1820	1820 - 1870	1870 - 1913	1913 - 1950	1950 - 1973	1973 - 1998
W. Europe	0.4	1.6	2.1	1.2	4.8	2.1
USA	0.9	4.2	3.9	2.8	3.9	3.0
Japan	0.3	0.4	2.4	2.2	9.3	3.0
World	0.3	0.9	2.1	1.8	4.9	3.0
World	**1820 – 1998**			**2.2**		
World	**1870 – 1998**			**2.7**		
World	**1913 – 1998**			**3.0**		

Source: A. Maddison. The World Economy: A Millennial Perspective. Paris: OECD, P. 262

The issue of convergence

62. Convergence refers to the process whereby real per capita incomes in currently rich and poor countries are assumed gradually to converge over time. For this to happen, economic growth rates in the developing world must be faster than growth rates in the developed world. The greater the divergence in growth rates, the faster convergence occurs. Convergence matters for the emissions scenarios because it implies more rapid growth in the developing world, thus increasing emissions, at least in the first instance. The IPCC SRES aggregates national outputs using market exchange rates (MER), which we have already observed is incorrect. But, taking their own MER-based data, a 1990 ratio of 16.1 reduces to a maximum of 4.2 in 2100 (the A2 scenario) and a minimum of 1.5 (the A1FI scenario which is fossil-fuel intensive and with a near 3% growth rate). In other words, rapid convergence is assumed in all of the scenarios. In the A2 scenario, for example, incomes per capita rise at about 1% per annum for the OECD countries, but 2.3% in the developing world. In the A1B scenario, the respective rates are 1.6% and 4%[61]. In all scenarios, income per head in the developing world is well above income per head in the OECD countries today.

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59 Evidence from A. Maddison (Vol II, pp 249-256). Professor Maddison's estimates suggest a world GDP of some $27 trillion in 1990 would grow to nearly $90 trillion in 2030. 1900 GDP was some $2 trillion, all at 1990 prices.

60 Evidence from P. Johnson (Vol II, pp 151-156)

61 N. Nakicenovic et al. *Special Report on Emissions Scenarios*. Cambridge: Cambridge University Press, 2000, p33.

63. **We consider the convergence assumptions in the IPCC scenarios to be open to some question.** In no case do they consider future ratios of income of currently rich to poor countries to be greater than four. Unfortunately, in the SRES these ratios are expressed in market exchange rate terms, so comparisons with the recent evidence shown in Table 2, which uses purchasing power parity exchange rates, cannot be made. Nonetheless, Table 2 does show recent convergence between Western Europe/USA and Asia. But for a scenario exercise to capture feasible futures, at least one scenario should explore the result of assuming that significantly less convergence occurs. In his evidence to us, Professor Tol suggested that scenarios in which limited convergence took place would be politically difficult for IPCC to contemplate, but the scenarios are meant to be based on reasonable scientific assumptions and should encompass realistic possibilities. **In our view, political factors should not be allowed to influence the scenarios, whether over the issue of convergence or indeed in any other context.**

TABLE 2

The historical record on convergence

	1870	**1913**	**1950**	**1998**
W. Europe/ Asia	3.8	5.8	7.9	**6.4**
USA/Asia	4.5	8.3	15.0	**9.3**
W. Europe/ Africa	4.7	6.3	**5.9**	13.7
USA/Africa	5.5	9.1	11.2	20.0
W. Europe/ L. America	3.0	2.4	**2.0**	3.2
USA/ L. America	3.5	3.5	3.7	4.7

Source: Computed from data in A. Maddison. *The World Economy: A Millennial Perspective.* Paris: OECD, p.264. W. Europe here excludes Portugal and Spain. Asia excludes Japan. Bold figures indicate an endpoint where some convergence has occurred.

PPP versus MER

64. As we noted above, much of the debate over the realism of the IPCC scenarios was stimulated by the original critiques of Professor Henderson and Mr Castles which focussed mainly, but not exclusively, on the choice of the proper exchange rates for aggregating world output ("Gross World Product"), and for expressing economic growth rates. Since these critiques, further contributions to the debate have appeared. We note in particular papers by Professor Richard Tol, Professors Alan Manne and Rich Richels,

Drs Alfsen and Holtsmark, and Professor Nordhaus[62]. We are encouraged to see that IPCC itself recognised the need to open the scenario exercise to more scrutiny by co-sponsoring an Expert Meeting on the scenarios in January 2005 in Washington DC. Several of the contributions we cite appeared at that conference.

65. Professor Nordhaus's paper to that conference seems to us to be especially important.

- First, he shows why using MERs is categorically the wrong procedure for aggregating world income. He remarks: "estimates of output or income at MER are simply wrong—they are constructed on an economically incorrect basis", and, "Incomes estimated at MER are fundamentally wrong because they use the price of a non-representative bundle of goods to compare the different countries"[63].
- Second, using a simple example of two countries, one with high prices of non-traded goods and one with low prices of non-traded goods[64], Professor Nordhaus demonstrates that the error in using MER can be very large compared to the use of correct PPP measures.
- Third, economic growth rates should also be computed using PPP data.
- Fourth, while PPP approaches are conceptually superior, there are some significant data problems with their use, but "it is likely that the PPP imprecision is small relative to the MER bias".
- How far the IPCC emissions scenarios are in error is an empirical issue because other factors influence the emission levels, notably what is assumed about carbon-intensity trends. In reviewing the available corrections to the IPCC scenarios, Professor Nordhaus finds some of them arguing for significant changes in emissions projections and other suggesting very little difference. In his view: "The jury is out on how much using PPP as compared to MER will affect aggregate emissions".
- Other potential errors in emission projection models, such as population and technological change assumptions, may be at least as important as the MER/PPP issue, and perhaps more so. We consider some of these other issues here.

66. We cannot of course infer that errors in the emissions projections translate into comparable errors in the projections of greenhouse gas concentrations and rates of warming. **In general, any change in emissions due to changed economic assumptions will translate into a smaller effect on**

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62 R. Tol, Exchange rates and climate change: An application of FUND. *Climate Change*, forthcoming; K. Alfsen and B. Holtsmark. PPP correction of the IPCC emissions scenarios: Does it matter? *Climate Change*, forthcoming; A. Manne, R. Richels and J. Edmonds. Market exchange rates or purchasing power parity: does the choice make any difference to the climate debate? *Climate Change*, forthcoming. (This paper supersedes an earlier one: Market exchange rates or purchasing power parity: does the choice make a difference in the climate debate? www.stanford.edu/group/MERGE/marketEx.pdf.). W.Nordhaus, *Alternative Measures of Output in Global Economic-Environmental Models: Purchasing Power Parity or Market Exchange Rates?* Paper presented to IPCC Expert Meeting on Emission Scenarios, US Environmental Protection Agency, Washington DC, January 2005.

63 W. Nordhaus, *Alternative Measures of Output in Global Economic-Environmental Models: Purchasing Power Parity or Market Exchange Rates?* Paper presented to IPCC Expert Meeting on Emission Scenarios, US Environmental Protection Agency, Washington DC, January 2005.

64 "Non-traded" goods are goods that do not enter into international trade and hence do not have very similar prices.

concentrations and an even smaller effect on temperature. This in no way excuses poor analysis in the emissions scenarios, but it may mean that projections of warming are not themselves greatly affected. This is borne out by the models. Table 5 shows the results from the model of Manne and Richels.

TABLE 3

Effects of MER and PPP on emissions, concentrations and rates of warming

Base case	Total Carbon emissions in 2100 (billion tonnes carbon)	CO_2 concentrations (ppm)	Temperature change 2000 to 2100. °C
MER	21	731	+2.5
PPP	18	678	+2.4

67. The use of PPP does make a difference in emissions, by about 15%. But the variation in temperature is only 5%.

Are the emissions and concentrations trajectories plausible?

68. Many factors affect greenhouse gas emissions and atmospheric concentrations. Thus, even if the underlying assumptions about economic growth were correct in the IPCC SRES, a further test of reasonableness would be to compare projected and past emissions and atmospheric concentrations. In her evidence to us, Ms Rosemary Righter, Associate Editor of *The Times*, drew attention to the divergence between recent historical trends in CO_2 per capita emissions and CO_2 and CH_4 concentrations, and the high emission scenarios[65]. A similar point was made by Mr Martin Ågerup of the International Policy Network in his evidence[66]. Table 6 shows historical data on emissions. The table shows that, while emissions of CO_2 are increasing, the rate of global increase has fallen steadily since 1960. Similarly, per capita emissions are falling, not rising, and "carbon intensity"—carbon emissions divided by GDP—is also falling at a fairly constant rate. These changes in the past 30 years or so can be compared with the IPCC emissions scenario projections for 1990-2020. Table 4 shows that even the low emissions scenario (B1) has rates of growth of carbon emissions higher than the recent historical rates of change. **This suggests that the IPCC scenarios are not capturing recent experience in their short term projections.**

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65 Evidence from R. Righter (Vol II, pp 290-293). Ms Righter's evidence was partly based on an article she wrote in *The Times* of 15 February 2005. Ms Righter remarks in her evidence that she received no correspondence at all about this article, despite the fact that it showed the disparity between the IPCC high emission scenarios and historical evidence.

66 Evidence from M. Ågerup (International Policy Network) (Vol II, pp 238-249)

TABLE 4

World emission trends and the IPCC scenario trends

	Average annual growth in CO2 emissions (excluding land-use change) % p.a.		Average annual growth in CO2 emissions per capita % p.a.	Average annual growth
1960-2000	2.3		+0.2	- 1.3
1970-2000	1.6		- 0.1	- 1.5
1980-2000	1.3		- 0.3	- 1.6
1990-2000	1.2		- 0.2	- 1.4
IPCC projections 1990 – 2020	A1F1 AIB A1T A2 B1 B2	2.1 2.4 1.7 2.0 1.7 1.4		

Note: The final row refers to the different scenarios produced by the IPCC.

69. Our simple analysis in Table 4 is borne out by more sophisticated work submitted to us by Professor Ross McKitrick of Guelph University in Canada[67]. Their analysis shows per capita emissions as a stationary constant at around 1.1 tonnes C per person on a global basis. They compute the implied per capita emission levels in the 40 IPCC scenarios and find that only seven of these scenarios remain in 2050 within even a wide margin of error relative to this current average emission level. Of course, assumptions about very rapid growth in emissions in developing economies could change this, i.e. scenarios can be constructed that assume a break between the time series for the past decades and the coming 100 years. But what cannot be justified is an assumption whereby most of the scenarios assume that break will happen. The work of McKitrick and his colleague Dr Mark Strazicich seems to us to point, once again, to the failure of the IPCC scenarios to be rooted in historical precedent.

The population projections

70. Table 5 compares the IPCC's assumption about population change in the main scenarios with historical growth rates and with the United Nations projections of world population. While the A1, B1 and B2 scenarios are seen to be consistent with official estimates, scenario A2 has a population growth rate more than 50% higher than the UN's medium variant population projection.

[67] Evidence from R. McKitrick (Vol II, pp 262-266)

TABLE 5

Population projections

	IPCC projections by scenario, billions			United Nations Projections, billions
	A1, B1	B2	A2	
World Population 2050	8.7	9.3	11.3	9.1 (range 7.7 to 10.3)
World Population 2100	7.0 - 7.1	10.4	15.1	9.1 (medium variant)
Implied growth rate, % p.a. 1990 – 2050 (1990 = 5.3 billion)	0.8	0.9	1.2	0.9 (range 0.6 to 1.1)

Source: IPCC projections from N. Nakicenovic et al. *Special Report on Emissions Scenarios.* Cambridge: Cambridge University Press, 2000, statistical annex. UN projections from www.unpopulation.org

Projecting global cooling effects

71. In discussing the science of global warming we noted that there are several agents with "negative forcing", i.e. factors which produce cooling rather than warming. A significant cooling agent is sulphate produced from sulphur dioxide emissions. The IPCC scenarios include these cooling effects. If the world cuts back on sulphur emissions in order to protect local environments and human health, then this reduces the extent to which these emissions inhibit warming. Hence warming scenarios are partly dependent on the assumed efforts the world makes in controlling such emissions. Our attention was drawn to a literature which debates this issue. One prominent study suggests that the IPCC SRES has an upwards bias in its upper-range temperature changes[68]. Much of this bias is due to the IPCC's optimistic assumption (from the point of view of local pollution control) about the extent to which sulphur emissions will be controlled.

Conclusions on the high emissions scenarios

72. **We received a significant amount of evidence on the realism of the IPCC emissions scenarios, and doubts were raised, particularly about the high emissions scenarios. The balance of this evidence suggests to us that the high emissions scenarios contained some questionable assumptions and outcomes.** First, they may not be consistent with trends over the past 25 years. Total emissions are indeed increasing, but the rates of increase have slowed significantly, as has the carbon-intensity of the world economy. Second, it also seems wrong to attach equal credibility to the scenarios in general and we believe the IPCC is now working on this issue. Third, high economic growth of around 3% per annum for the world economy is not unprecedented, but the Treasury indicated in their evidence to us that they thought growth of this magnitude over the next 100 years is unlikely[69]. Fourth, the assumptions made by IPCC about the rate of convergence in per capita incomes, which affect the projections of greenhouse gas emissions, should at least embody less optimistic

[68] M. Webster et al. Uncertainty in emissions projections for climate models. *Atmospheric Environment*, 36, 2002, 3059-3670.

[69] Evidence from P. Johnson (Vol II, pp 151-156)

assumptions. Political considerations should not be allowed to cloud what should be a scientific procedure in constructing the scenarios. Fifth, population projections in some of the high emission scenarios seem to us to be unrealistic. Sixth, there may also be some questions about underestimating the cooling effects of sulphur. Finally, while we acknowledge Professor Nordhaus's judgement that "the jury is still out" on the extent to which PPP conversion rather than MER conversions will affect emissions predictions, several critiques show that predictions could be significantly affected by the use of PPP exchange rates. PPP is the right procedure, as Professor Nordhaus's study amply clarifies. **While such errors do not translate into equal magnitude errors in concentrations or warming, it seems to us important that the IPCC emissions modellers give serious attention to adopting the correct procedures.**

CHAPTER 5: THE COSTS OF TACKLING CLIMATE CHANGE

73. If the costs of tackling climate change are small, then a cautious approach to decision-making in the face of uncertainty would dictate that those costs should be incurred as an insurance against the chances of the worst effects of global warming occurring. But the costs of tackling global warming may be large. Moreover, those costs will largely be borne by the current generations, while the benefits will accrue to generations yet to come, who are projected to be significantly wealthier and technologically more advanced. **Hence it is very important that a realistic picture of the likely costs be conveyed to, and understood by, people today who will have to pay them. We note the considerable efforts that the IPCC has made in constructing likely cost estimates for the world as a whole. We are far less satisfied with the data currently available on the costs to the United Kingdom, and we call for a significantly greater effort to clarify and estimate those costs.**

74. We heard evidence on costs and we were interested to note the different ways in which this cost information was conveyed. We therefore outline below our own understanding of the cost data.

Global costs

75. We acknowledge that estimating abatement (or "mitigation") costs is very complex. First, costs are lower if the world in general adopts the lowest cost emission-reduction technologies first and the highest cost technologies last—but we have no guarantee the world will behave that way. Costs are estimated in different ways. Usually they are based on the direct costs of the technologies, e.g. the cost of building a nuclear power station. But many other kinds of costs are involved and technology costs do not necessarily correspond with the correct concept of cost which is measured by the "welfare" losses incurred to consumers and producers. Costs can vary considerably, depending on how compliance policies are introduced. For example, market-based instruments, such as carbon taxes and tradable permits, are thought to have lower compliance costs than simply telling emitters what technology to use ("command and control"). It is for this reason that so much emphasis is being placed on the newer policies such as permit trading systems. Many economists believe that costs will be lower than anticipated because emitters will find new technologies and the cheaper ways of overcoming compliance problems: climate regulation may "force" innovation[70]. But others believe that there are many hidden costs in regulation, so that actual costs may prove to be higher than estimated. For all these reasons, and others, we would expect wide variations in the estimates of the costs of control.

76. Integrated Assessment Models (IAMs), in which simplified climate models are combined with economic models of the world economy, produce estimates of costs. As one would expect, as the target for atmospheric CO_2-equivalent concentrations gets tougher and tougher, so not only the total costs of meeting those targets rise, but so do the incremental costs (the "marginal" cost). In a very interesting diagram, the IPCC *Synthesis Report*

[70] In the business literature this tends to be known as the "Porter hypothesis", after Professor Michael Porter.

2001 tries to bring together the cost estimates of several of the IAMs, and links them with emissions reductions and atmospheric concentrations. Table 6 shows the IPCC estimates converted to an "annual" form and with some adjustments to current year prices and using a lower discount rate than that used by IPCC.

TABLE 6

Costs to the world of achieving the 550 ppm target, expressed in annual terms, $2005 prices, per annum

Present value of cost $2005 prices, trillion	Annual cost at 3%, borne in first 50 years, billion	Annual cost at 3%, borne in first 20 years, billion
2	78	134
17	661	1141

Notes: For 50 years at 3% divide the present value by 25.7. For 20 years, divide by 14.9. The above figures are therefore annuities derived from the present values. Present values taken from R. Watson et al. *Climate Change 2001: Synthesis Report.* Cambridge: Cambridge University Press. 2001. Figure 7.3

77. Table 6 suggests that getting to the 550 ppm level may cost the equivalent of $2 trillion to $17 trillion in present value terms, i.e. equivalent of spending this sum of money once and for all today[71]. Expressed, more meaningfully, as an annual flow, the sums are $78 billion to $1141 billion per annum. To get some idea of these sums, the world's annual GNP is currently about $35 trillion. Annual expenditures would therefore be 0.2 to 3.2% of annual current income. Unless "Kyoto plus" agreements extend to developing countries, these costs would be borne by the richer nations of the world alone, suggesting that the burden would rise to 0.3 to 4.5% of their annual current income. However, in both cases, world income would be growing. For example, if the world economy grows at 2% per annum, then the "worst case" level of costs (assuming all costs are borne in the next 20 years) would fall to some 2.3% of world income in 2035. If the costs are spread out over 50 years, the fraction would fall to 1.3% of world income.

World costs per tonne carbon

78. While Table 6 shows costs in formats that convey an overall picture of the likely cost burden to current generations, expressing these costs as an average cost of removing carbon is also useful. Indeed, we show in Chapter 6 why such figures are needed for a comparison with the damage done by carbon emissions in a cost-benefit framework. Table 7 shows our attempt to translate the figures into costs per tonne of carbon. While the IPCC *Synthesis Report* shows these costs as rising at an increasing rate per unit of change in CO_2 concentrations, the resulting figures in terms of costs per tonne of carbon emissions reduced do not show this pattern[72].

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71 For comparison, Professor Nordhaus of Yale University has suggested that the cost of achieving the Kyoto Protocol targets (inclusive of US participation), and assuming the emissions levels in 2010 are sustained through 2100, would be some $3 trillion (in 2005 prices). See W. Nordhaus, Global warming economics. *Science*, 294, 9 November 2001, 1283-4

72 This is rather counter-intuitive and we have been unable to determine why. There is a question arising as to why the incremental costs first go down and then up.

TABLE 7

World costs expressed in $ per tonne carbon

Concentration target (ppm)	Cumulative emissions, billion tC	Incremental reduction in emissions billion tC	Incremental cost at 3% discount rate $2005, trillion		Incremental cost per tC $2005	
			MERGE	FUND	MERGE	FUND
750	1348	-	0.7	0.0	-	-
650	1239	109	2.0	8.7	18.3	79.8
550	**1043**	**196**	**3.5**	**8.7**	18.3	44.4
450	714	329	4.3	19.5	13.1	59.3

Column 1 shows the various concentration targets. Column 2 shows the cumulative emissions corresponding to those targets. Column 3 shows the change in emissions, i.e. the emission reductions, needed to secure targets of 650 ppm or less. Column 4 shows the total worldwide cost of achieving these reductions, according to two different Integrated Assessment Models – MERGE and FUND. The final column shows this cost expressed per tonne of carbon reduced.

79. The "cost per tonne of carbon" for the 550 ppm target is thus embraced by figures like $18 to $80 tC, or about £10 to £44 tC.

Conclusions on world costs

80. We conclude that there are several ways of presenting global costs of controlling emissions so as to achieve a long run goal of atmospheric concentrations of 550 ppm. In present value terms—akin to a "one off" payment—the sums are anything from $2 trillion to $17 trillion. In annuitised form—the present value expressed as an annual payment—the range is $80 billion to $1100 billion per annum, assuming these costs are borne in the first 20 to 50 years. In terms of cost per tonne of carbon removed or avoided, the figures range from $18 to $80 tC.

The technologies to tackle climate change

81. A key issue is the range of the technologies that are available to tackle climate change. It is clear to us that there is no shortage of innovations available. The more important issue is their cost and the capacity to diffuse them at a rapid rate in the world economy. Professor Dennis Anderson of Imperial College London was especially helpful in providing cost information on the likely candidates[73]. His data are presented in Table 8.

[73] Supplementary evidence from D. Anderson (Vol II, pp 147-150)

TABLE 8

Illustrative costs of emissions-reducing technologies

Technology	Marker	Cost unit	Cost of Marker	Cost of Substitute	Net cost
Near term estimate (10 years time)					
Nuclear	NG/CC	c/kWh	3.5	6.0	2.5
Hydrogen from coal or gas + CCS	NG	$/GJ	4.0	8.0	4.0
Electricity from fossil fuels + CCS	NG/CC	c/kWh	3.5	5.0	1.5
Wind	NG/CC	c/kWh	3.5	5.0	1.5
Photovoltaic (solar input = 2000kWh/m^2)	Grid electy.	c/kWh	10.0	15.0	5.0
Biofuels	Petrol	$/GJ	12.0	15.0	3.0
Distributed generation	Grid electy.	c/kWh	10.0	15.0	5.0
Long term estimate:					
Nuclear	NG/CC	c/kWh	4.0	5.0	1.0
Hydrogen from coal or gas + CCS	NG	$/GJ	5.0	10.0	5.0
Electrolytic Hydrogen (onsite & distributed)	NG (distributed)	$/GJ	10.0	30.0	20.0
Electricity from fossil fuels + CCS	NG/CC	c/kWh	4.0	6.0	2.0
Wind	NG/CC	c/kWh	4.0	6.0	2.0
Photovoltaic (solar input = 2000kWh/m^2) [b/]	Grid electy.	c/kWh	10.0	8.0	-2.0
Biofuels	Petrol	$/GJ	12.0	15.0	3.0
Distributed generation	Grid electy.	c/kWh	10.0	10.0	0.0

Source: Professor Dennis Anderson, Imperial College London. Notes: NG = natural gas; NG/CC is natural gas - combined cycle power plant; CCS is carbon capture and geological storage; GJ = gigajoule; kWh = kilowatt hour; c = US cents

82. Table 8 expresses the costs of carbon-reducing technologies relative to a "marker", i.e. the technology that would be displaced by the "new" technology. In the longer term, the costs remain above the marker technologies by the same margin other than for solar photovoltaic in regions where there is fairly high levels of sunlight. The fact that the costs of most of these technologies remain above the current technologies means that the present free (or, rather, quasi-regulated) market will not bring about their natural substitution. That substitution must be managed, first by judging whether the extra costs of these technologies is smaller or greater than the money value of the environmental benefits they bring, and second, by designing incentive systems to accelerate the diffusion of these technologies.

The former is an exercise in cost-benefit analysis, the second is an exercise in designing market-based environmental policies such as carbon taxes and tradable permit schemes, or of government directly sponsoring the required R & D. Professor Anderson also argued that, once incentives are in place, they will in turn accelerate the process whereby unit costs are reduced[74].

83. **Given the wide array of potential technologies in Professor Anderson's list, we are surprised that the Government's *Energy White Paper*[75] should place such emphasis on just one technology, wind energy.** (There is also a debatable assumption about the likelihood of pervasive energy efficiency gains.) It is one of the technologies with a low excess cost burden over the marker technologies. Also, Professor Anderson's table relates to the global picture, not just the United Kingdom. Nonetheless, we would have preferred a wider vision in the White Paper. Dr Dieter Helm of Oxford University noted that, whereas the R & D budget in the US embraced the "big" technologies such as linked coal and hydrogen, the UK research programme has been "captured" by certain renewable technology interests[76].

84. Finally, we note the position of (conventional) nuclear power in Table 8. It is well known that nuclear power carries an excess cost penalty at the moment. Indeed, this is why British Energy has experienced such financial difficulties with the current electricity market. But Table 8 suggests that this excess penalty will be reduced significantly over time. **In our view, it would be unwise to close the nuclear energy option. It is prudent to maintain as wide an energy portfolio as possible. We argue that the current capacity of nuclear power, before further decommissioning occurs, should be retained.**

85. Additionally, there are serious doubts about the extent to which energy efficiency and wind energy can get the country on to a trajectory of emissions consistent with the 60% target. As Dr Helm indicated to us, such a policy is heavily reliant on "picking winners" among the technology options. We are not confident that the Government, indeed any government, can be so sure of the effectiveness of the technologies they choose to back. It is far better that government sets the goal and the price signals to achieve that goal, leaving the market to select the technologies and their rate of diffusion through the economy.

Costs to the United Kingdom

86. Estimating the costs to the United Kingdom for the UK's own programme is not straightforward. Indeed, this appears to us to be a point of criticism—government estimates of cost are unhelpfully vague for something as important as climate control. However, the Government's long run target of 60% reduction in CO_2 emissions by 2050 is supposed to be geared to the 550 ppm target since it assumes that "others" act likewise. According to the Department of Trade and Industry, the cost of this target is assumed to be between £10 billion and £42 billion in 2050, with an assumption that costs

74 Evidence from D. Anderson (Vol II, pp 137-150)

75 Our energy future—creating a low carbon economy, February 2003

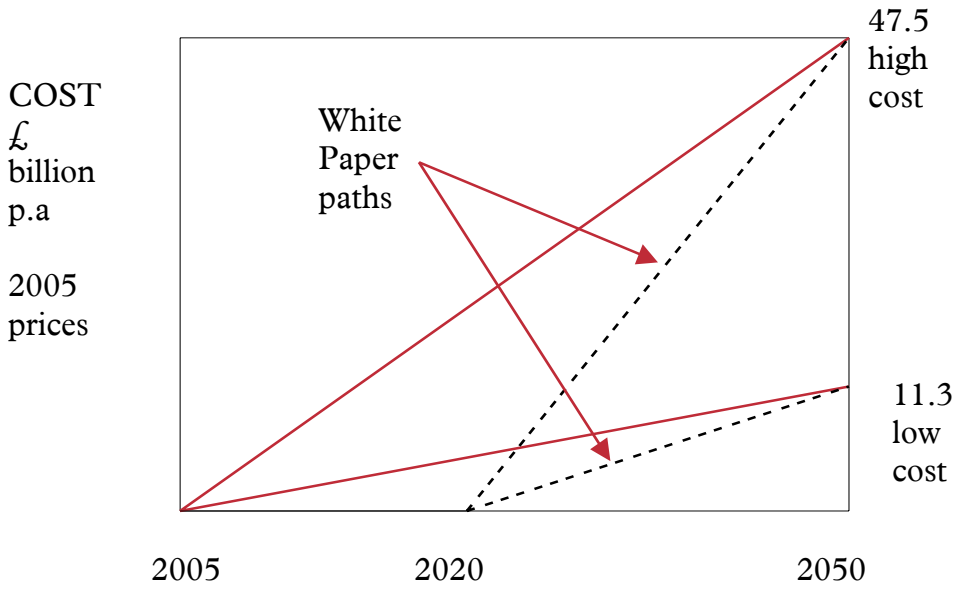
76 Evidence from D. Helm (Vol II, pp 87-95). In his evidence (Vol II, pp 96-106), Sir David King was particularly keen on the development of nuclear fusion. However, it seems to us that this technology remains a distant prospect and we have discounted it in our analysis.

up to 2020 are "negligible" because the emission reductions are secured by energy efficiency. The evidence presented to us by Dr Dieter Helm suggests that this latter assumption is wildly optimistic. Indeed, we detect signs that the Government is aware that its *Energy White Paper* embodies very optimistic assumptions about the exclusive roles afforded to energy efficiency and renewable energy to achieve this long run target[77]. In an effort to prompt better and clearer estimates from the Government, Table 9 below presents our best guesses of the costs to the UK.

87. Figure 1 presents a very stylised picture of our assumptions. The dashed lines represent the DTI's assumption of zero cost to 2020 and rising costs thereafter. The continuous lines represent our assumption that costs begin now, as indeed they must have done through the current climate action programme.

FIGURE 1

Stylised cost trajectories for the UK



88. The trajectories encompass the DTI's optimistic assumptions about energy efficiency and a more pessimistic scenario (not subscribed to by the Government) in which the costs are incurred immediately, i.e. before 2020 which is when the White Paper assumes costs begin to rise.

[77] Our energy future—creating a low carbon economy, February 2003

TABLE 9

Possible costs for UK 60% target, present values and annuities

End point costs in 2050 p.a. £ billion, 2005 prices	Present value of costs at 3% discount rate, 2005 prices, £ billion	
	DTI path, positive costs starting in 2020	Pessimistic case, positive costs start in 2005
11.3	63	94
47.5	265	398
	Annualised costs 2005-2050 at 3% discount rate, 2005 prices, £ billion	
11.3	2.6	3.8
47.5	10.8	16.2

Source: EAC estimates

89. Table 9 suggests that the UK faces "one-off" costs equal to £60 to £400 billion, or an annual cost burden of £3 to £16 billion per year for nearly the next 50 years. This annual cost would be higher still if we assumed the cost burden has to be met in the next 20 years. In supplementary evidence, Defra advised us that the marginal control costs (the costs of reducing additional tonnes of greenhouse gases[78]) for the UK might lie in the range £25 - £150 tC in 2030, and £300 - £600 tC in 2050[79]. However, even the 2030 estimates could be understatements if energy efficiency does not progress as fast as assumed. Equally, widespread emissions trading schemes for greenhouse gases could lower these costs.

90. We acknowledge the rough and ready nature of our cost estimates for the UK's long term target of 60% reduction in CO_2 emissions by 2050, but the fact that we can only produce such figures arises from the poor information embodied in the *Energy White Paper* and elsewhere. We urge the DTI and the Treasury to produce more detailed estimates of these costs. Moreover, the cost trajectories should show sensitivity to the serious doubts over the White Paper assumptions about the roles of renewable energy and energy efficiency.

Costs of meeting UK goals as a percentage of GNP

91. Several of our witnesses conveyed their view that the costs of control to the United Kingdom are trivial. They expressed costs as a fraction of anticipated GNP. For example, if GNP grows at 2% for the next 45 years, it would be 2.4 times the current GNP in 2050. Currently, UK GNP is £1.16 trillion. In 2050 it would therefore be £2.8 trillion. If we take the "high" DTI figure of £47.5 billion climate change control cost in 2050, this is 1.7% of GNP. If we take the low figure, it is 0.4% of 2050 GNP. We doubt if this way of expressing cost will convey information in a comprehensible manner to more than an expert audience, but we accept that "benchmarking" costs on GNP is useful. However, fractions like 0.4 to 1.7% of GNP are not trivial. If this benchmarking approach is to be used, it is appropriate to relate it to other costs. For example, even the lower end of the range exceeds the current international development budget in the UK.

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78 The cost estimates in Table 9 are annual averages, not marginal costs.

79 Evidence from Defra (Vol II, pp 107-130)

92. Other witnesses adopted a variant of the GNP benchmarking approach and asked what climate change controls will do by way of reducing UK economic growth rates. It was put to us that instead of growing at an average of 2% per annum for the next 45 years, the UK would grow at 1.95% to 1.99%, a barely perceptible difference. The temptation is to conclude that such changes in growth rates are trivial compared to the rewards of avoiding the worst impacts of climate change. But we regard this manner of presenting cost data as sleight of hand. It has to be recalled first that the UK climate target only has meaning if all other countries adopt the same course. If they do not, then the UK will have undertaken unilateral action to no purpose. Hence the "return" secured by the UK from pursuing its long run target is highly uncertain. But, in any case, no other item of government expenditure is treated this way. If it was, it would be easy to justify almost any large scale item of public expenditure. We were therefore surprised to see this approach being quoted by Defra in their supplementary evidence to us on costs. We think it important to avoid the deception embodied in the "change in the rate of growth" approach.

93. Finally, we note that the Government uses the MARKAL model to estimate the costs of meeting various emission targets. The use of this model was noted approvingly by Professor Paul Ekins of the Policy Studies Institute[80]. But Dr Dieter Helm of Oxford University was scathing in his criticism of the model which he characterised as "garbage in, garbage out"[81]. Dr Helm's criticisms centre on both the nature of the model and the assumptions built into it about the costs of energy efficiency and the costs of renewable energy. He argued that both these costs are understated by the Government and hence MARKAL produces the answer that the costs to the UK of meeting the 60% target are similarly low. If Dr Helm is right, then even our estimates in Table 9 are likely to be understatements of the true cost.

94. **We are concerned that UK energy and climate policy appears to rest on a very debatable model of the energy-economic system and on dubious assumptions about the costs of meeting the long run 60% target. We call on DTI and the Treasury to improve substantially (a) the cost estimates being conveyed to the public and (b) the manner of their presentation.** Without these improvements we do not see how the Government can argue that it has adequately appraised its long-term climate targets in terms of likely costs and benefits. Indeed, in our examination of the witness from the Treasury, it was clear to us that no such cost-benefit analysis exists in substantial form. **We believe that the Treasury should be more active in scrutinising and publicising these costs and benefits, in association with Defra and DTI.**

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80 Evidence from P. Ekins (Vol II, pp 178-196)

81 Evidence from D. Helm (Vol II, pp 87-95)

CHAPTER 6: THE BENEFITS OF CLIMATE CHANGE CONTROL

95. In Chapter 3 we outlined the likely impacts of climate change. We noted that there is considerable uncertainty about these impacts and when they might occur. We also noted that some of them will be reduced in terms of impact because of automatic ("autonomous") and managed adaptation. We urged that more attention be given to adaptation strategies in the face of realistic risks that the world will not act fast enough or on a sufficient scale to prevent impacts occurring. But other impacts are not subject to adaptation and this will be especially true for the low probability but singular irreversible events such as reversal of the thermohaline current. While impacts can be expressed in terms of individual events and their probable magnitude, it remains the case that some overall summary indicator is needed. Chapter 3 briefly investigated the estimates of "population at risk". But, ideally from a policy standpoint, the relevant indicator should bear comparison with the costs of control. This is why the monetised benefits of control are attractive indicators, however difficult they are to produce. We turn to the evidence on monetised benefits.

Estimates of monetised damage from warming

96. Economists have estimated the monetary impact of global warming. These estimates are very uncertain, but uncertainty cannot be an argument for ignoring the estimates, since the same uncertainty exists for any other "metric" that might be used to measure these damages. Moreover, if a money metric is not used, it is possible only to conduct cost-effectiveness analysis rather than cost-benefit analysis. In cost-effectiveness analysis the measures of impact reduction arising from warming control are expressed in diverse units or in units such as change in population-at-risk. If the units of damage reduction (i.e. benefit) are not the same as the units for cost, it is not possible to say if a given level of expenditure on warming control is justified.

97. Table 10 summarises available estimates of the money value of the damage done by global warming. Care has to be taken to interpret the numbers. The Integrated Assessment Models used to get these estimates use different assumptions about the level of temperature change, so one has to be careful to compare like with like. The models vary according to the level of adaptation to warming that they assume. The estimates of Professor Mendelsohn, for example, contain a lot of adaptation. The early IPCC estimates (which date from 1995) assume hardly any adaptation. The figures are "benchmark" estimates. If the science of warming is correct, warming does not stop at the temperature increases used in the models. So one would see damages carrying on rising. The convention in the studies is that damages are expressed as a percentage of current world GNP. So long as GNP keeps growing, those same damages expressed as a percentage of future GNP would be much lower. Only the Mendelsohn estimates relate damage to future GNP. Damages can be expressed in different ways. For example, to get a global figure, one might weight the damages in each region by regional output or population. Similarly, damages might be "equity weighted" as explained to us by Professor Richard Tol of Hamburg University[82] and

[82] Evidence from R. Tol (Vol II, pp 66-77)

Dr Chris Hope of Cambridge University[83]. Equity weighting attaches a higher weight to damages borne by low income countries in order to reflect that these damages will assume a bigger proportion of their incomes than will damages to richer people.

98. So, if we take, say, the Nordhaus estimates, these tell us that for a +2.5°C warming one might expect to see global damage amounting to 1.5-1.9% of world GNP. However, in Africa that impact might be closer to 4% and in India 5%. The scale of the aggregate impacts reflects (a) the geographical incidence of warming and associated weather events, (b) the variable vulnerability of the economies of developing nations to these impacts, and (c) the smaller GNP of the relevant countries. Finally, Table 10 shows estimates for damages only. Controlling climate change will avoid some (not all) of these damages, but it may also bring other benefits known as "ancillary benefits". For example, if CO_2 emissions are controlled through traffic restraint, then congestion might ease and there will be benefits from the reduced congestion, better local air quality, and so on. It is generally accepted, though not by all economists, that these ancillary benefits can be added to the reduced global warming damages when conducting a cost-benefit analysis. Moreover, there will be some additional costs too, due to the dynamic effects of diverting expenditures towards climate control and away from other uses of resources.

99. **Table 10 suggests that, in terms of percentages of world GNP, damage is relatively low, even for +2.5°C. The damages are not evenly spread. In general, developing countries lose more than developed economies. Some models suggest no real net damage to rich countries.**

[83] Evidence from C. Hope (Vol II, pp 24-35)

TABLE 10

Damages as % of regional and world GNP

Region	IPCC 1995 +2.5°C	Mendelsohn et al 2000 +2.5 °C	Nordhaus and Boyer 2000 +2.5 °C	Tol 1999 +1.0 °C
N America USA		 - 0.3	 + 0.5	-3.4
W Europe EU			 + 2.8	-3.7
OECD Pacific Japan		 + 0.1	 + 0.5	-1.0
FSU E. Europe Russia		 -11.1	 + 0.7 - 0.7	-2.0
Mid East			+ 2.0	-1.1
L America Brazil		 + 1.4		+ 0.1
S Asia India		 + 2.0	 + 4.9	+ 1.7
China		-1.8	+ 0.2	-2.1
Africa			+ 3.9	+ 4.1
All developed countries		0.0		
All developing counties		+ 0.2		
World – output Weighted	+1.5 to + 2.0	 - 0.1	+ 1.5	- 2.3
World – population weighted			+ 1.9	+ 2.7
World – equity weighted				- 0.2

100. The monetised estimates do not seem to be consistent with the more alarming pictures of global warming damage painted in much of the scientific literature. However, only crude efforts are made in some of the models to account for impacts such as thermohaline reversal etc. Most of the models make no effort to account for large-scale singular events. The estimates are also benchmarked on a doubling of CO_2 concentrations relative to pre-industrial levels, i.e. on approximately 550 ppm. Damages will be larger if concentrations are permitted to go beyond this level. Finally, average world damages conceal the bias in the damages towards developing countries. Rich countries may still wish to act to prevent damage to these countries even if they might suffer little damage themselves.

101. **The evidence presented to us indicates that these estimates of monetised damage are highly controversial within IPCC deliberations.** Indeed, we note that in the 1995 Second Assessment Report, damages and benefits were afforded a separate chapter in the report of Working Group III. In the Third Assessment Report of 2001 the monetary estimates are confined to a sub-section of Chapter 19 of the report of Working Group II. That chapter is intended to be a summary of other chapters, but the monetary damage estimates are introduced there for the

first time. Moreover, there is no discussion at all of the estimates in the 2001 IPCC *Synthesis Report*. It appears to us that the IPCC has made a conscious effort to downplay the economic approach to measuring damages. We acknowledge, as does IPCC, that these estimates are uncertain. But it is hard to justify the minimal discussion of the estimates on this basis since all the IPCC Reports contain detailed discussions of various non-monetised impacts that must be equally uncertain. **We urge the Government to press the IPCC for a proper detailing of the estimates and a discussion of the uncertainties in the next IPCC Assessment Report in 2007.** Brief inspection of the plans for that report does not provide encouragement. According to the outline on the IPCC's website, there is to be no discussion at all in 2007 of the "integrated assessment" models and the estimates of damage costs are given even less space (in Chapter 20 of WGII and Chapter 2 of WGIII).

102. In his evidence to us, Dr Terry Barker of Cambridge University confirmed that some past controversies on monetary valuation have made the IPCC nervous of monetised damage estimates. In particular, he noted that monetised values of "human life"—more strictly, what people are willing to pay to reduce risks to life and limb—were widely criticised[84]. We can see why such procedures would appear controversial, especially as "willingness to pay" will be constrained by income, making the life of someone in a poor country appear less "important" than a life in a rich country. But placing money values on life risks is in fact commonplace, and is part of the Government's approach to cost-benefit appraisal of regulations and of major investments in transport and in health and safety. No government treats life risks as if they should be zero. Hence costs and risks are traded off on a regular basis. If the argument is not about monetising the risks but about the inequality of the valuations used, then it is possible to have more sympathy. But the procedures for "equity weighting" described above go a long way to correct this basis in the use of a willingness-to-pay metric. Whatever the rights and wrongs of these arguments, we are concerned that, by trying to avoid controversy, the IPCC is not facing up to the realities of making choices. If nothing else, economics forces those choices into the open.

The social cost of carbon

103. A very convenient way of summarising the money value of the damage done by warming is to compute the extra damage done to the world as a whole from one extra tonne of carbon released now. In the economist's language, this is the "marginal damage" from emissions. It has also come to be known as the "social cost of carbon" (SCC). Defra currently has an "official" guide value for SCC of £70 tC, but with a range of £35-140 tC. This was based on an earlier review of the integrated assessment models. In 2004 Defra instituted a review of these estimates, culminating in two consultancy reports in 2005 which have yet to be finally reviewed and released. Since these estimates of the SCC are derived from the monetised values of damages, they are just as subject to issues of uncertainty, equity weighting, discounting, and so on.

104. We applaud Defra and the Treasury for pursuing a consensus view of the size of the SCC. Failure to arrive at such a number (or range of numbers)

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84 Evidence from T. Barker (Vol II, pp 78-86)

encourages misallocation of resources between government departments, and this has been the driving force behind finding an agreed SCC. Moreover, SCC estimates can be compared directly with the marginal costs of abatement discussed in Chapter 5[85]. If the SCC exceeds the marginal costs of control, then, *prima facie*, the climate target being considered is too strict. If the SCC is less than the marginal cost of control, there is scope for making the target stricter. Effectively, these comparisons amount to conducting a cost-benefit analysis[86]. It seems to us that this is exactly the kind of exercise that Defra and the Treasury should be conducting in their climate policy appraisal, whether it is the Kyoto Protocol targets, the long-term 60% target, or any of the mechanisms being used to meet these targets—such as the Renewables Obligation or adoption of windpower. Dr Helm made it clear that he thought these policies would not pass a cost-benefit test if this comparison was made[87].

Conclusions on benefit estimates

105. **While we agree with others that the monetised benefit estimates for controlling global warming are uncertain, we are concerned that the IPCC appears to be playing down these estimates in favour of often detailed descriptions of individual impacts that cannot be brought into comparison with the likely costs of control. Perhaps one reason for this lack of emphasis is that the economic measures of damage give the impression that the benefits of warming control are smaller relative to the costs.** But whatever the outcome of a comparison of costs and benefits, such a comparison needs to be made. Not providing it conveys the impression of a partial approach to the economics of climate change. It is imperative that the damages from greenhouse gas emissions be spelled out in monetary terms so that the public and government can better appreciate the trade-off between current sacrifices and future benefits from emissions control. **We urge that explicit comparisons be made between the monetary cost of adaptation measures and their benefits. While we were reassured by Defra that they would be pressing for a higher profile for the economics in the IPCC's Fourth Assessment Report, we consider that the Treasury has a duty to reinforce Defra's intent. Indeed, given the potential importance of this issue, both in terms of public expenditure and of overall economic cost, the Treasury should become directly involved itself, making its own economic assessment of the issue.**

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85 Marginal benefits are the same as the SCC avoided.

86 As noted previously, one might want to add the (marginal) ancillary benefits of control to the SCC to derive an overall marginal benefit of control. This would then be compared to the marginal cost of control.

87 Evidence from D. Helm (Vol II, pp 87-95)

CHAPTER 7: THE IPCC PROCESS

106. In the previous chapters we have several times referred to some limitations in the IPCC process. This process is an international one involving all governments and hundreds if not thousands of experts. Inevitably, in such a large-scale venture there will be weaknesses and errors. But the stakes are high and it is imperative that the process is an open one, capable of receiving criticism, and insistent on the highest standards of scientific and economic procedures. While HM Government and the many UK experts comprise just one collective player in the IPCC process, it is important that they are vigilant in ensuring that any errors and defects are brought to the attention of the IPCC and the scientific community in general. In this chapter we elaborate on our previous concerns and introduce some others.

The Special Report on Emissions Scenarios

107. In Chapter 4 we listed a number of criticisms of the IPCC Special Report on Emissions Scenarios (SRES). We noted that the original criticisms advanced by Professor David Henderson and Mr Ian Castles on the use of market exchange rates in aggregating world income has generated a much broader literature that questions (a) the credibility of the IPCC high emissions scenarios, and (b) the relevance of purchasing power parity exchange rate conversions. Whatever the resulting outcomes of making the scenario exercise more robust, it is clear to us that IPCC does need to reconsider its SRES exercise. This requires more than making allowance for new data, which Dr Nakicenovic told us would figure in the 2007 exercise[88]. We urge the IPCC to go beyond making adjustments for improved data. There is a need to reconsider the economic basis on which the scenarios are constructed.

108. In terms of process, we heard from several witnesses that the IPCC SRES exercise does not reflect the most appropriate expertise. While there are some national accounts statisticians involved in the exercise, it seems to us that a broader representation from the economics and statistics community is called for, along with a perspective from economic historians. The failure to take adequate account of the consistency between projections and past experience is a case in point, and an issue that was raised early on by Professor Henderson and Mr Castles, and again by Professor Tol and by Professor Ross McKitrick in their evidence to us[89].

The policy-makers' summaries

109. The IPCC main reports of Working Groups I to III consist of detailed technical chapters. Each chapter then has a "policy-makers summary" designed for those who need a fairly rapid guide to what the technical chapter has said. But there is a stark contrast in the way the technical chapter and the summary are written. The former is written by lead authors who in turn have a team of experts who make inputs to that chapter. The latter may be written by the same authors but is scrutinised in detail by government representatives to the IPCC meetings. As Dr Barker put it to us:

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88 Evidence from N. Nakicenovic (Vol II, pp 131-137)

89 See, for instance, evidence from R. Tol (Vol II, pp 69-77)

"governments…do have a say in the Summary for Policy Makers [which is] taken extremely seriously by governments, and it is a line-by-line acceptance, and each word can count, and the process can actually collapse if governments will not accept a particular phrasing, a particular word".

110. Dr Barker went on to say that government representatives can be very sensitive to some issues. For example, wording that suggests costs of control are large might upset governments whose policy stance is based on the view that costs are small and easily bearable. Dr Barker concluded that:

"…what happens is that there is a political process which uses words which can have different meanings for different people and the outcome is a Summary for Policy Makers that everybody will sign up to"[90].

111. **We can see no justification for this procedure. Indeed, it strikes us as opening the way for climate science and economics to be determined, at least in part, by political requirements rather than by the evidence. Sound science cannot emerge from an unsound process.**

112. We sought examples of the kind of problem that has arisen because of such interference in what should be a scientific process. Examples were not hard to find. In the 1995 Second Assessment Report, the Summary of Chapter 6 on *The Social Costs of Climate Change* bears little resemblance to the technical chapter it is supposed to summarise. Indeed, the lead authors of that chapter disowned the Summary. In the 2001 Working Group II Report our attention was drawn to the following statement in the *Summary for Policymakers* (p.8):

"Benefits and costs of climate change effects have been estimated in monetary terms and aggregated to national, regional and global scales. These estimates generally exclude the effects of changes in climate variability and extremes, do not account for the effects of different rates of change, and only partially account for impacts on goods and services that are not traded in markets. *These omissions are likely to result in underestimates of economic losses and overestimates of economic gains* [from climate change]"(our emphasis).

113. Chapter 19 (p.942), on which the Summary quotation above is supposedly based, actually says:

"Overall, the current generation of aggregate estimates may understate the true cost of climate change because they tend to ignore extreme weather events, underestimate the compounding effect of multiple stresses, and ignore the costs of transition and learning. *However, studies also may have overlooked positive impacts of climate change. Our current understanding of (future) adaptive capacity, particularly in developing countries, is too limited, and the treatment of adaptation in current studies is too varied, to allow a firm conclusion about the direction of the estimation bias*" (our emphasis).

114. **In short, the Summary says that economic studies underestimate damage, whereas the chapter says the direction of the bias is not known.**

IPCC and scientific expertise

115. Given the global scale of the IPCC process, it should be expected that it will attract the best experts. In his evidence to us, Professor Paul Reiter raised

[90] Evidence from T. Barker (Vol II, pp 78-86)

doubts about the extent to which this is the case[91]. He refers to the Second Assessment Report of Working Group II in 1995, Chapter 18 of which is concerned with human health impacts of warming. A significant part of this chapter discussed malaria. Yet, according to Professor Reiter, none of the lead authors had ever written a paper on malaria, the chapter contained serious errors of fact, and at least one of the chapter's authors continues to make claims about warming and malaria that cannot be substantiated. Professor Reiter's concerns extend to the same chapter in the Third Assessment Report of 2001, where he was initially a contributory author. While he expresses far more confidence in this chapter than the equivalent one in the Second Assessment Report, Professor Reiter notes that "the dominant message was that climate change will result in a marked increase in vector-borne disease, and that this may already be happening". In Professor Reiter's view, no such conclusion is warranted by the evidence, and he speaks as a malaria specialist of more than thirty years' experience. While nominated by the US Government to serve on the comparable group for the Fourth Assessment Report, the next one that will appear from IPCC, Professor Reiter learned that his nomination had not been accepted by IPCC. Yet Professor Reiter tells us that of the two lead authors for that chapter, one had no publications at all and the other only five articles.

116. We cannot prove that Professor Reiter's nomination was rejected because of the likelihood that he would argue warming and malaria are not correlated in the manner the IPCC Reports suggest. But the suspicion must be there, and it is a suspicion that lingers precisely because the IPCC's procedures are not as open as they should be. It seems to us that there remains a risk that IPCC has become a "knowledge monopoly" in some respects, unwilling to listen to those who do not pursue the consensus line. We think Professor Reiter's remarks on "consensus" deserve repeating:

"Consensus is the stuff of politics, not science. Science proceeds by observation, hypothesis and experiment. Professional scientists rarely draw firm conclusions from a single article, but consider its contribution in the context of other publications and their own experience, knowledge and speculations".

We are concerned that there may be political interference in the nomination of scientists whose credentials should rest solely with their scientific qualifications for the tasks involved.

IPCC and economics expertise

117. In his evidence to us, Professor Ross McKitrick suggested that the IPCC no longer commanded the allegiance of mainstream economists[92]. In scrutinising the authorship of chapters, we believe his perception has arisen because some of the economics that was originally subsumed in Working Group III was moved in the 2001 Report to Working Group II. Working Group II is concerned with impacts, adaptation and vulnerability. Its authorship is dominated by impact specialists who tend not to be economists. The fact that the chapter that deals with monetised benefits of warming control now appears in that volume may explain its apparent downgrading, although we note that this is also consistent with IPCC's desire to avoid the

91 Evidence from P. Reiter (Vol II, pp 284-288)

92 Evidence from R. McKitrick (Vol II. Pp 262-266)

politically-inspired debates over the benefit estimates. Working Group III deals with the remaining economic issues and the amount of economic expertise is more significant.

Conclusion

118. **Overall, we are concerned that the IPCC process could be improved by rethinking the role that government-nominated representatives play in the procedures, and by ensuring that the appointment of authors is above reproach.** If scientists are charged with writing the main chapters, it seems to us they must be trusted to write the summaries of their chapters without intervention from others. Similarly, scientists should be appointed because of their scientific credentials, and not because they take one or other view in the climate debate. The IPCC publications as a whole contain some of the most valuable summary information available to the world on what we know about climate change. The standards employed are clearly very high. But this is all the more reason to ensure that procedures are unimpeachable. **At the moment, it seems to us that the emissions scenarios are influenced by political considerations and, more broadly, that the economics input into the IPCC is in some danger of being sidelined. We call on the Government to make every effort to ensure that these risks are minimised.**

CHAPTER 8: UNITED KINGDOM POLICY AND THE INTERNATIONAL NEGOTIATIONS ON CLIMATE CHANGE

119. Our inquiry was primarily concerned with the projections of economic activity that underline the IPCC forecasts of climate change, with the costs of tackling climate change and the benefits that would accrue to the world as a whole. Difficult and controversial though it is, we believe that conscious efforts must be made to weigh up the costs and benefits of climate change policy at every level. Because of this focus we spent less time in our inquiry on current UK policy on climate change. Moreover, as we noted in the introduction, other Parliamentary committees have been examining these issues. Nonetheless, we did take the opportunity to explore some issues of policy. These are documented in this chapter.

UK and EU policy

120. Boxes 9 and 10 summarise our understanding of the various climate targets that the United Kingdom and the European Union have signed up to. Some of these targets are legally binding and some are not. The original 1992 "Rio" target was a voluntary one and non-compliance carried with it no penalties. In the event, the United Kingdom was one of very few countries that complied with the Rio targets, though not through policy design—compliance was largely secured because of the choices of newly privatised electricity utilities to switch to natural gas and out of coal[93]. The UK "Kyoto" target is determined by the EU burden sharing agreement. In other words, it is the EU that has to comply with its overall target, compliance that is required in international law. Non-compliance by individual EU Member States with the burden sharing agreement is a matter for internal EU law. Targets that have no legal compliance requirements are the Government's 1997 Manifesto commitment of 20% reduction in CO_2 emissions (relative to 1990) by 2010, and its long-term 60% reduction target for around 2050. Moreover, while the 2050 target is frequently referred to as a unilateral target, close inspection of the language used to describe it makes it clear that it is conditional on other countries pursuing similar goals. Some other EU states have confirmed comparable targets, but most have not. Thus the targets vary substantially in the extent to which legal compliance is required.

93 Germany also complied with the Rio targets because reunification led to wholesale economic restructuring and the closure of many heavily polluting plants.

BOX 9

United Kingdom Climate Targets

Year agreed	The gases covered	The target	Comment
1992 Framework Convention on Climate Change, Rio	CO_2 only	2000 emissions no greater than 1990 emissions: voluntary agreement	Incidentally achieved very largely via electricity privatisation introduced by Conservative Government
1997 Labour Manifesto	CO_2 only	2010 emissions 20% less than 1990 emissions	Language of commitment varies, e.g. Energy White Paper 2003 states it as "to move towards a 20% reduction".
1997 Kyoto Protocol, agreed in EU 1998	GHGs	2008-12 emissions 12.5% below 1990 emissions	UK's share under the EU burden sharing agreement for the Kyoto Protocol
2003 Energy White Paper	CO_2 only	c 2050 emissions 60% less than in 1990 "with real progress by 2020".	Commitment is to be "on a path towards" the target. In absolute terms it equals around 65 mtC in 2050. Also stated as a global goal for the "world's developed economies"

BOX 10

The EU Climate Targets

Year agreed	The gases covered	The target	Comment
1996, 1939th European Council Meeting, Luxembourg		Warming above pre-industrial level should not exceed +2°C: this is "an overall long-term objective to guide global efforts to reduce climate change risks". Conforms to CO_2 concentration goal of 550 ppm.	Note that this includes roughly 0.6°C warming in 20th century + additional warming already committed. Probably equivalent to +1°C compared to now.
1992 FCCC	CO_2	2000 emissions should be no greater than 1990 emissions	EU over-complied with target (-3% on 1990) due to UK, France and Germany, Sweden, Luxembourg over-complying
1997 Kyoto Protocol	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6	2008-2012 emissions in EU-15 must be at least 8% below 1990 emissions. This target then allocated unequally between Member States.	Slight relaxation of these targets secured at Bonn and Marrakech

121. The absence of the United States from the ratified Kyoto Protocol is, of course, a serious deficiency and we are concerned that there are few signs to indicate how the ratifying countries intend to persuade the US to re-enter the negotiations. Just as important, the participation of Russia has been secured through political horse-trading in order to ensure the Protocol has the required minimum number of ratifiers. Yet Russia's emissions commitments constitute "hot air", that is, they do not correspond to any real reductions in greenhouse gases.

The Kyoto Protocol

122. **We also note that the compliance mechanisms in the Kyoto Protocol are very weak and even counter-productive.** Essentially, any signatory that fails to comply receives a penalty target in the context of any post-Kyoto agreement. Thus, a country not achieving the 2008-12 target must not only make up the shortfall in the second compliance period (yet to be negotiated), but must also achieve an additional 30% of this amount. The obvious problem is that anyone who does not comply is unlikely to sign up to this form of self-punishment in the later rounds. As Professor Scott Barrett of Johns Hopkins University has pointed out, if anything, the compliance

mechanism is a deterrent to further participation[94]. In large part, this kind of deficiency in the Kyoto Protocol arises from the international negotiators' preoccupation with agreements that set emission targets. Moreover, **we heard from several witnesses that the Kyoto targets themselves were going to make little difference to rates of warming** – see Table 11. In other words, Kyoto only begins to make environmental sense if it is the first of several, and maybe many, such future agreements. In his evidence to us, Professor Michael Grubb was insistent that this was always part of the design of Kyoto and that its own environmental ineffectiveness is not important since it is merely the first step in a longer run process[95].

TABLE 11

The environmental ineffectiveness of the Kyoto Protocol

	Business as Usual (BAU)	Kyoto Only = Kyoto + BAU 2010+	Kyoto + constant emissions 2010+	Kyoto + 1% p.a. emissions reduction 2010 to 2100
Concentrations:				
1990 ppm	350			
2100 ppm	700	680	660	625
Increase in temperature °C by 2100	2.1	2.0	1.9	1.8
Sea level rise cm	50	48.5	47.5	45.5

Source: adapted from T. Wigley The Kyoto Protocol: CO2, CH4 and climate implications. *Geophysical Research Letters*, 25 (13), 1998, 2285-2288.

Notes: scenarios assume Annex B countries only (i.e. those countries with emission reduction commitments), but including the US, take action. BAU = business as usual. "Kyoto only" is the effect of Kyoto assuming no further agreements, with some BAU scenario following. "Kyoto+constant emissions" assumes Annex B countries stay at their 2010 emission levels once the Kyoto targets are achieved. "Kyoto+ 1% reduction" assumes Annex B countries reduce emissions at 1% p.a. to 2100 after 2010. SLR = sea level rise. ppm = parts per million by volume. All figures approximate and assume 2.5°climate sensitivity – i.e. the temperature response to greenhouse gas forcing.

The analysis assumes that the US signs up to the Kyoto Protocol, so the estimates here overstate the effectiveness of the Kyoto Protocol if the US continues with its current policy of not ratifying the treaty.

123. But if Kyoto is simply the first step on a ladder of agreements, the issue of devising compliance incentives looms even larger. If there is widespread non-compliance, which is what many observers suggest will be the case, it means that participants have experienced difficulties in reaching the targets. Those difficulties may be economic, political or other. But if there are difficulties in meeting the Kyoto targets, there are likely to be even greater difficulties meeting yet stricter targets. Non-compliance with the first rung of the ladder

94 S. Barrett, Kyoto plus. In D. Helm (ed.), *Climate Change Policy*, Oxford: Oxford University Press, 2005.

95 Evidence from M. Grubb (Vol II, pp 165-177)

makes it far less likely that there will be participation in later agreements. Professors William McKibbin and Peter Wilcoxen have stated that "…the Kyoto Protocol is an impractical policy focused on achieving an unrealistic and inappropriate goal"[96]. Moreover, while China, India and Russia have ratified the Kyoto protocol, China and India do not have emission targets, and, as already noted, Russia's commitments constitute "hot air". **One of our observations, therefore, is that the "beyond Kyoto" negotiations, which start this year, will have to take a far more innovatory approach than simply assuming that the Kyoto targets will be tightened**[97].

Kyoto and the United States

124. The environmental effectiveness of any future international agreements on climate change will depend critically on both the United States and the developing world adopting active programmes to combat emissions growth. As we note above, this may not mean adopting agreements based on further emissions targets—an alternative approach will be required. But if the US remains outside future agreements, as they have done with respect to Kyoto, then their effect will be seriously limited. The US currently accounts for just over 20% of the entire world emissions of greenhouse gases, and closer to 25% for carbon emissions from fossil fuels. After Australia (which has also declined to ratify Kyoto), the US has the highest per capita greenhouse gas emissions of any country.

125. The developing world emitted roughly half the world's greenhouse gases in 2000. Whereas the developed world is likely to increase emissions by around 35% 2000-2025, the developing world's increase is likely to be over 80%[98]. It seems obvious to us that both the US and the developing world have to take on active programmes of reducing emissions with immediate effect, or the efforts of Europe and the rest of the world will be wasted.

126. With this in mind, we sought some explanation for the position of the United States. It seems to us that scrutiny of the costs and benefits to the US provides invaluable insights into the US position.

127. There are several elements to the cost burden that the US would bear if it ratified Kyoto. First, it would have its own domestic emissions reduction programme and the costs of that would fall on industry, transport and households. The US judged early on that these costs would be unacceptable, but had always maintained that the prospect of acceptability would exist if

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96 W. McKibbin and P. Wilcoxen, The role of economics in climate change policy. *Journal of Economic Perspectives*, 16(2), 2002, 107-129.

97 There is a growing literature on the limitations of the Kyoto Protocol and alternative means of achieving climate change goals. For example, see S. Barrett, Kyoto plus. In D. Helm (ed.), *Climate Change Policy*, Oxford: Oxford University Press, 2005; J. Aldy, S. Barrett and R. Stavins, *Thirteen Plus One: A Comparison of Global Climate Policy Architectures*, Working Paper RWP03-012, John F Kennedy School of Government, Harvard University, 2003; D. Bodansky, *International Climate Efforts Beyond 2012: A Survey of Approaches*, Washington DC: Pew Center for Climate Change.

98 All of these data come from K. Baumert and J. Pershing, *Climate Data: Insights and Observations*. Washington DC: Pew Center for Climate Change, 2004.

there was widespread emissions trading[99]. In the event, the Kyoto Protocol enabled various forms of trading: trades between rich nations based on allocated permits (cap and trade), project-based trades between (roughly) OECD countries and East Europe and Former Soviet Union ("joint implementation"), and project-based trades between OECD countries and developing countries ("Clean Development Mechanism"—CDM). Moreover, the US had already sponsored major efforts at joint implementation in order to learn how to operate such projects. Arguably, the limited prospects for extensive cap and trade systems (which is what the EU has developed), and the comparatively small role playable by joint implementation and the CDM, persuaded the US government that compliance costs to the US would be higher than they hoped.

128. Second, the US has been insistent that developing countries must quickly assume targets of their own. We noted above that this is a rational position to take since rates of warming cannot be adequately affected without this happening. The developing countries have always maintained that warming was not their responsibility. If the rich countries want to bring the developing countries on board, they might therefore have to pay for developing country reductions as well as their own. The Kyoto Protocol does have "flexibility mechanisms" which permit reductions in developing countries to be credited to developed economies provided the latter pay for them. But what the US may have feared was the prospect that the developing countries would maintain their "you not us" stance and eventually the US would have to become a major contributor to the costs of reducing emissions in developing countries, without emission credits being secured.

129. Third, "relative" cost matters, i.e. the burden on the US relative to the burden borne by others. Apart from any feelings about "unfairness" if others did not appear to bear as big a burden, there are concerns about competitiveness, and about impacts on specific sectors of the economy—not least oil and coal producers.

130. A fourth factor relates to the Integrated Assessment Models (IAMs) that influenced the US government. These were primarily those that showed comparatively small global benefits from Kyoto (the work of Professors Nordhaus, Mendelsohn, Manne and Dr Richels). Thus the US was being asked to bear a "big" cost (as they saw it) for uncertain global benefit. The climate models themselves were showing little or no effect on rates of warming from Kyoto. However, a dominant feature of the minor impact of the Kyoto Protocol on warming is also the fact that developing country rates of growth of emissions are the fastest. President Bush clearly stated: "I oppose the Kyoto Protocol because it exempts 80% of the world, including major population centers such as China and India"[100].

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[99] Emissions trading works by having permits allocated to emitters. Those who find it easiest to abate will sell their permits and abate emissions. Those who find it hardest to abate will not abate but will buy permits instead. In this way, emissions trading minimises the compliance costs. Throughout all the negotiations leading to the Kyoto Protocol, the US insisted on the substantive role of trading precisely because it would reduce the costs of compliance to the US.

[100] This position somewhat reneges on the first President Bush's commitment to the Rio Framework Convention on Climate Change (of which Kyoto is the first Protocol) since that speaks of "differentiated responsibilities and respective capabilities" for combating climate change. Historically, the US accounts for around 30% of cumulative CO_2 emissions and, as the richest country in the world, has more capability to reduce emissions than other countries.

131. We offer this brief analysis of the position of the US not because we wish to defend that position, but in order to argue that there is an economic rationality to the stance taken. Failure to understand that rationality will misdirect efforts to bring the US into future negotiations in a more positive way. Again, we believe that if the "Kyoto plus" negotiations simply attempt to impose stricter emissions targets on the world—what Professor Scott Barrett of Johns Hopkins University has called "the Kyoto only" approach—the position of the US will not change[101]. Indeed, if the US has been unwilling to sign up to the Kyoto targets, we do not see how it will sign up to even stricter targets. In our view, there is a real risk that the international negotiators will render their own efforts fruitless if they persist in an exclusive adoption of the targets-based approach.

132. **Finally, the US has repeatedly stressed the role of technological change in securing greenhouse gas emission reductions. While the Kyoto Protocol should, in principle, encourage technological change, we are not convinced that it has sufficient focus on this central issue.** We return to this point when considering how the "Kyoto process" might be taken forward.

Alternative architectures for "Kyoto Plus"

133. **We argue above that the "more of the same" approach to emissions targets may not tackle the global warming threat. We urge the UK Government to help broaden the debate through its membership and current presidency of the G8 and using its position of being internationally respected in the scientific world.** While we have not investigated the alternative means of tackling warming in any detail, we draw attention to two alternative approaches to international negotiations.

134. Any "Kyoto plus" treaty has to provide incentives for long run emissions reductions. This means there must be changes in technology and/or behaviour that can be sustained through time and, importantly, that there must be effective compliance mechanisms. The Kyoto Protocol is essentially a legal regime that attempts to punish short-term non-compliance but, as noted above, does so with an enforcement mechanism that is so weak it is likely to be counter-productive, i.e. it will encourage reduced participation in the future, not the widening participation that is required. At the moment, it is hard to see how countries will sign up to a stricter target-based regime than already exists with the Kyoto Protocol. One possibility is that Kyoto-plus should adopt stricter targets but with much more effective enforcement. One of the few international environment treaties to be effective is the Montreal Protocol which controls ozone-depleting chemicals. This treaty can be enforced using trade sanctions. One possibility is that Kyoto-plus could introduce trade sanctions as a non-compliance penalty. However, the chances of this succeeding seem to us remote. Controlling climate change is not like controlling ozone depletion—in the latter case alternative technologies were already being advanced and the costs of "buying in" the developing countries were small. Taking ozone depleting chemicals out of economic systems is trivial compared to taking carbon out. In contrast, the benefits of reducing ozone depletion are enormous. It is a mistake, therefore,

[101] S. Barrett, Kyoto plus. In D. Helm (ed.), *Climate Change Policy*, Oxford: Oxford University Press, 2005.

to assume that any Kyoto-plus treaty should simply copy the format of the Montreal Protocol.

135. There are many proposals for a changed approach to Kyoto-plus[102]. These include harmonised national carbon taxes, more rapid progress to world-wide emissions trading, a more forceful agreement on adaptation measures than is contained in the Kyoto Protocol, and what to us seem more fanciful ideas about allocating carbon budgets between nations so that per capita emissions converge at some future date.

136. **It could be argued that it is late in the day to be suggesting a significant change of focus in the climate negotiations. But we fear that the present "more of the same" approach, focusing on targets for emissions reductions,** will fail. It is better to aim for cost-effective technologies, and the right balance between adaptation and mitigation.

Adaptation

137. We reiterate our concern that adaptation measures have become the "Cinderella" of the negotiating process. The chances that a politically feasible set of emissions reduction measures along current lines will significantly alter the rate of warming are, in our view, small. Hence it is vital to look urgently at what can be done to diffuse technologies on, for example, water conservation, new water supplies, avoidance of the worst impacts of weather extremes etc. A sensible strategy is to have a robust adaptation strategy in place as well. While we acknowledge that the Kyoto Protocol discusses adaptation, there is little evidence that adaptation is being pursued aggressively. To some extent, current decisions are already being modified to take adaptation "on board", as with flood control decisions in countries like the United Kingdom. But much more needs to be done and **climate adaptation should become one of the mainstream elements of investment decisions, particularly with respect to infrastructure, housing, coastal development and international development assistance.** Of course, adaptation has its limits—it is not obvious what it would mean to adapt to the large scale one-off events discussed earlier. But before those limits are reached, there seems to us to be enormous scope for a global adaptation strategy on a par with the mitigation strategies that preoccupy the IPCC process and the national debate.

International carbon taxes

138. One approach not based on setting further emissions targets would be an internationally harmonised carbon tax. The advantages of such a tax are:

- it raises the price of emissions;
- it could be introduced only after a per capita income threshold has been reached, avoiding any initial rejection of the measure by developing countries but gradually bringing them into the agreement as their development proceeds;
- it could be based on consumption;

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[102] Most of these are very conveniently summarised and reviewed in D. Bodansky, *International Climate Efforts Beyond 2012: A Survey of Approaches*, Washington DC: Pew Center for Climate Change.

- it avoids tariffs in relation to trade between parties to the agreement, but with border tax adjustments for trade between participating and non-participating countries; and
- it avoids potential large changes in permit prices which can have a detrimental effect on investment decisions. The tax remains constant, or rises steadily over time, and emissions adjust.

139. The arguments against international carbon taxes are well known. For example, taxes may fail to achieve quantitative goals if governments fail to estimate accurately the response of emitters. Varying the tax as information about such responses evolve is one option, but this may only reinforce the uncertainty that emitters face. However, the political prospects of a harmonised international tax may be remote. For example, the European Union was singularly unsuccessful in introducing an EU-wide energy/carbon tax. But this should not prevent unilateral action by individual nations or groups of nations.

140. We share the criticisms expressed by some of our witnesses that the UK's current "climate tax", the Climate Change Levy, is anything but a carbon tax. It is an energy tax and the tax rate does not vary directly with the carbon content of fuels. It is not applicable to transport or households, and it offers electricity generators no incentives to switch between low and high carbon fuels. Further, it is associated with numerous exemptions and links to Climate Change Agreements which themselves may have secured illusory emission reductions due to "hot air" trading. **We therefore urge a thorough review of the Climate Change Levy regime, with the aim of moving as fast as possible to replacing it by a carbon tax.**

International technology agreements

141. **There appears to be growing support for the idea that Kyoto-plus should focus on technology and research and development.** Professor Scott Barrett of Johns Hopkins University notes that such a technology-based approach has worked for ocean oil pollution where, after years of trying unsuccessful procedures, standards for ships to separate ballast water and oil were agreed[103]. These standards have been followed by others, such as double hulls for new tanker ships. The features of this approach are (a) that compliance is easily verified, (b) each state has an incentive to protect its own waters from pollution, and (c) as more countries ratified the agreement, the bigger the incentive tanker owners had to comply because of the need to have access to as many ports as possible. Professor Barrett asks if a similar approach cannot be adopted for Kyoto-plus. International agreement on R & D in low or zero-greenhouse gas technology might help to lower future costs of these technologies at a rapid rate. In the same vein, the bigger the scale of the technological innovation, the lower the costs of adopting it. In some cases, adoption of the technology by a major player, for example, the US or Europe, will provide major incentives for other countries to adopt the same technology in order to gain access to the markets of the US and Europe. Vehicle technology is a case in point. As major purchasers, technological standards set by large importers would require that those technologies are adopted in the exporting nations. Moreover, technology

[103] S. Barrett, *Environment and Statecraft*. Oxford, Oxford University Press. 2001.

standards are compliant with the WTO rules. Finally, incentives for technology transfer to the developing nations would be built into the agreement.

142. **The International Energy Agency (IEA) has estimated that the R & D expenditure needed, if carbon-free energy is to become economically viable through the use of solar photovoltaics, biomass and carbon sequestration, is around $400 billion[104]. This is a little over 1% of current global annual GDP. This might be compared to the costs of the 1963-72 US Apollo programme that put man on the moon. The Apollo programme cost around 2.5% of US GNP in about 1970, or 1% of then global annual GNP[105]. The IEA renewable energy programme would therefore cost about the same now as the Apollo programme did then—1% of world GNP.** Spread over 30 years, this $400 billion would amount to around 0.03% of world GNP each year. Moreover, such an R & D programme would be a true global public good: one in which everyone would have a share of the benefits. An agreement of this kind would have the potential to overcome the major obstacles that currently inhibit further progress on tackling climate change—the need to find incentives to get the United States and the developing countries to join others in the quest for low carbon energy futures. The US is already investing heavily in such technology. The developing world would gain substantially by acquiring it. **We offer these thoughts as an illustration of what international negotiators might now consider—an agreement on technology and its diffusion.**

143. We do not pretend to have worked through in any detail proposals of the kind outlined above. **The important issue is to wean the international negotiators away from excessive reliance on the "targets and penalties" approach embodied in Kyoto.** We acknowledge that this approach could work, provided there was a powerful enforcement mechanism. The problem is that countries are not going to agree to such an enforcement mechanism, as the compliance negotiations over the Kyoto Protocol have already shown. Existing international institutions such as the United Nations simply do not have credible threats for participants to secure compliance. **Hence there should be urgent progress towards thinking about wholly different, and more promising, approaches based on a careful analysis of the incentives that countries have to agree to any measures adopted.**

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104 Evidence from M. Grubb (Vol II, pp 165-177)

105 R.D. Launius, *Proceedings of the 41st Aerospace Engineers Meeting* 6-9 January 2003

CHAPTER 9: CONCLUSIONS AND RECOMMENDATIONS

Introduction

144. We welcome the Government's recognition of the central role of economics in considering climate change. But we believe that the Chancellor needs to broaden the scope of the Government's interests, and the Treasury's interests in particular, in aspects of the climate change debate that we feel have not yet been given sufficient emphasis (para 2).

145. We are concerned that the links between projected economic change in the world economy and climate change have not been as rigorously explored as they should have been by the IPCC. We believe the complex interactions between world economic growth and climate change need additional scrutiny at the international level, and that the UK Government has a role to play in ensuring that this happens. We are also concerned that clearer messages should be conveyed to the public about the likely costs and benefits of climate change control, who will bear those costs and benefits, and when (para 2).

146. We are not convinced that there is sufficient public awareness of the economics of climate change. Any public misperception on these issues could threaten the political feasibility of getting plans of action put into effect. If climate change is as serious as most scientists claim, and as the Government accepts, then it is important to convey the complementary message that the action to tackle it will also have to be serious and potentially life-changing. It is better to be honest now than to shield the public from the economic realities inherent in the more pessimistic forecasts (para 3).

The uncertain science of climate change

147. The scientific context is one of uncertainty, although as the science progresses these uncertainties might be expected to diminish and be resolved, one way or the other. Hence it is important that the Government continues to take a leading role in supporting climate science, and encourages a dispassionate evidence-based approach to debate and decision making (para 18).

148. We do not believe that today's scientists are "crying wolf" about climate change: they may turn out to have been wrong in some respects, but arguments on which they base their case are better researched than in earlier cases. That said, we have sought to highlight some pressing issues which we believe deserve a further response from the scientific community in order to enhance understanding and resolve current controversies (para 24).

The future impacts of the enhanced greenhouse effect

149. Whatever the validity of temperature projections, the science of measuring impacts remains speculative. Many of the adverse effects of warming can be offset by adaptation and we believe that the economic and social returns from investing in adaptation should be properly weighed against the cost of mitigation (para 27).

150. We noted evidence from Professor Paul Reiter of the Institut Pasteur in Paris, which strongly disputed the IPCC's arguments on the likely spread of malaria as a result of warming (para 32).

151. We draw attention to the fact that, if extreme events are indeed to be considered the most important impacts from climate change, there is uncertainty and controversy about the underlying data required to substantiate this claim (para 37).

152. How catastrophic threats such as disintegration of Antarctic ice caps should influence decision-making depends on the scale of the effects, their probability of occurrence, and when they might occur. The scale of these events is clearly very large (para 39).

153. If cataclysmic events which threaten the viability of existing societies are even remote possibilities, it is important that policy makers construct frameworks for analysing and debating probability and risks, since the threats associated with such "doomsday" scenarios are fundamental elements in driving the international discourse (para 40).

154. We think it important that the IPCC moves towards clearer judgements on the probabilities of the projected global temperature increases (para 41).

155. We are clear that fuller consideration needs to be given to the literature on the positive effects of warming (para 43).

156. We conclude that there are weaknesses in the way the scientific community, and the IPCC in particular, treats the impacts of climate change. We call for a more balanced approach and look to the Government to take an active role in securing that balance of research and appraisal (para 44).

157. The issue of adaptation verses mitigation is clearly one of balance. Most adaptation expenditures would be local, while mitigation requires action on a global scale. Few would suggest doing nothing by way of mitigation, and few would suggest no adaptation expenditures at all. But the policy literature seems to us to be overly focussed on mitigation. We therefore urge the Government to ensure that greater efforts are made to understand the relative costs and benefits of adaptation compared to those of mitigation (para 47).

Forecasting greenhouse emissions and temperature change

158. Serious questions have been raised about the IPCC emissions scenarios, and a reappraisal of the scenarios exercise is urgently needed (para 60).

159. We consider the convergence assumptions in the IPCC scenarios to be open to some question. In our view, political factors should not be allowed to influence the scenarios, whether over the issue of convergence or indeed in any other context (para 63).

160. In general, any change in emissions due to changed economic assumptions will translate into a smaller effect on concentrations and an even smaller effect on temperature. This in no way excuses poor analysis in the emissions scenarios, but it may mean that projections of warming are not themselves greatly affected (para 66).

161. It appears that the IPCC scenarios are not capturing recent emissions experience in their short term projections (para 68).

162. We received a significant amount of evidence on the realism of the IPCC emission scenarios, and doubts were raised, particularly about the high emission scenarios. The balance of this evidence suggests to us that the high emissions scenarios contained some questionable assumptions and outcomes. While errors do not translate into equal magnitude errors in concentrations or warming, it seems to us important that the IPCC emissions modellers give serious attention to adopting the correct procedures (para 72).

The costs of tackling climate change

163. It is very important that a realistic picture of the likely costs be conveyed to, and understood by, people today who will have to pay them. We note the considerable efforts that the IPCC has made in constructing likely cost estimates for the world as a whole. We are far less satisfied with the data currently available on the costs to the UK, and we call for a significantly greater effort to clarify and estimate those costs (para 73).

164. Given the wide array of potential technologies, we are surprised that the Government's *Energy White Paper* should place such emphasis on just one technology, wind energy (para 83).

165. In our view, it would be unwise to close the nuclear energy option. It is prudent to maintain as wide an energy portfolio as possible. We argue that the current capacity of nuclear power, before further decommissioning occurs, should be retained (para 84).

166. We are concerned that UK energy and climate policy appears to rest on a very debatable model of the energy-economic system and on dubious assumptions about the costs of meeting the long run target of 60% reduction in CO_2 emissions. We call on DTI and the Treasury to improve substantially (a) the cost estimates being conveyed to the public and (b) the manner of their presentation. We believe that the Treasury should be more active in scrutinising and publicising these costs and benefits, in association with Defra and DTI (para 94).

The benefits of climate change control

167. Research suggests that, in terms of percentages of world GNP, monetised damage is relatively low, even for warming of 2.5°C. The damages are not evenly spread. In general, developing countries lose more than developed economies. Some models suggest no real net damage to rich countries (para 99).

168. The evidence presented to us indicates that the estimates of monetised damage are highly controversial within IPCC deliberations (para 101). We urge the Government to press the IPCC for a proper detailing of the estimates and for a discussion of the uncertainties in the next IPCC Assessment Report in 2007 (para 101).

169. While we agree with others that the monetised benefit estimates for controlling global warming are uncertain, we are concerned that the IPCC appears to be playing down these estimates in favour of often detailed descriptions of individual impacts that cannot be brought into comparison with the likely costs of control. Perhaps one reason for this lack of emphasis is that the economic measures of damage give the impression that the benefits of warming control are smaller relative to the costs (para 105).

170. We urge that explicit comparisons be made between the monetary cost of adaptation measures and their benefits. While we were reassured by Defra that they would be pressing for a higher profile for the economics in the IPCC's Fourth Assessment Report, we consider that the Treasury has a duty to reinforce Defra's intent. Indeed, given the potential importance of this issue, both in terms of public expenditure and of overall economic cost, the Treasury should become directly involved itself, making its own economic assessment of the issue (para 105).

The IPCC process

171. We can see no justification for an IPCC procedure which strikes us as opening the way for climate science and economics to be determined, at least in part, by political requirements rather than by the evidence. Sound science cannot emerge from an unsound process (para 111).

172. The IPCC Summary for policy makers says that economic studies underestimate damage, whereas the chapter says the direction of the bias is not known (para 114).

173. We are concerned that there may be political interference in the nomination of scientists to the IPCC. Nominees' credentials should rest solely with their scientific qualifications for the tasks involved (para 116).

174. The IPCC process could be improved by rethinking the role that government-nominated representatives play in the procedures, and by ensuring that the appointment of authors is above reproach. At the moment, it seems to us that the emissions scenarios are influenced by political considerations and, more broadly, that the economics input into the IPCC is in some danger of being sidelined. We call on the Government to make every effort to ensure that these risks are minimised (para 118).

UK policy and the international negotiations on climate change

175. We note that the compliance mechanisms in the Kyoto Protocol are very weak and even counter-productive. We heard from several witnesses that the Kyoto targets themselves were going to make little difference to rates of warming (para 122).

176. We consider that the "beyond Kyoto" negotiations, which start this year, will have to take a far more innovatory approach than simply assuming that the Kyoto targets will be tightened (para 123).

177. The US has repeatedly stressed the role of technological change in securing greenhouse gas emission reductions. While the Kyoto Protocol should, in principle, encourage technological change, we are not convinced that it has sufficient focus on this central issue (para 132).

178. We argue that the present "more of the same" approach, relying exclusively on targets for emissions reductions, may not tackle the global warming threat. We urge the Government to help broaden the debate through its membership and current presidency of the G8 and using its position of being internationally respected in the scientific world (para 133).

179. It could be argued that it is late in the day to be suggesting a significant change of focus in the climate negotiations. But we fear that the "more of the same" approach, focusing on emissions targets, will fail (para 136).

180. Climate adaptation should become one of the mainstream elements of investment decisions, particularly with respect to infrastructure, housing, coastal development and international development assistance (para 137).

181. We urge a thorough review of the Climate Change Levy regime, with the aim of moving as fast as possible to replacing it by a carbon tax (para 140).

182. There appears to be growing support for the idea that Kyoto-plus should focus on technology and R & D (para 141).

183. The International Energy Agency has estimated that the R & D expenditure needed, if carbon-free energy is to become economically viable through the use of solar photovoltaics, biomass and carbon sequestration, is around $400 billion. The IEA programme would cost about the same now as the 1963-73 US Apollo programme that put man on the moon cost then—1% of world GNP. Such an R & D programme would be a true global public good: one in which everyone would have a share of the benefits. This is an illustration of what international negotiators might now consider—an agreement on technology and its diffusion (para 142).

184. The important issue is to wean the international negotiators away from excessive reliance on the "targets and penalties" approach embodied in Kyoto. Hence there should be urgent progress towards thinking about wholly different , and more promising, approaches based on a careful analysis of the incentives that countries have to agree to any measures adopted (para 143).

APPENDIX 1: ECONOMIC AFFAIRS COMMITTEE

The members of the Select Committee which conducted this inquiry were:

† Lord Elder
Lord Goodhart
Lord Kingsdown
Lord Lamont of Lerwick
Lord Lawson of Blaby
Lord Layard
Lord Macdonald of Tradeston
† Lord Marsh
⋆ Lord Paul
⋆ Lord Powell of Bayswater
Lord Sheldon
Lord Sheppard of Didgemere
Lord Skidelsky
Lord Vallance of Tummel
Lord Wakeham

† until 11 April 2005
⋆ since 6 June 2005

The Committee records its appreciation to Professor David Pearce OBE, Emeritus Professor, University College London, for his work as Specialist Adviser for the inquiry.

Declaration of Interests

Lord Elder
Consultant, First Group plc
Consultant, Forth Ports Plc
Consultant, The Smith Institute
Adviser to Daval International Ltd
Chancellor, Al-Maktoum Institute for Arabic and Islamic Studies
Member of the Action Committee for the Scottish National Photography Centre

Lord Goodhart
Vice President, International Commission of Jurists
Trustee, Fair Trials Abroad
Vice Chair of Council, JUSTICE

Lord Kingsdown
38 acres of woodland in North Kent
President, Canterbury Cathedral Trust
Chairman, Canterbury Cathedral Council
President, Kent County Agricultural Society
Trustee, Leeds Castle, Maidstone, Kent
Honorary Trustee, Royal Agricultural Society of England
Trustee, East Malling Trust for Horticultural Research
Emeritus Trustee, Royal Academy of Arts

Lord Lamont of Lerwick

Consultant, Rotch Property Group
Consultant, Fintrade
Stanley Leisure plc
Chairman, East European Food Fund (Investment Fund)
Director, Anglo-Arabian Projects Limited
Director, Balli Group plc (steel and commodity trading house)
Director, Compagnie Internationale de Participations Bancaires et Financieres (Investment Company)
Director, European Growth and Income Trust (Investment Trust)
Director, Jupiter Finance and Income Trust (Investment Trust)
Director, Scottish Annuity and Life Holdings (Reinsurance Company)
Director, RAB Capital plc
Member of the Advisory Board, MerchantBridge & Co
Secretary and office at Balli plc (steel and commodity trading house) (Secretary primarily business and personal but some parliamentary work)
Chairman, Le Cercle
Chairman, British Iranian Chamber of Commerce
President, British Romanian Chamber of Commerce
Co-Chairman, Bruges Group

Lord Lawson of Blaby

Chairman, Central Europe Trust Co Ltd (Advisory and private equity)
Shareholding in Central Europe Trust Company Limited
Member of Governing Body of Westminster School

Lord Layard

Non-executive Director, Firebird New Russia Fund Ltd
Director, Well-being Programme, Centre for Economic Performance, London School of Economics
House in Chalk Farm, London NW3 and house in Cornwall

Lord Macdonald of Tradeston

Senior Advisor, Macquarie Bank Ltd (which manages and invests in infrastructure assets across communications, transport and utility sectors, including renewable energy)
Member, Fabian Society

Lord Marsh

Senior European Consultant, Taisei Corporation, Tokyo, Japan
Chairman, The Income & Growth Trust (a quoted split capital investment trust)

Lord Paul

Chairman and Director, Caparo Group Ltd
Board Member, London Development Agency
Visit to Scotland (16-17 June 2004) to view various power facilities as a delegate with the Parliamentary Group for Energy Studies
Caparo Group Ltd (Lord Paul, Hon.Ambar Paul, Hon. Akash Paul and Hon. Angad Paul are jointly interested in the whole of the issued share capital of the Company through shareholdings registered in the name of Caparo International Corporation, a Company registered in the British Virgin Islands)
Caparo Group, through its subsidiary Caparo plc, has a 35.5% interest in Core Growth Capital LLP, which manages two venture capital trusts, Core VCTI and Core VCTII plc

Chancellor of the University of Wolverhampton
Member of the DTI Industrial Development Advisory Board
Member of the Corporation of the Hall of Arts and Sciences
Advisory Board Member, Foreign Policy Centre
Member of the Board of London 2012
Non-executive Director, London 2012 Ethics Advisory Group
Director, Parliamentary Broadcasting Unit Limit
Vice President, Engineering Employers' Federation
Co-Chairman, Associated Parliamentary Manufacturing Industry Group
Chairman of the Board of PiggyBankKids (a children's charity) and its trading subsidiary PiggyBankKids Projects Limited
Trustee, Ambika Paul Foundation
President, Family Service Units
Patron, Plan International
Patron, UK Youth

Lord Powell of Bayswater

Adviser to Eastern Star Publications
Adviser to the Chairman of BAe Systems
Chairman, LVMH (Moet-Hennessy Louis Vuitton) UK
Chairman, Sagitta Asset Management Limited
Director, British Mediterranean Airways
Director, Caterpillar Inc
Director, Financière Agache
Director, LVMH (Moet-Hennessy Louis Vuitton)
Director, Mandarin Oriental Hotel Group
Director, Matheson & Co
Director, Textron Corporation
Director, Yell Group Limited
Director, Schindler Holdings, Switzerland
Director, Northern Trust Global Services
Member, Barrick Gold International Advisory Board
Member, Diligence Advisory Board
Chairman, GEMS Private Equity Fund Advisory Board
Member, Rolls-Royce European Strategy Board
Member, Textron International Advisory Council
Member, Wingate Capital International Advisory Board
Member, International Advisory Board of Magna Corporation
Member, the Advisory Board of the European Advisory Group GMBH
Member, Advisory Board of Thales UK (15 September 2004)
Member, Advisory Board of Alfa Capital (15 September 2004)
Chairman, Trustees of the Said Business School Foundation, Oxford University
Trustee, Aspen Institute (USA)
Trustee, British Museum
Chairman, Atlantic Partnership
Director, Singapore Millennium Foundation
Director, UK-China Forum
President, China-Britain Business Council
Trustee, Karim Rida Said Foundation

Lord Sheldon

Tonrose Ltd (textile distribution)
Trustee, Sheldon Group Pension Fund

Lord Sheppard of Didgemere

Didgemere Consultants Ltd
Non-executive Chairman, McBride plc (household and personal care products)
Non-executive Chairman, Unipart Group (automotive, rail, telecommunication, logistics etc)
Non-executive Chairman, One-Click HR plc (HR software etc)
Non-executive Director, Nyne Ltd (investor group) (currently not directly remunerated)
Non-executive Chairman, Global Tote Ltd (Satellite transmission services to Russia and Eastern Europe)
Non-executive Chairman, Namibian Resources Ltd (Diamond Mining)
Didgemere Consultants Ltd (business Advisory service)
Didgemere Farms Ltd (farming)
McBride plc (household and personal care products) (shareholding with a nominal value of over £50,000)
One-ClickHR plc (human resources management systems) (shareholding of more than 5% of issued share capital of the company)
DeltaDot Limited (an unquoted biotechnology) (shareholding of more than 5% of issued share capital of the company)
Namibian Resources Ltd
Farmland in Essex
Chancellor, Middlesex University
Hon. Fellow, Governor, London School of Economics
President, London First
Director, East London Business Alliance
Director, Central London Partnership
Director, London Business Board (London First/London Chamber/London CBI)
Vice President, Beer and Pub Association (formerly Brewers Society)
Member of the Various Professional Bodies (accountants etc)
Hon. Doctorate/Hon Fellow of various universities
Member, Protection of Roydon and Area (PORA) Committee
Vice President (formerly Appeal Chairman for 'Sheppard House') of Blue Cross (animal/peoples charity for pets of those unable - for reasons of health, etc - to pay vet fees)
Vice President United Response (charity for people with learning difficulties)
Fellow, Animal Health Trust
Member, UK Cancer Research Charity
Vice President, (past Chairman) Business in the Community
Past Chairman, The Prince's Trust (and Prince's Youth Business Trust) (now only infrequently involved)
Chairman of Trustees, Civilians Remembered Trust (Trust developing memorial park, etc for 60,000-plus civilians killed by bombing in 1939-45 war)
Patron of Trees for Cities

Lord Skidelsky

Non-executive Director, Janus Capital Group
Director, Transnational Insights
Non-executive Director, Greater Europe Fund
Professor of Political Economy, Warwick University, Department of Economics
Transnational Insights Ltd (100% of stock)

Governing Body, Brighton College
Member, Advisory Council, Wilton Park
Chairman, The Centre for Global Studies
Director, Moscow School of Political Studies

Lord Vallance of Tummel

Vice Chairman, Royal Bank of Scotland Group (served on the board in the early stages of the inquiry)
Member, Supervisory Board Siemens AG (engineering and services)
Director (Chairman), Nations Healthcare Ltd
International Advisory Board, Allianz AG (insurance)
European Advisory Council, Rothschild et cie (investment banking
Advisor, Amsphere Ltd (computing services)
Advisor, Postmasternet Ltd (retail services for postmasters)
425,000 shares in De Facto 479 Ltd (family owned investment company)
Wife is a member of the Committee on Standards in Public Life
Honorary Governor, Glasgow Academy
Honorary Fellow, Brasenose College, Oxford
Honorary Fellow, London Business School
Chairman, European Services Forum
Vice President, Princess Royal Trust for Carers

Lord Wakeham

Advisory Board, LEK Consultancy
Chairman, Genner Holdings plc
Genner Holdings Ltd (Investment Company)
Genner Farms Ltd (small family company)
Chairman of Governors, Cothill House
Chairman, Alexandra Rose Day
Chancellor, Brunel University
Deputy Lieutenant for Hampshire
Governor, Sutton's Hospital, Charterhouse
Justice of the Peace, Inner London Commission (Non-active)
Member of Council, St. Swithun's School
President, Brendoncare Foundation
Trustee, H.M.S. Warrior 1860
Trustee, Carlton Club

APPENDIX 2: LIST OF WITNESSES

The following witnesses gave evidence. Those marked ⋆ also gave oral evidence.

⋆ Professor Dennis Anderson, Imperial College

⋆ Dr Terry Barker, Cambridge University

Mr Christopher Beauman, former adviser, Cabinet Office

BP

Dr Leonard Brookes, Fellow of the Energy Institute

Sir Ian Byatt

Dr Ian Castles, Australian National University, Canberra

CSERGE (the Centre for Social and Economic Research on the Global Environment)

⋆ Department for Environment, Food and Rural Affairs (Defra)

⋆ Professor Paul Ekins, Policy Studies Institute

George C Marshall Institute, Washington DC

Dr Indur M Goklany

⋆ Professor Michael Grubb, Imperial College

⋆ Dr Dieter Helm, New College, Oxford

Dr Cameron Hepburn, St High's College, University of Oxford

⋆ Professor David Henderson, Westminster Business School

Mr David Holland, MIEE

⋆ Dr Chris Hope, University of Cambridge

⋆ Sir John Houghton

International Council for Capital Formation (ICCF)

International Policy Network

⋆ Sir David King, Chief Scientific Adviser to the UK Government

⋆ Professor Richard Lindzen, Massachusetts Institute of Technology

⋆ Professor Bjorn Lomborg, University of Aarhus

Professor Angus Maddison

Dr David Maddison, University College London

Professor Ross McKitrick, University of Guelph, Canada

Professor Robert Mendelsohn, Yale University

Professor Nils-Axel Morner, Stockholm University

Professor Julian Morris, University of Buckingham

⋆ Professor Nebojsa Nakicenovic, , IIASA and Vienna University

⋆ Dr R Pachauri, Chairman, IPCC

Dr Peter Read

Professor Paul Reiter, Institut Pasteur, Paris

Research Councils UK

* Professor Colin Robinson, University of Surrey

Ms Rosemary Righter, The Times

The Royal Society

Professor S Fred Singer, University of Virginia

* Professor Richard Tol, University of Hamburg

* Mr Paul Johnson, HM Treasury

* Mr Adair Turner

Tyndall Centre for Climate Change Research

Evidence received by the Committee but not printed can be inspected in the House of Lords Record Office (020-7219 2333), e-mail hlro@parliament.uk

APPENDIX 3: CALL FOR EVIDENCE

The Economic Affairs Committee has decided to conduct an inquiry into 'Aspects of the Economics of Climate Change'.

Evidence is invited by 31 March 2005. The Committee will welcome written submissions on any or all of the issues set out below.

Following the recent ratification of the Kyoto Protocol, the Committee has decided to inquire first into the ways in which the problem of climate change has been assessed.

- How are the current estimates of the scale of climate change damage derived?
- How far do the estimates of damage depend on assumptions about future global economic growth, and how valid are those growth assumptions?
- How does uncertainty about the scale of the problem and its impact affect the economics of climate change?

The Committee will also inquire into the key role of the Intergovernmental Panel on Climate Change in compiling and assessing technical information on climate change.

- What has been the approach within the IPCC to the economic aspects of climate change, and how satisfactory has it been?
- Is there sufficient collaboration between scientific and economic research?
- Could IPCC member governments, and the UK in particular, do more in future to contribute to the robustness of the economic analysis?

The Committee then plans to go on to consider the question of who bears the brunt of climate change and of the costs of controlling it.

- In monetary terms, the impact of change and the costs of control may be greater in rich countries than poor ones. But is this an adequate measure?
- What would be the relative costs and benefits of using resources, otherwise expected to be allocated to climate change control, instead to expand international development assistance?
- When are damages likely to occur and how satisfactory is the economic approach to dealing with costs and benefits that are distant in time?
- What other associated benefits might there be from reducing greenhouse gas emissions?

At this stage the Committee does not intend to investigate the comparative merits of different policies for the control of climate change.

APPENDIX 4: GLOSSARY

BAU	'business as usual' – usually of a scenario that involves no policy changes
Biofuels	fuels based on biomass, e.g. wood
C	carbon (one tonne carbon = 3.67 tonnes CO_2)
C_2F_6	perfluoroethane, a greenhouse gas
CCS	carbon capture and storage
CDM	Clean Development Mechanism: process under the Kyoto Protocol whereby one country can pay for emissions reductions in a developing country and collect the 'credit' for the reduction
CF_4	perfluoromethane, a greenhouse gas
CH_4	methane (natural gas), a greenhouse gas
c/kWh	(US) cents per kilowatt hour
Concentrations	Concentrations of greenhouse gases in the atmosphere
Convergence	View that per capita real incomes in rich and poor countries will converge to the same level at some time in the future
CO_2	carbon dioxide, the main greenhouse gas
Defra	Department of the Environment, Food and Rural Affairs
$/GJ	(US) dollars per gigajoule
DTI	Department of Trade and Industry
Emissions	Emissions of greenhouse gases, mainly from the combustion of fossil fuels and burning of forests
Equity weighting	Procedure for adjusting economic costs and benefits to reflect their relative importance to different income levels.
FSU	Former Soviet Union
GCM	global circulation model
GDP	Gross Domestic Product (measure of a nation's economic output)
GNP	Gross National Product (= GDP + net property income from abroad)
GHGs	greenhouse gases
GJ	gigajoule = one billion joules
GtC	gigatonnes of carbon (one gigatonne = 1 billion (10^9) tonnes of carbon
Hockey stick	figurative name for the suggested time-profile of temperature change over long periods of time – fairly constant until the 19th century with a sharp upturn thereafter (the blade of the stick).

IAM	Integrated Assessment Model – a model combining a simplified form of a climate model and a model of the global economic system
IEA	International Energy Agency
Insolation	incoming solar radiation
IPCC	(United Nations) Intergovernmental Panel on Climate Change
kWh	kilowatt hour
kWh/m^2	kilowatt hours per square metre
Kyoto Protocol	first protocol (1997 ratified 2005) to the UN Framework Convention on Climate Change (1992) setting GHG emission reduction targets for industrialised nations
Land use change	alteration of land uses such that carbon emissions (especially) are likely to change, e.g. conversion of forest to agriculture
MARKAL	a computerised model integrating energy and economic magnitudes
MER	market exchange rate
MtC	million tonnes of carbon
NG	natural gas
NG/CC	natural gas combined cycle
N_2O	nitrous oxide, a greenhouse gas
Nuclear fusion	possible future form of nuclear power, based on a nuclear reaction in which atomic nuclei of low atomic number fuse to form a heavier nucleus with the release of energy
ppm	parts per million (a measure of atmospheric concentration)
PPP	purchasing power parity exchange rate
Proxy measure	(in the current context) a measure of temperature that is not derived from direct observation via thermometers, e.g. tree rings, ice cores
PV	present discounted value
PV	photovoltaic
R & D	Research and Development
SF_6	sulphur hexafluoride, a greenhouse gas
SRES	(IPCC) Special Report on Emission Scenarios
tC	tonne of carbon
tCO_2	tonne of carbon dioxide
THC	ocean thermohaline circulation (deep ocean currents)
WTO	World Trade Organisation