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Waste or resource? Stimulating a bioeconomy

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CONTENTS

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References in footnotes to the Report are as follows:
Q refers to a question in oral evidence;
Witness names without a question reference refer to written evidence

SUMMARY

The UK produces almost 300 million tonnes of waste every year.[1] This tonnage is roughly equivalent to that of 200 million cars, over six times the total number of cars in the UK. Waste takes many forms, from household food, to building materials, to gases emitted from factory chimneys. Waste is managed in accordance with a 'waste hierarchy' which prioritises waste prevention, followed by re-use, recycling, recovery and disposal. Much of the household waste produced in the UK is still put into landfill or incinerated (57%).[2] While preventing the creation of waste in the first place is a laudable policy goal, it is inevitable that there will always be waste—or unavoidable by-products—such as orange peel, coffee grounds or waste gas from factories and power stations.

Science and technology can be deployed in order to transform certain kinds of waste into useful and valuable products. These include lower value products such as heat and power through to chemicals, pharmaceuticals, fragrances, bio-plastics and aviation fuels of higher value. This inquiry investigated the science and technology underpinning the transformation of carbon-containing waste into useful and high value products, and assessed the economic and environmental opportunities for the UK, the potential scale of this bioeconomy and the role of Government. It is important to note, however, that some waste has valid existing uses and should not necessarily be diverted into a high value bioeconomy; the spreading of manure to land, for example, is an important way of returning nutrients to the soil.

We conclude that the economic and environmental opportunities presented by exploiting carbon-containing waste as a resource and feedstock are substantial. Companies in the UK are already starting to exploit carbon-containing waste as a resource. We heard, however, that measures could be taken both to remove barriers and to facilitate the growth of this industry. The Government, we conclude, is not sufficiently seized of the potential economic prize for the UK. Waste policy is often framed in environmental terms, and while we do not diminish environmental considerations, it is the considerable economic benefits that we stress in this report. The crucial point is that environmental and economic imperatives need not be seen to be in conflict.

We argue in this report that a clear, long-term strategy and stable policy environment is needed to encourage and stimulate the waste-based bioeconomy. There is a lack of a clear lead within Government, with responsibilities spread across several Government departments, and inadequate coordination and cohesion. We therefore recommend that a Minister in the Department for Business, Innovation and Skills (BIS) is given responsibility for the development of a waste-based, high value bioeconomy. The Minister should be a champion for waste as a resource and should coordinate activities across Government. He or she should ensure that a long-term plan, with at least a 15 year horizon, is produced in order to support the development of a high value waste-based bioeconomy.

1 Total waste managed in the UK in 2010 was 286 million tonnes (Defra).

2 Waste and Resources Action Programme (WRAP).

To this end, we heard evidence that access to waste resources must be improved. This includes ensuring waste is collected and treated in a way that maximises its value as a resource. Furthermore, action is required to enable far greater understanding of waste streams so that potential investors can easily obtain a clear picture of how waste can be located and used efficiently.

Reducing the risk of investment in this emerging industry is also essential. Pre-market demonstration facilities are crucial in this regard, and open access facilities have been installed in the High Value Manufacturing Catapult in Teesside over the last two to four years. The Government should, however, regularly review whether the UK has sufficient facilities to support scale up and commercialisation.

Waste or resource? Stimulating a bioeconomy

CHAPTER 1: INTRODUCTION

1. There has been no shortage of studies into waste over recent years. Indeed, this Committee conducted an extensive inquiry into waste reduction in 2007–08.[3] The House of Lords EU Agriculture, Fisheries, Environment and Energy Sub-Committee will shortly report following an inquiry into food waste prevention. In our inquiry, however, we focused very specifically, not on preventing and reducing waste, but on exploring how unavoidable waste can be transformed into useful, high value products and contribute to a bioeconomy.

2. The term bioeconomy has been widely used in international policy and has been defined in several different ways.[4] In this report, 'bioeconomy' describes the use of biological feedstocks,[5] or processes involving biotechnology, to generate economic outputs in the form of energy, materials or chemicals. The growth of a bioeconomy is underpinned by new technologies. This enables the use of a wider range of feedstocks, reducing dependence on non-renewable feedstocks, including fossil fuels.

3. A bioeconomy can make use of a range of feedstocks, including crops grown specifically for this purpose. This inquiry, however, looked specifically at the use of carbon-containing wastes as a feedstock for a bioeconomy. Carbon-containing wastes include bio-waste or organic wastes such as food, agricultural and forest residues, as well as sewage sludge.[6] It also includes plastics and waste gases from industrial processes or landfill sites. In this report, the term 'waste' therefore refers to bio-waste, waste gases[7] and materials such as plastics that contain carbon.[8] For short-hand we refer to the waste-streams included in our investigation, which could be used as a resource, as 'carbon-containing waste.'

4. We considered by-products and co-products as part of the inquiry. Co-products and by-products may be generated alongside the main product, but are not waste as they have an established use. An example of a co-product is spent grain from brewing where it is used as animal feed. Examples of by-

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3 House of Lords Science and Technology Committee, *Waste Reduction*, (6th Report of Session 2007–08, HL 163). Available online: http://www.publications.parliament.uk/pa/ld200708/ldselect/ldsctech/163/163.pdf.

4 OECD (2009) The Bioeconomy to 2030: Designing a Policy Agenda; European Commission (2013) Innovating for Sustainable Growth: A Bioeconomy for Europe; The Whitehouse (2012) National Bioeconomy Blueprint; Federal Ministry for Research and Education (2011) National Research Strategy Bioeconomy 2030; Schmid et al. (2012) 'The Bio-Economy Concept and Knowledge Base in a Public Goods and Farmer Perspective'. Bio-based and Applied Economics 1(1): 47–63.

5 A feedstock is a raw material which can be used to supply a manufacturing process.

6 The 'Circular Economy' uses the term 'biological nutrients.' e.g. The Ellen MacArthur Foundation (2013) *Towards the Circular Economy*. Volume 1.

7 Other non-carbon containing gases, such as hydrogen, may also be used as feedstocks for a bioeconomy.

8 Although minerals such as calcium carbonate also contain carbon, we did not include them in the scope of our inquiry.

products might be straw and tallow generated in food production, but this will depend on the market opportunity. Put simply:

> "A waste is something that costs you money to have taken away, a by-product is more or less cash neutral to your business, and a co-product is something that contributes profit to profitability."[9]

5. In some cases, new technologies will make it possible to divert by-products and co-products into higher value uses. Careful consideration must be given to the environmental impacts of diverting by-products and co-products from an existing use. In some cases, however, there will be both economic and environmental benefits. Using new technologies, wastes may become by-products and by-products become co-products.

6. In terms of the legislative framework for waste policy, there are several EU Directives relating to waste that have been transposed into national legislation. The Waste Framework Directive[10] and the Landfill Directive[11] are most relevant to this inquiry. The Waste Framework Directive defines waste as any substance or object that the holder discards or intends to discard or is required to discard. Once classified as waste, a material must be handled according to specific rules to protect human health and the environment. The Government works with the Environment Agency to enforce regulation on waste to protect human health and the environment. The Waste Framework Directive sets out the requirement to manage waste in accordance with a 'waste hierarchy'. The hierarchy affords top priority to waste prevention, followed by preparing for re-use, then recycling, other types of recovery (including energy recovery), and last of all disposal (e.g. landfill).

7. Government policy focuses on meeting the requirements of the EU Directives which are transposed into domestic law. Waste policy is devolved, meaning that each part of the UK is responsible for establishing its own policies. These are set out in *Government Review of Waste Policy in England 2011*,[12] Scotland's *Zero Waste Plan*,[13] Wales' *Towards Zero Waste*[14] and Northern Ireland's *Delivering Resource Efficiency*.[15] All four administrations provide funding to, and work with, the Waste and Resources Action Programme (WRAP). WRAP is a not for profit, private company with responsibilities for delivering the UK governments' policies on waste and resource efficiency.

8. The EU Waste Framework Directive sets a target that by 2020 50% of waste from households should be recycled. The EU Landfill Directive sets out measures to control and disincentivise the disposal of waste, requiring Member States to reduce landfill of biodegradable municipal waste. By 2016, the amount of biodegradable municipal waste sent to landfill should be reduced to 35% of the 1995 amounts. Historically, the UK has relied more heavily on landfill than many of its European counterparts. Although the UK

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9 Q 83 (Professor Murphy).

10 See: https://www.gov.uk/waste-legislation-and-regulations.

11 See: https://www.gov.uk/government/publications/environmental-permitting-guidance-the-landfill-directive.

12 See: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69401/pb13540-waste-policy-review110614.pdf.

13 See: http://www.scotland.gov.uk/Resource/Doc/314168/0099749.pdf.

14 See: http://wales.gov.uk/docs/desh/publications/100621wastetowardszeroen.pdf.

15 See: http://www.doeni.gov.uk/wms_2013.pdf.

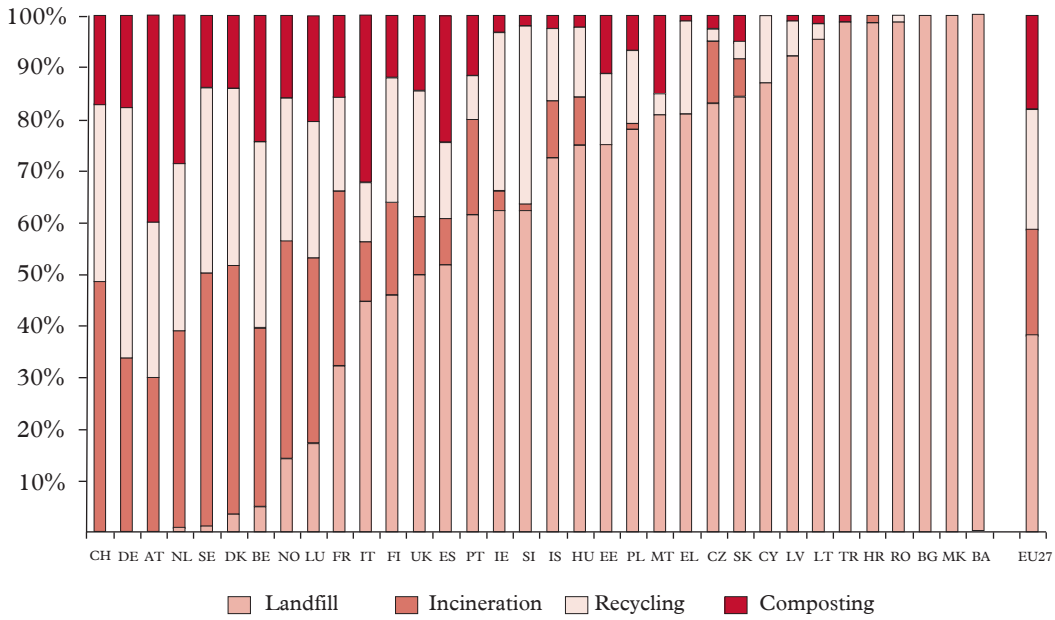
is meeting its targets, it continues to lag behind some other European countries:

> "Some Member States, such as Germany and the Netherlands, have virtually stopped using landfill to dispose of waste and now recycle, compost or incinerate all but a very small fraction of their household waste."[16]

Figure 1 shows that European countries which have successfully eliminated the landfill of all types of municipal waste treat their waste through a combination of incineration, recycling and composting.

FIGURE 1

Municipal waste treatment, Europe 2009



(Eurostat, 2011) Treatment of municipal waste (mixed waste, including biodegradable waste, produced by households and similar sources and collected by, or on behalf of, municipal authorities)

9. Although the UK is sending more waste to landfill than some of its European neighbours, this may, perversely, represent an opportunity; the UK's current reliance on landfill means that there is a gap in the provision of infrastructure for handling waste. This could be a strength in enabling the future development of a high value bioeconomy—the UK needs to find ways of diverting carbon-containing waste from landfill and could achieve this by putting in place facilities and processes which extract maximum value from it. With this proposition in mind, we set out to try and answer the following questions:

- Does it make economic sense to try to generate useful, high value products from carbon-containing wastes?
- Does it make environmental sense?
- What is the scale of the opportunity?
- What are the barriers facing industry?
- What is the Government's role?

16 WRAP.

10. This report first of all sets the context for our analysis by describing the concept of a bioeconomy and establishing the sources of waste, the types of waste and how waste is treated in the UK. We then assess the economic and environmental opportunities at stake. Chapter 3 explores the key issues that need to be addressed to enable a high value waste-based bioeconomy to develop.

11. Waste is a policy area rich in jargon and acronyms. What is more, it touches on a range of complex scientific processes. At the outset of this report, we hope the following box of explanatory terms is helpful.

BOX 1

Definitions

Anaerobic digestion: AD is a natural process in which microorganisms break down organic matter (carbon-containing molecules), in the absence of oxygen, into biogas (a mixture of carbon dioxide [CO_2] and methane [CH_4]) and digestate (a nitrogen-rich residue, which can be used as fertiliser).[17]

Chemicals:

- **Commodity** chemicals are commercially produced in high tonnage quantities.
- **Fine** chemicals are produced industrially in relatively small quantities and with a high purity; e.g. dyes and drugs.[18]
- **Speciality** chemicals are made in very low quantities compared to commodity chemicals, are generally of high price, but have specific effects or properties not shared with others.

Fermentation: the biochemical pathway in which organic compounds are broken down enzymatically in the absence of oxygen.[19]

Gasification and pyrolysis: high temperature treatments of carbon containing waste, without allowing enough oxygen for complete combustion. Municipal waste, commercial and industrial waste and refuse derived fuel or solid recovered fuel can be used as feedstocks. Gasification uses temperatures of >700°C and a controlled amount of oxygen. Pyrolysis uses temperatures of around 500°C in the absence of oxygen. Products from these processes include syngas, oil and a solid residue or char.[20]

Refuse derived fuel: RDF is a crude fuel, subjected to low levels of treatment in order to ensure it is no longer classified as solid mixed waste, and to marginally improve its fuel status. It does not function as a fossil fuel replacement due to its low calorific value and variable composition.[21]

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17 Defra (2011) *Anaerobic Digestion Strategy and Action Plan*.

18 Oxford University Press (2008) *Oxford Dictionary of Chemistry*.

19 Chambers Harrap Publishers Ltd. (1999*) Chambers Dictionary of Science and Technology.*

20 See: CIWM website http://www.ciwm.co.uk/CIWM/InformationCentre/AtoZ/GPages/Gasification.aspx; WRAP (2012) *Energy From Waste Development Guidance*; REA (2011) *Energy from Waste, A Guide For Decision Makers*; Star COLIBRI (2011) *European Biorefinery Joint Strategic Research Roadmap*.

21 See: Environment Agency website http://www.environment-agency.gov.uk; Associate Parliamentary Sustainable Resource Group (2013) *Exporting Opportunity*.

Solid recovered fuel: SRF is a refined fuel meeting a defined specification. Functions as a fossil-fuel replacement in many applications.[22]

Syngas: 'synthetic gas', produced by gasification and pyrolysis. Syngas typically contains carbon monoxide [CO], hydrogen [H_2] and methane [CH_4]. It can be purified to produce biomethane and hydrogen, or used as a feedstock to generate higher value products.

Synthetic biology: aims to design and engineer biologically based parts, novel devices and systems as well as redesigning existing, natural biological systems.[23]

12. We would like to thank everyone who gave evidence to us, both at oral evidence sessions, which we held in the autumn of 2013 and early 2014, and in writing. We also wish to thank our Specialist Adviser, Mr Ian Shott CBE FREng, whose expertise assisted our work greatly.

[22] European Recovered Fuel Organisation website http://erfo.info/SRF.67.0.html; Associate Parliamentary Sustainable Resource Group (2013) *Exporting Opportunity*.

[23] The Royal Academy of Engineering (2009) *Synthetic Biology: scope, applications and implications*.

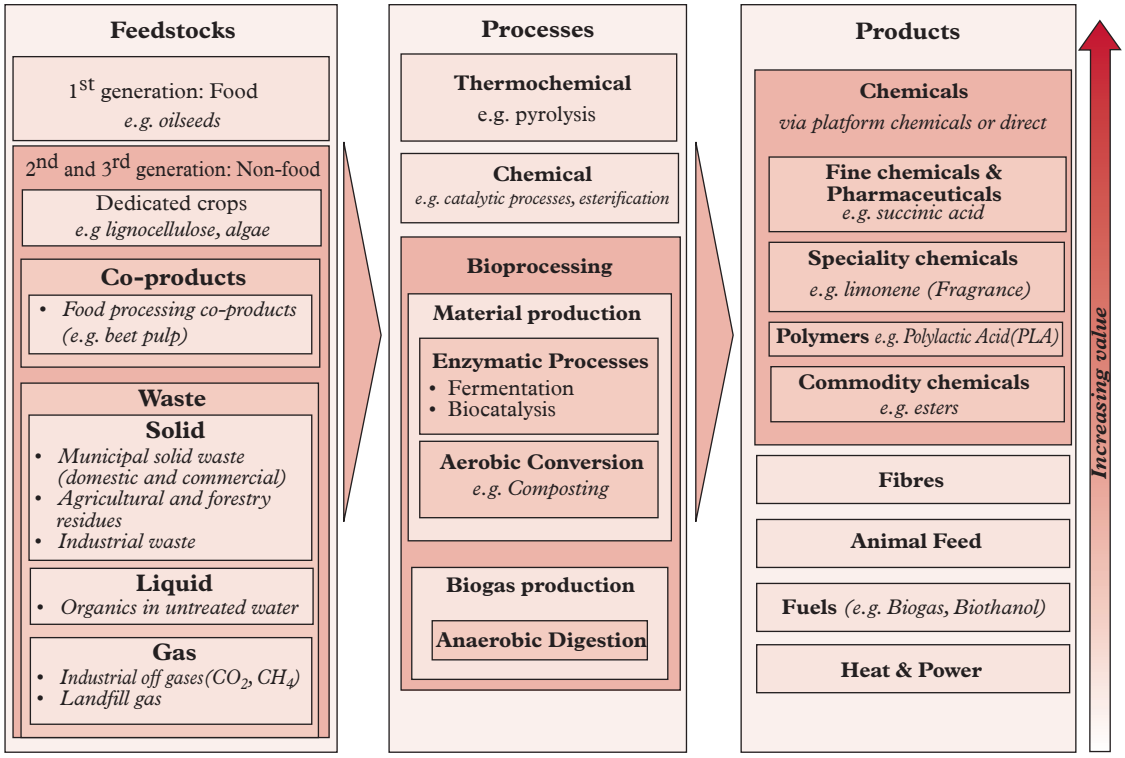
CHAPTER 2: THE OPPORTUNITY

A Bioeconomy

13. A bioeconomy can make use of a range of feedstocks and use different processes to convert these feedstocks into a wide variety of different products. Examples of the wide range of feedstocks, products and processes involved in a bioeconomy are provided in Figure 2.

FIGURE 2

Feedstocks, processes and products in a bioeconomy



This sets out what is put into the bioeconomy (the feedstock) what is done with it (the process) and what comes out at the other end (the product). The diagram divides ***feedstocks*** *into two major catagories: 'first generation,' and 'second and third generation.' This is because the science was initially developed using 'first generation' feedstocks, containing easy to access carbon. These feedstocks were predominantly food crops, such as oilseeds or sugar beet. 'Second and third generation' feedstocks contain carbon which is more difficult to access or make use of. Such feedstocks include dedicated non-food crops (such as willow or algae), co-products (or by-products - which are usually formed at any stage of processing and are not explicitly identified in the figure) and waste. Only co-products, by-products and waste are included within the scope of this inquiry. Although agricultural and forestry residues are shown as a waste within the figure, it is important to note that in many cases they have an existing use and should therefore be classified as a co-product or by-product. Liquid waste comprises organics in untreated water, particularly the organic fraction of sewage sludge in municipal waste water treatment and other waste streams such as those from the food processing industry. Three main types of* ***processes*** *are illustrated in the diagram: thermochemical, chemical and bioprocessing. Bioprocessing can produce materials through enzymatic processes or aerobic conversion or it can produce biogas through anaerobic digestion.* ***Products*** *are illustrated in the figure in order of increasing value, with the lowest value at the bottom of the column. Chemicals are at the top end of the value chain. Some processes will result in the direct production of the desired chemical product. In other cases there is an intermediate step, where a platform chemical is produced, which is then converted into the desired product. Chemical products include fine chemicals and pharmaceuticals, speciality chemicals, polymers and commodity chemicals. This figure was provided by A.D. Little.*

Feedstocks

14. Waste has the potential to provide an important feedstock for the bioeconomy. We heard that:

> "Waste biorefining has the potential to completely eliminate the competition for land that is inherent in the use of most other feedstocks, such as food crops. This may result in waste becoming the most sustainable feedstock of all."[24]

15. Whilst this may be an optimistic view, waste can certainly make an important contribution to fuelling a bioeconomy, and can therefore be transformed from a problem into a resource. As set out in Figure 2 above, carbon-containing wastes come in different forms and from different sources. This includes municipal solid waste, which is the 'black bin bag waste,' from households and similar sources, which is collected by municipal authorities. It also includes a proportion of commercial and industrial waste and construction and demolition waste, which is collected separately by specialist firms.

16. There are mixed waste streams and also segregated wastes, such as food waste and green waste from parks and gardens. Food supply chain wastes such as potato peelings, pea pods or orange peel provide particularly good sources of feedstock for a bioeconomy as they have a consistent composition.[25] The generation of wastes such as these are unavoidable, and yet we were told that they can provide a rich source of valuable chemicals. Agricultural residues, forestry residues and liquid wastes such as sewage sludge can also provide feedstocks for a bioeconomy. Finally, gases like carbon monoxide, carbon dioxide and hydrogen, which would usually be emitted to the atmosphere or burnt, can be captured and used as a feedstock for the bioeconomy. These gases are emitted from industrial processes, such as from steel mills, oil refineries or natural gas extraction.[26] Large amounts of methane are produced from managed landfill sites.[27] Paragraphs 28 to 41 provide further information on the types and quantities of waste available.

Processes

17. A range of processes can be used to transform wastes into useful products. Rather than using fossil fuels as a source of carbon, waste can be used instead. The carbon in waste, however, is present in a less easily accessible form. It is usually necessary to begin by breaking the carbon in solid and liquid wastes down into simpler molecules. This can be done using high temperature, thermochemical processes, using chemical processes, or using biological processes (Figure 2 above). Although many different processes have been developed, it can be challenging to ensure that the feedstock-process-product combination represents an economically and environmentally viable proposition.

18. Thermochemical processes, such as pyrolysis and gasification, involve heating municipal waste or biomass residues to high temperatures to produce

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24 Dr Philp, OECD (acting in a personal capacity).

25 IBLF, Q 67 (Professor Clark, University of York Green Chemistry Centre).

26 LanzaTech, Virgin Atlantic, Dr Philp, Q 16 (Professor Tucker).

27 LanzaTech, Government supplementary evidence.

'syngas,' a mixture of methane, hydrogen and carbon monoxide. This gas can be burnt to generate energy, cleaned up and injected into the gas grid, or used as a feedstock for further reactions to generate fuels or other chemicals.[28]

19. As an alternative to high temperatures, catalysts or enzymes can be used in reactions to transform the carbon in waste into sugars and then into useful chemicals. Biological processes, which make use of the ability of microbes to digest complex molecules and create chemicals, can also be used. Biological processes include fermentation and anaerobic digestion. In some cases the microbes used in these processes can be found in nature. In other cases, synthetic biology approaches can be used to adapt microbes to undertake a particular function. We heard that there was considerable potential for synthetic biology. By specifically altering the DNA of microbes, it is becoming possible to make use of an increasingly wide range of feedstocks or substrates and to produce valuable chemicals:

> "With the advent of synthetic biology, because the costs now of building genetic material—building DNA—are now much cheaper than they were, we have a great repertoire of potential genes that we can put into the organism chassis to produce these products. For me the trick of this is the A to Z of pulling through the substrate flexibility through the organism chassis and also developing the pathway that will produce the high-value product with the minimum of other contaminant byproducts. The UK research base is superb in terms of how it drives itself."[29]

20. We were informed that microbes can be used to directly fix waste gases (Figure 3 and Box 2) and produce useful chemicals.[30] These gases can be high volume by-products of industrial processes such as steel production. Syngas produced from solid wastes, landfill gases or biogas produced by anaerobic digestion can also provide feedstocks.[31]

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28 Government.

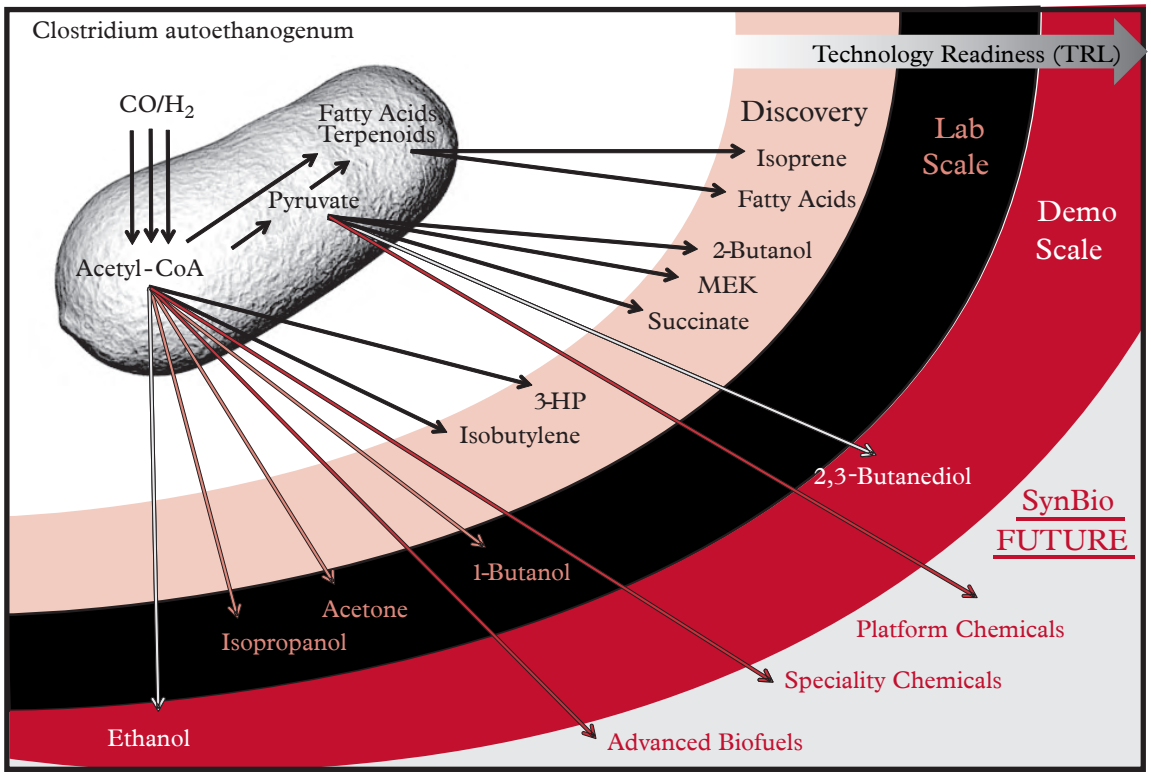
29 Q 45 (Professor Hunter).

30 RCUK, University of Nottingham, LanzaTech, Virgin Atlantic.

31 LanzaTech.

FIGURE 3

Gas fermenting microbes



Gas fermenting microbes, such as Clostridium autoethanogenum, can be used to transform carbon monoxide (CO) and hydrogen (H_2) into useful chemicals. As illustrated in this figure, the microbe transforms CO and H_2 gases into useful chemicals through metabolic pathways, involving the key metabolic intermediates Acetyl Coenzyme A (Acetyl-CoA), pyruvate, as well as fatty acids and terpanoids (secondary metabolites). A range of alcohols such as ethanol and isopropanol or acids such as 3-Hydroxypropionic Acid (3-HP) and succinate are produced at different points of the metabolic pathway. The figure shows the progress of this technology, using C. autoethanogenum, through different Technology Readiness Levels.[32] It is already possible to use this technology to produce ethanol at the pre-commercial, demonstration (demo) scale. Lab-scale production of isopropanol, acetone and 1-butanol is also possible. At the discovery stage, research is underway to produce chemicals such as isobutylene and isoprene. In the future, using synthetic biology, it may be possible to use C. autoethanogenum to directly produce advanced biofuels, speciality chemicals and platform chemicals from waste gases. This figure was provided by LanzaTech.

21. Several of the processes described above are often coupled together to transform waste feedstocks into useful products. Indeed, it has been suggested that there is a need to develop 'green biorefineries,' where processes are brought together, enabling flexibility in the type of feedstock used and generating multiple products in the same way as oil refineries do today (Figure 4):

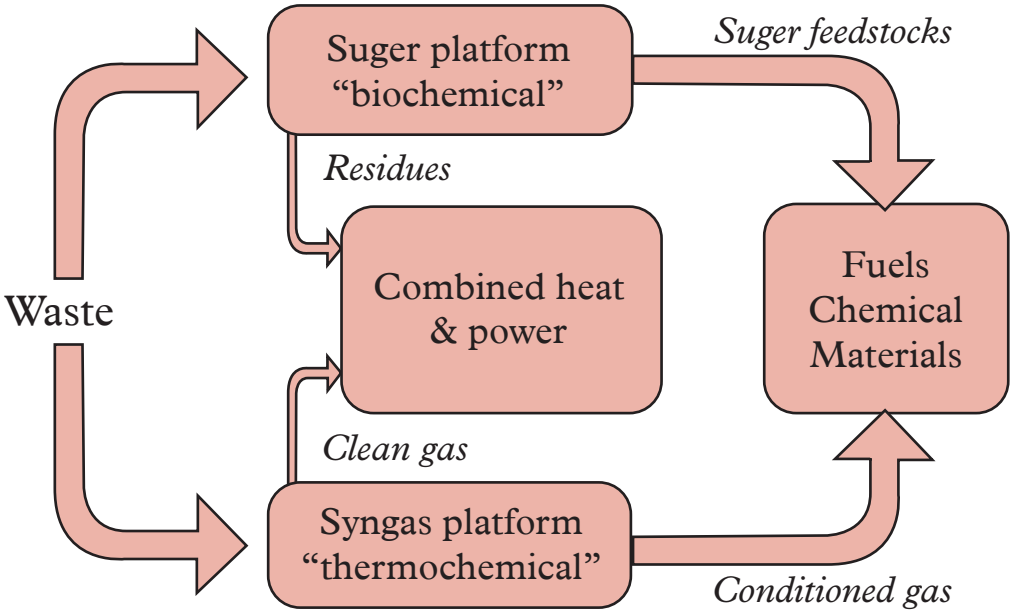
> "The integrated biorefinery would make full use of all the components of multiple feedstocks (particularly cellulosic and waste streams) to produce value-added multiple co-products including energy (electricity and steam) and various bio-based chemicals and plastics, along with

[32] The Technology Readiness Level (TRL) describes the stage of development of a technology from basic idea, through discovery and research, innovation and finally commercialisation. Demonstration scale is a stage immediately prior to commercialisation.

fuel-grade ethanol or other fuels, and perhaps even other products such as paper."[33]

FIGURE 4

The integrated biorefinery concept[34]



Products

22. The processes described above can generate a range of different products. As the Royal Society of Chemistry told us:

> "Sugars, oils and other compounds in bio-waste can be converted into platform chemicals directly. These building block chemicals have a high transformation potential for conversion into new families of useful molecules such as lubricant, flavours, nutriceuticals, solvents, polymers and pharmaceuticals."[35]

23. At the most basic level, gases such as methane, produced from anaerobic digestion, can be combusted to generate heat and power and digestate can be spread to land. Alternatively, methane can be cleaned up to be injected into the gas grid. Methane can also be converted into other products. For example, Calysta Energy told us about their technology which can be used in producing biodegradable plastic from methane, and that, "in the future, we will be able to convert biogas to methanol, a basic chemical building block and also a valuable gasoline additive."[36] This type of technology has the potential to create more valuable products for the bioeconomy.

24. Biofuels for road transport or for aviation can also be produced from waste (Box 2).[37] In addition, bioethanol can be used as a building block to generate other higher value products. We heard that a range of commodity chemicals

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33 Dr Philp, OECD (acting in a personal capacity).

34 The integrated biorefinery concept. See: http://www.nrel.gov/biomass/biorefinery.html.

35 Royal Society of Chemistry.

36 Calysta Energy.

37 INEOS Bio, Virgin Atlantic, British Airways.

could be produced. Green Biologics told us about their technology for transforming household waste into biobutanol, which:

> "… goes into the chemical market. It is a relatively high-value commodity chemical. It forms a precursor for polymers, plastics, paints, coatings in a market worth approximately $6 billion. Also it is a very good advanced biofuel."[38]

BOX 2

Case studies: sustainable aviation fuels—Virgin Atlantic and British Airways

"In October 2011 we [Virgin Atlantic] announced our partnership with LanzaTech to pioneer their ground breaking new technology, to develop the first of the next generation of low carbon fuels. Their technology uses a microbe to convert waste carbon monoxide gases from steel mills (which would otherwise be flared off direct to the atmosphere as CO_2) into ethanol. The alcohol is then converted to jet fuel through a second stage process. Initial Life Cycle Analyses suggest that the resulting biofuel will emit 60% less carbon than the fossil fuel it will replace, kerosene. Moreover, because it uses a waste-stream, it creates a biofuel that does not impact on land use or food production. We're pleased to report that LanzaTech recently secured Roundtable of Sustainable Biomaterial (RSB) approval for the plant in China that will produce our first fuel. RSB is widely agreed to be the gold standard sustainability certification scheme for biofuels. The process is also expected to improve local air quality in the vicinity of steel plants by reducing emissions of nitrogen oxide and other particulate emissions.

The technology is scalable. The first plant in China will produce enough fuel for us to uplift all of our fuel out of Shanghai as a 50:50 mix with kerosene, with plenty left over for other customers. In addition, LanzaTech estimates that its process could apply to 65% of the world's steel mills, offering the potential to provide up to 19% of the world's current jet fuel demand."[39]

"British Airways is working with a US-based technology company to construct a state-of-the-art facility that will convert around 500,000 tonnes of waste normally destined for landfill—into 50,000 tonnes of sustainable low-carbon jet fuel, 50,000 tonnes of biodiesel and 20,000 tonnes of bio-naphtha per annum. The plant itself will be powered by the waste feedstock. The work on the detailed plant design is about to commence and we expect construction to begin in early 2015 …

The Solena Greensky project intends to use residual waste that has been processed via Mechanical and Biological Treatment (MBT) from the South East of England. Solena's plasma technology is feedstock flexible and can take a wide variety of materials, including waste agricultural material, waste wood etc. However, economics favour the use of residual materials that would otherwise be destined to go to landfill or incineration …

The use of residual wastes yields very high greenhouse gas lifecycle savings and avoids the conflict with land use and food production that affects some other biofuel production methods. In addition lower costs (or even negative cost) of feedstock makes these technologies more economically viable. Many

[38] Q 46 (Dr Green).

[39] Virgin Atlantic.

> waste-derived fuels only require minimal incentives to make them cost competitive with first generation technologies. More challenging are the barriers to investment which are as a result of policy uncertainty and investors' attitudes to investing in first-of-a-kind projects."[40]

25. We also heard about speciality chemicals. For example, Professor James Clark from the University of York told us about the extraction of flavours, fragrances and solvents from citrus peel:

> "We already take out oils from citrus waste in some other countries for various applications, flavours and fragrances and so on. We can also now get solvents. Limonene, a very well-known chemical you can get from citrus waste, is now being used for cleaning printer circuit boards, displacing halogenated chemicals, so also providing a greener, safer alternative to current technology. Similarly with citrus waste, you can also get materials like pectin, which is widely used in the food industry. That is happening already and I think could happen a lot more."[41]

26. In addition, it is possible to produce entirely novel products with novel properties. Dr Philp from the OECD noted that: "the laboratory biosynthesis of 1,4-butanediol has also been described, a significant achievement as it is an entirely synthetic compound without natural precedent."[42]

27. To maximise the potential of the bioeconomy, it will be important to extract as much value from waste as possible, and ensure that higher value products, such as commodity and speciality chemicals are generated. This inquiry asked how processes, which deliver maximum value from carbon-containing waste, can be supported.

Waste as a resource

28. During this inquiry, we received a wide range of different figures relating to the amounts of waste produced, managed and disposed of. According to figures provided by the Department for Environment, Food and Rural Affairs (Defra), in 2010 the UK disposed of, or recovered, 286 million tonnes of waste.[43] Figure 5 provides information on the sources of waste, the types of waste, and the treatment of waste in the UK as classified into the broad categories required for EU reporting purposes. This includes types of waste which do not fall within the scope of this inquiry. The UK is making progress both in terms of reducing the amount of waste sent to landfill and increasing the amount recovered.[44] There is, however, clearly further room for improvement.

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40 British Airways.

41 Q 56.

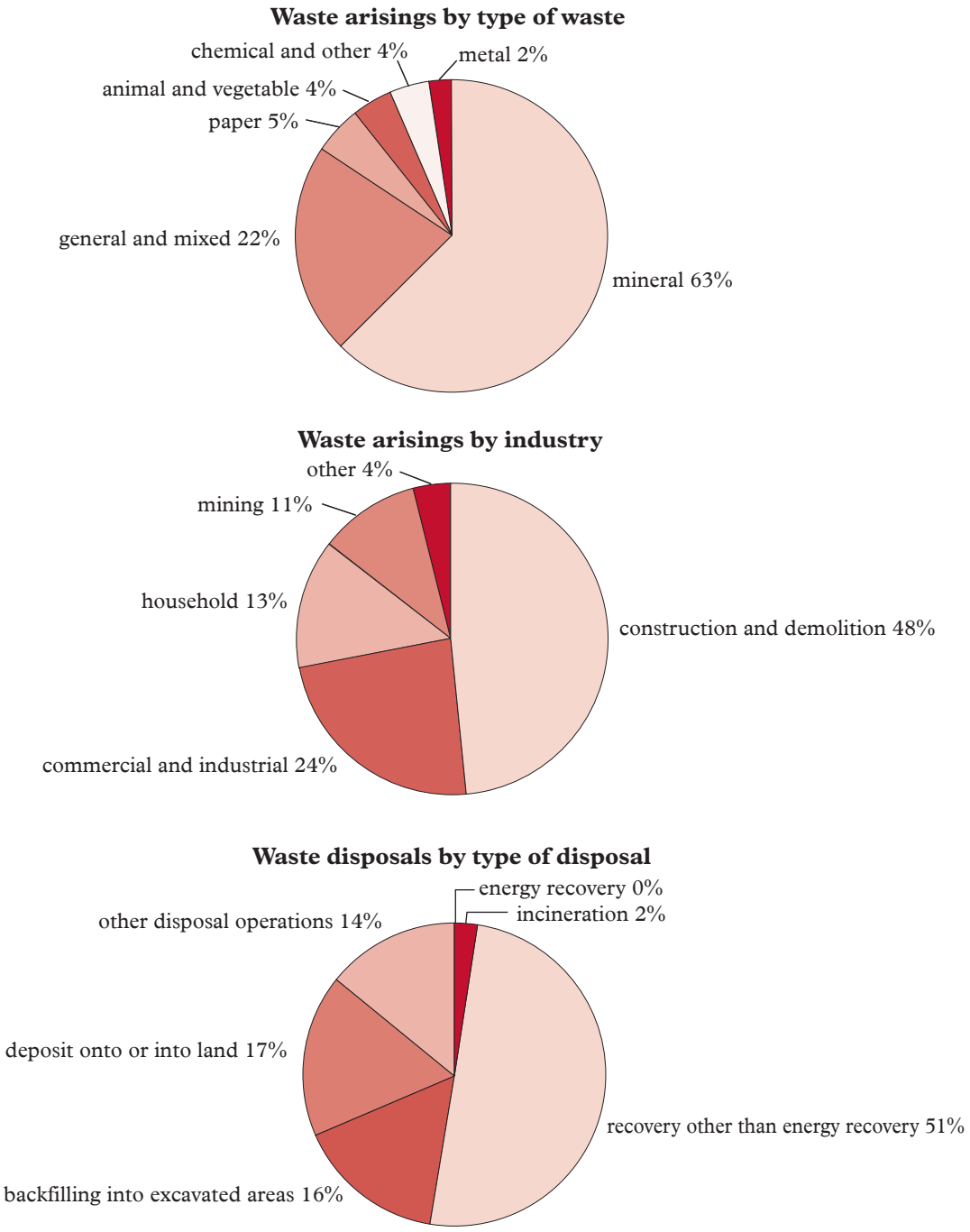
42 Dr Philp, OECD (acting in a personal capacity).

43 Government further supplementary evidence.

44 See: Defra (2011) *Waste Data Overview* http://webarchive.nationalarchives.gov.uk/20130123162956/http:/www.defra.gov.uk/statistics/files/20110617-waste-data-overview.pdf.

FIGURE 5

Sources, types and treatments of waste in the whole of the UK in 2010



Data provided by Defra.[45] *The two waste arisings charts present percentage values of a total of 218 million tonnes of waste. The waste 'disposals' chart presents percentage values of a total of 286 million tonnes of waste. Arising and disposal figures are best estimates and do not reconcile as completely different data sources are used. Less than 1% of waste (316 thousand tonnes) enters energy recovery. Backfilling into excavated areas is classed as a form of recovery as the use of waste for this purpose replaces the use of other materials.*

29. Not all of this waste is carbon-containing waste which could be used for the bioeconomy. Of the categories described in Figure 5, wastes of relevance to our inquiry are predominantly animal and vegetable waste, paper and a proportion of general and mixed waste. The evidence we heard suggested

[45] Government further supplementary evidence.

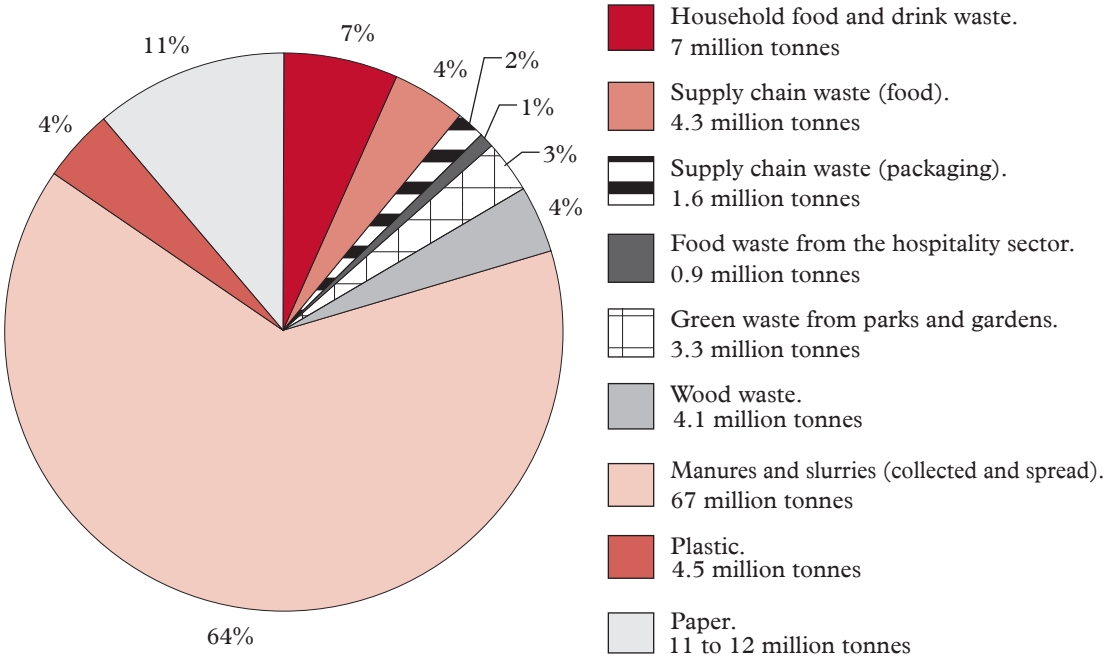
that between 100 million tonnes and 150 million tonnes of carbon-containing waste is generated in the UK.

> "Here in the UK, on the generally-accepted figures, we have about 120 million tonnes of biomass-type material. If you include carbon material, 130 million to 150 million tonnes of carbon-based material is flowing through a system. Some of that is pure biomass, some of it is impure like cardboard, and some of it is pure carbon like plastics and so forth."[46]

30. Defra estimates that 100 million tonnes of biowaste is available for biogas production.[47] This includes agricultural residues, food and drink waste and sewage sludge. We also heard that nine million tonnes of residual waste, comprising bio-waste and plastic, remains after recyclable plastic, metal and glass has been removed from unsegregated household waste.[48] WRAP provided further information on the amounts of different types of biowaste and waste plastic generated in the UK (Figure 6).

FIGURE 6

Quantity of biowaste and waste plastic recorded in the UK per annum



In the UK altogether 103.5 to 104.5 million tonnes of biowaste and waste plastic are produced from these sources. Green waste comprises that collected by local authorities and sent to composting operations. These data were provided by WRAP from a range of sources.[49] The uncertainty of adding together data from different sources should be noted.

31. There are, however, also additional sources of carbon-containing waste which might be used as a resource. Taken together, and including waste gases, these additional sources may be as large, or larger, than the 100 million tonnes reported above. For example, Water UK told us that one million tonnes of dry solids are produced from sewage sludge.[50] The Institute

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46 Q 130 (Peter Jones OBE).

47 See: http://archive.defra.gov.uk/environment/waste/ad/documents/implementation-plan2010.pdf.

48 Q 1 (Dr Tomkinson).

49 WRAP supplementary evidence.

50 Water UK.

for European Environmental Protection told us that there may also be considerable amounts of crop and forestry residues which could be used:

> "Crop residues are by far the largest in terms of availability. They are in the order of 122 million tonnes a year for Europe as a whole, versus around 40 million tonnes of forestry residues as a whole."[51]

32. British Airways told us that "up to €15 billion could flow into Europe's rural economy if all the available sustainable agricultural and forest harvest residues could be utilised."[52] We heard, for example, that 10 million tonnes of straw are produced in the UK each year, although there is debate as to how much of this could be diverted from existing uses.[53] Improved management of forests could deliver both an important source of local biomass and environmental benefits. In Britain, it has been estimated (making a number of assumptions) that if all existing broadleaf and conifer forests were brought into full sustainable yield production, and material not suited for use by existing markets was recovered, up to 4.2 million (dry) tonnes could potentially be made available.[54]

33. It is important to note that there is a difference between the amount of waste arising and the amount that could be used in a bioeconomy. The information provided above does not describe existing routes of treatment or distinguish between true wastes, co-products and by-products, although for some sources estimates of this are available.[55] Indeed, as a result of the way in which the data on biowaste is collected, much of it is already used. The spreading of manure to land, for example, is an important way of returning nutrients to the soil. We heard, however, that making use of waste in a bioeconomy to generate high value products does not necessarily eliminate an existing use. Anaerobic digestion can be used to treat manure to produce biogas and high quality digestate, which can be returned to soil. Although the economic feasibility would need to be examined, Professor James Clark told us:

> "I am not too far away from Drax power station where the volume of biomass to be burned is staggering. I look at it and I think, "If you are going to burn it, then why can we not extract the chemicals first?" You can extract a lot of valuable chemicals in very large volume, given the volumes we are talking about, and calorific value is not affected. In fact, in many cases you can end up with a material that is easier to co-fire with coal, for example. I have always believed that for chemicals manufacturing we should sit alongside the energy industry, not try to compete with it but go alongside it, taking some of the higher value products, as we have learned from petroleum."[56]

34. In terms of characterising the amount of waste which may be available for use in a bioeconomy, it is also important to note that the UK exports considerable amounts of waste. This is discussed further in Chapter 3 of this report.

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51 Q 4.

52 British Airways

53 BSBEC, Q 2 (Dr Tomkinson)

54 ADAS (2008) *Addressing the land use issues for non-food crops, in response to increasing fuel and energy generation opportunities*.

55 WRAP, WRAP supplementary evidence.

56 Q 54.

35. In addition to solid and liquid wastes, we also heard that waste gases from industry represent potentially important feedstocks for a bioeconomy.[57] A recent report from the Ellen MacArthur Foundation described carbon dioxide [CO_2] as a 'rough diamond.'[58] This report identified CO_2 as a high volume by-product of manufacturing processes, which could be transformed into valuable products using emerging technologies. This raises the possibility of moving from carbon capture and storage to carbon capture and reuse. The Government will need to be aware of this in developing future policies. During our inquiry, the Industrial Biotechnology Leadership Forum told us:

> "Process gases from industry containing CO_2, CO and H_2 are currently emitted to the atmosphere contributing to the carbon footprint of many companies, something that they are looking to reduce or avoid."[59]

36. Dr Colin Tattam, Director of Operations, Chemistry Innovation Knowledge Transfer Network, told us that considerable quantities of industrial gases were emitted in the North East of England:

> "… process gases are an important consideration and there is an abundant supply. Anecdotal evidence says that there are probably about 10 million tonnes per annum out of the north-east alone, perhaps 30 to 40 across the UK per annum in total. That is an important consideration, and the very basic answer to your question is that capturing and translating that feedstock through to higher value products is not being done routinely on that scale right now."[60]

37. LanzaTech provided further information on waste gases from a range of sources.[61] They told us that gas from steel mills, for example, represents a potentially important feedstock for gas fermentation technologies:

> "LanzaTech has evaluated in detail the potential for ethanol production from the UK steel industry. The two plants with the highest potential combined would yield over 300,000 tons (>100 million gallons) per year of ethanol from Basic Oxygen Furnace off gases alone. Blast furnace gases from all three UK mills have the potential to yield over a million tons per year (350 million gallons) of ethanol. Coke oven gases from UK steel mills and coke production facilities could add up to another 600,000 tons of ethanol (>200 million gallons)."

38. In addition, LanzaTech told us that waste gases from oil refineries, natural gas extraction and landfill sites could be used. Defra told us that in 2011, nearly 300 million tonnes of methane alone were emitted from industrial facilities, including landfill sites and the energy sector.[62]

39. It is important to note that the amount of many types of waste is declining. For example, the Technology Strategy Board, citing WRAP, told us that: "As an example, looking at the food waste 2010 figures for UK household waste totalled 12 million tonnes, with an additional 6.5 million tonnes through supply chain activities. By 2011 household waste had reduced by about

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57 RCUK.

58 Ellen MacArthur Foundation (2014) *Towards a Circular Economy Volume 3*.

59 IBLF.

60 Q 74.

61 LanzaTech.

62 Government supplementary evidence.

1Mt."[63] Solvert, a company specialising in the development of technology to produce renewable chemicals from sustainable raw materials, specifically the organic fraction of waste, noted that: "Although it is important to promote waste reduction and reuse it is not possible to eliminate waste at a national level."[64] WRAP echoed this point, stating:

> "In the UK, 15 million tonnes of food waste is generated each year. While great efforts are being made to reduce the quantity of food waste being produced, for example through WRAP's Love Food Hate Waste campaign, there will always be an unavoidable portion of food waste (such as vegetable peelings, tea bags and egg shells) which cannot be reused and therefore must be treated."[65]

40. In the view of Dr Ed Green from Green Biologics, however: "There is lots of opportunity, even as waste arisings continue to drop, for investment opportunities, new technologies and so on." The Chartered Institution of Wastes Management (CIWM) told us that: "Waste composition and quantity is very far from static," noting that this is influenced by many different factors.[66] The CIWM also noted difficulties with accurately forecasting future waste composition. Declining or changing compositions of waste may pose a challenge for a waste based bioeconomy and it will be important that the available resource is effectively characterised and that technology is developed which is able to deal with changing waste streams. The Centre for Process Innovation (CPI) told us that in order to be future-proofed against declining waste streams:

> "The most effective bio-economy process plants are designed with the flexibility to use more than one waste stream. This gives the plant operator the opportunity to select the most economically attractive or easily available feedstock. Without this flexibility in feedstock it is highly unlikely that bio waste based processes will be viable in the long-term."[67]

41. **The information we received indicated that there are likely to be considerable amounts of waste which could be used as a resource in a bioeconomy. There is, however, no single source of this information and it has proved very difficult to get a clear picture of the quantities available for use. In our view, there is therefore an urgent need for improved information on the availability, quantities and quality of waste now and in the future.** This is discussed further in Chapter 3 of this report.

Economic opportunity

42. During the course of this inquiry, we have heard that there are significant opportunities for the growth of a bioeconomy. We received a range of different estimates as to the contribution waste could make towards this. The Department for Business, Innovation and Skills (BIS), invited to supply information on the overall potential size of the bioeconomy, stated that while "the total value of the economic opportunity can only be an estimate …

63 TSB.

64 Solvert.

65 WRAP.

66 CIWM.

67 CPI.

statistics suggest that we could be looking at a total economic market of around £100bn."[68] BIS estimates that transport biofuels alone could have a value of £60bn. Products derived from carbon-containing waste will form only a proportion of this total value of £100bn.

43. There is also a significant market for renewable chemicals, already estimated at $57bn worldwide and forecast to rise to $83 billion by 2018.[69] The UK chemical industry currently has sales of over £60bn per annum. The inquiry heard that around £6bn of this might be replaced with renewable chemicals produced from waste materials.[70] Professor James Clarke from the University of York noted:

> "We calculated that the amount of organic carbon present in the food wastes, as calculated by the UN, is almost the same as the amount of carbon we [the world] use in all of the chemicals today."[71]

44. Dr Peter Williams from INEOS told us that bioethanol, derived from waste, could make a considerable contribution to the UK's transport fuel needs:

> "… at the moment about 13 million tonnes of petrol is used in the UK, alongside diesel of course. If we look at the waste available, even engineered waste such as a solid-recovered fuel, probably about 25 million tonnes is available now. In principle, with the right technology approach, that could be converted into roughly 5 million tonnes of bioethanol. If we compare the 5 million tonnes to the 13 million tonnes, that can have potentially a material impact on fuel supply."[72]

45. Figures provided by the Department for Transport suggest that this could have a value of around £2.4 billion.[73] We also received evidence suggesting that a waste based bioeconomy has the potential to create skilled jobs, particularly in rural areas.[74] Dr Philp pointed to the importance of the chemicals sector to the UK. He noted that the job creation opportunities for products higher up the value chain, such as bio-based chemicals and other bio-materials, were greater than for biofuels and energy applications.

> "Whilst environmental aspirations for the bio-based industries are important, the job creation possibilities are likely to be at least as important a priority for policy makers … For every job created in the business of chemistry in the US, 7.6 jobs are created in other sectors,[75] and on average they are high-paying compared to other manufacturing jobs. Meanwhile, modelling in Europe indicates that bio-based chemicals and plastics production can support many more jobs than biofuels and bioenergy applications. Carus et al. (2011) have estimated that materials use can directly support 5–10 times more employment

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68 Government supplementary evidence.

69 Professor James Clark.

70 Q 73 (Dr Tattam).

71 Q 63.

72 Q 70.

73 This figure represents the cost of purchasing five million tonnes of bioethanol on the wholesale market, using the wholesale ethanol price of 10 January 2014.

74 INEOS Bio.

75 See: http://www.americanchemistry.com/Jobs.

> and 4–9 times the value-added compared with energy uses, principally due to longer, more complex supply chains for material use."[76]

46. It has been estimated that if all sustainably available resources (agricultural residues, forestry residues and refuse derived fuel) in the EU were to be used for advanced biofuel production, in theory between 147 and 307 thousand jobs could be created across Europe, with 38 to 43% of these jobs primarily based in rural communities.[77] There is clearly a large amount of uncertainty associated with these estimates and such analysis makes a number of necessary assumptions in reaching these figures. During the inquiry, however, we also received estimates of the number of jobs which could be created by specific technologies or sectors. For example, the Anaerobic Digestion and Biogas Association told us that in the UK, 35,000 jobs could be supported in the anaerobic digestion sector.[78] British Airways told us that their Solena Greensky project "will provide approximately 1,000 construction jobs and 180–200 permanent jobs once in operation."[79] The Energy Technologies Institute told us that the gasification technology developed under their projects had the potential to sustain 2000 to 7000 jobs.[80] Meanwhile, Solvert told us that the technology they are currently developing to divert bio-waste from landfill into the production of high value commodity chemicals, has:

> "the potential to create at least 32 waste to chemical facilities generating over £2 billion of investment, creating up to 1600 permanent jobs and over £300 million positive contribution to the balance of trade."[81]

47. **We conclude that there are promising signs that a waste based bioeconomy could deliver substantial economic returns and support a considerable number of jobs. While there is clearly uncertainty in these predictions, it seems, however, that there is significant promise and the Government, industry and academia should take steps to further characterise this opportunity and ensure its full potential is realised.**

Environmental opportunity

48. There are potential environmental benefits of using waste as a resource. It can divert bio-waste from landfill and capture waste gases, reducing greenhouse gas emissions. In addition, it reduces reliance on petrochemicals:

> "The successful translation of research on utilising wastes and other feedstocks could help to reduce petrochemical use worldwide and help promote the use of renewables and potentially sustainable alternatives, contributing for example to reducing global carbon emissions."[82]

49. A major objective of the regulations relating to waste is to ensure its safe handling and to protect human health and the environment. Once a material is classified as a waste, it must be handled according to specific rules. The

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76 Dr Philp, OECD (acting in a personal capacity).

77 NNFCC (2014) *Use of sustainably-sourced residue and waste streams for advanced biofuel production in the European Union: rural economic impacts and potential for job creation*.

78 ADBA.

79 British Airways.

80 ETI.

81 Solvert.

82 RCUK.

Environment Agency, who have responsibility for enforcing regulations on waste, told us:

> "… as more material is diverted from landfill and there is greater financial incentive within the biowaste sector to take less proven materials and process greater volumes, there is an increasing risk of harm to soil and the wider environment."[83]

50. The Environment Agency noted, for example, a relatively high number of pollution incidents associated with waste permits for anaerobic digestion facilities. This illustrates the need to ensure that appropriate measures are put in place when making use of waste. The Environment Agency have been working on 'End of Waste' quality protocols, to help simplify the regulatory process associated with transforming a waste into a product. The continued development of such protocols, which reduce the regulatory burden of handling waste, whilst simultaneously ensuring environmental protection, will be important for enabling waste to be used as a feedstock for the bioeconomy.

51. The environmental benefits of using waste as a feedstock will vary on a case by case basis. It will depend on factors such as the environmental impacts associated with the current route of disposal or use, the energy required to transform it into a product, and the energy costs of transporting the waste to a site where it can be used. One of the central aims of a bioeconomy is to reduce greenhouse gas (GHG) emissions and so it is important that technologies deliver a positive greenhouse gas balance. As noted by the Industrial Biotechnology Leadership Forum:

> "Use of waste as feedstock reduces the amount going to landfill or escaping process facilities and therefore inherently is viewed more environmentally viable. However, all cases must be considered on an individual basis. The environmental viability and benefit needs to also consider logistics & transport, energy to process and end of life aspects i.e. the whole life cycle. However, the majority of LCA studies using lignocellulosic feedstocks in the production of chemicals demonstrate environmental benefits over petrochemical derived counterparts."[84]

52. Life Cycle Assessment (LCA) is a methodology used for systematically evaluating the environmental footprint of a product through all stages of its life cycle. It can be used to compare the environmental footprint of using different feedstocks or processes to generate products. The evidence we received suggested that there are environmental benefits associated with specific technologies or facilities. Virgin Atlantic told us that the technology they are developing with LanzaTech for producing aviation fuel from waste gases is anticipated to result in much lower greenhouse gas emissions:

> "Initial Life Cycle Analyses suggest that the resulting biofuel will emit 60% less carbon than the fossil fuel it will replace, kerosene. Moreover, because it uses a waste-stream, it creates a biofuel that does not impact on land use or food production."[85]

53. INEOS Bio also indicated that the LCA for a specific, proposed project on Teesside was estimated to have lower GHG emissions than alternative approaches for using waste:

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83 Environment Agency.

84 IBLF.

85 Virgin Atlantic.

> "The Eunomia life cycle GHG report for the proposed Seal Sands, Teesside plant confirms that producing biofuel from waste would be an environmentally sensible use of the waste as a resource compared to the alternatives, including composting, anaerobic digestion and biomass CHP."[86]

54. We also heard that there are limitations to LCA and outputs can be quite variable.[87] Dr Philp drew attention to an LCA of 60 bio-based chemicals, noting that the majority saved greenhouse gas emissions. He also observed, however, that it was difficult to predict the exact savings with accuracy and stated that: "I do not think the LCA is inaccurate. I think it is to do with the boundaries. One of the things we have said is that internationally we need to get this harmonised." Professor Murphy, an expert in LCA from the University of Surrey, agreed that there are limitations to LCA and explained how it should be used:

> "LCA is a good tool when you have reasonable data and clear and transparent system boundaries, you know what your question is at the beginning of the analysis and you have a very clear and transparent goal and scope. Then it works really well and it is entirely possible to do formal uncertainty analysis within an LCA, either by using measures of variation in the data or by doing scenarios and sensitivity analyses, which any good LCA is obliged to include according to the ISO standard in order to test the reliability or the reproducibility of the result when you vary important parameters."[88]

55. Professor Greg Tucker from the University of Nottingham noted that their LCA for converting wheat straw into ethanol delivered:

> "varying feedback on how much greenhouse gas emissions would be reduced, ranging from about 10% to about 30%. They all show positive reductions but how positive is quite a wide range, and I think it does rely on the accuracy of the evidence you are putting in as to how certain you are, and on the efficiency of the model that you are using."[89]

56. Professor Murphy noted that a positive greenhouse gas balance was less likely to be seen if co-products and by-products were diverted away from an existing use.[90] It will be important to take this into account, and to develop agreed standards for LCA, which allow different products and processes to be compared.

57. **Although it can be difficult to provide a precise evaluation of environmental impacts, the evidence we received suggested that in general there are environmental benefits from making use of waste as a resource. We conclude that more consistent approaches for analysing environmental benefits are needed so that the size of the opportunity can be better understood.** This is discussed further in Chapter 3 of this report.

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86 INEOS Bio.

87 BSBEC.

88 Q 89.

89 Q 22.

90 Q 83.

CHAPTER 3: KEY ISSUES

Government Strategy

58. Waste policy and regulation cut across several Government departments and agencies and it is not immediately straightforward to determine where responsibilities lie. The Committee received evidence (in writing, orally, or both) from the Department for Business, Innovation and Skills (BIS), the Department for Environment, Food and Rural Affairs (Defra), the Department for Transport (DfT), the Department for Communities and Local Government (DCLG), the Department of Energy and Climate Change (DECC) and the Environment Agency (EA), as well as local government.[91] This evidence revealed a panoply of policies and initiatives connected to waste and the bioeconomy. We were told, for instance, about the potential of industrial biotechnology, policy on biofuels, energy from waste, anerobic digestion, the Industrial Strategy, the Chemicals Strategy, Bioenergy Strategy and the circular economy.[92] For example, in oral evidence, the Minister of State for Business and Enterprise, Department for Business, Innovation and Skills (BIS) and the Minister of State for Energy, Department of Energy and Climate Change (DECC), told us about:

> "… the work we do with the chemicals industry through the chemical growth partnership that I co-chair with Neil Carson from Johnson Matthey. We are looking very specifically at the potential for waste resources to power green developments and a lot of effort is being put into targeting chemical and chemical-using businesses that do have the potential to adopt new processes to harness waste feedstocks for the future."[93]

59. It is indisputable that there is a considerable amount of Government activity on waste, but our inquiry revealed far less emphasis on the transformation of carbon-containing wastes into higher value products. We have some sympathy with the Government; the science and technology is developing quickly and it is not the Government's role to back certain technologies. In this regard, we agree with Dr Church, Director, Resource, Atmosphere and Sustainability, Department for Environment, Food and Rural Affairs, that:

> "… whenever Government tries to guess this technology, that technology, the other company, we make as many losers as we do winners. Historically, it is not something that Government is very good at doing. What we are trying to do is set a context, a market framework and a regulatory framework to the greatest extent we can. Then it is for the actors in the economy—be they early stage investors or late stage investors—to try things out. If there is something that is fundamentally flawed, there is a real market failure. If we are convinced of that, and it is a good place for the taxpayer money and taxpayer resources to go into, then we do act. That is why we have incentives to support low-carbon energy. Without those incentives we were not making the progress that

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91 It is worth noting that HM Treasury, though we did not hear from them directly, clearly have an interest in aspects of our inquiry.

92 Government.

93 Q 143.

> collectively, as a country, we need to do. We do not have in front of us an incontrovertible case that a particular kind of bioenergy or bioeconomy support is necessary in order for this country to thrive."[94]

60. As we set out in the previous chapter, however, the economic and environmental prize of developing a high value bioeconomy is substantial and may prove to be very considerable. Currently, policies and incentives tend to focus on lower value products, such as energy. Once one starts distorting the market by giving certain sectors incentives, there is an obligation to ensure that one is not disincentivising market entry by companies with the ability to produce higher value products.

61. For example, we heard a great deal about Anaerobic Digestion (AD), a natural process which is used to transform bio-wastes into bio-gas and digestate. The May 2010 Coalition Agreement stated that: "We will introduce measures to promote a huge increase in energy from waste through anaerobic digestion."[95] The *Anaerobic Digestion Strategy and Action Plan for England*, published jointly by Defra and DECC in 2011, sets out government strategy.[96] The Government's focus on AD recognises:

> "… the multiple benefits that the sector could deliver when processing food or farm wastes. As well as generating biogas for use as a fuel, it diverts food waste from landfill, provides greenhouse gas savings and income for the farming sector. The digestate from AD can be converted into a valuable by-product which would contribute to the wider bioeconomy."[97]

62. AD has been well supported by the Government and there are now almost 130 AD facilities in England with more than 200 in planning.[98] Germany, however, commissioned 1310 AD plants in 2011 alone.[99] While it might be tempting to conclude that the UK is lagging behind, we heard that there is over-capacity in Germany and, moreover, many of their AD plants tend to be crop-based. Germany is growing maize specifically to feed AD facilities. What therefore seems environmentally sustainable might well lead to a food versus fuel conflict. Professor Shah explained to us that the situation in Germany was:

> "… a result of the subsidy regime that is particularly present in Germany. It makes it profitable to use maize for AD to make gas, which is either then injected into the grid or turned into heat and power. It is more valuable than the maize as either animal feed, chemical feedstock or human feedstock. That is an example of perhaps where the system has gone wrong."[100]

Dr Warhurst from Friends of the Earth told us:

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94 Q 109.

95 See: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/78977/coalition_programme_for_government.pdf.

96 See: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69400/anaerobic-digestion-strat-action-plan.pdf.

97 Government supplementary evidence.

98 Q 97.

99 TSB.

100 Q 65.

> "Quite a lot of anaerobic digestion plants are being built around the country or are in place now. The worry is that lots of people are thinking that they are going to get something out of this waste, whereas in fact we will end up with the opposite thing where there is too little waste and then we will start using primary production of food in order to power these processes. I would say that is our biggest concern in this area."[101]

Peter Jones argued that other technologies offered greater efficiencies:

> "… to create 8500 Megawatt Hours (MwH) electricity (worth around £900,000) an AD plant requires 45,000 tonnes, advanced thermal oxidation requires 16,000 tonnes whilst high temperature gas plasma requires only 7,000 tonnes from the same material."[102]

63. Whilst noting the benefits of AD, we would urge some caution towards this technology, which the Government are perhaps too ready to champion. The UK should not seek to replicate the German model and we welcome Defra's position of not encouraging a policy such as that in Germany which has resulted in a reliance on crops grown specifically to feed AD installations.[103]

64. We were concerned to be told that current Government incentives are sector focused, supporting particular technologies such as AD, incentivising energy production and mitigating against higher value uses of waste:

> "The legislative and fiscal dynamics are currently pulling in different directions. Industries such as power production from anaerobic digestion are heavily subsidised to the point where chemical production, which would compete for the same feedstock in a non-subsidised market, only provides marginal returns and is therefore unlikely to see the investment due to the additional technical and commercial risk, even though in the long-term it provides the best economic solution for UK Plc."[104]

Similarly, the Royal Society of Chemistry told us:

> "Much of the Waste Policy review focuses on waste management practices, rather than treating waste as a resource (valorisation). Existing policy dealing with waste recovery is largely focused on energy generation, rather than creation of higher-value products."[105]

The Centre for Process Innovation noted that:

> "… the UK market is small relative to many EU nations. The market for anaerobic digestion—the main route for processing wet organic wastes—is still in its infancy and the market for gasification or pyrolysis based processing to syngas is also small. The bulk of UK bio-wastes are destroyed in incinerators. This legislation driven approach significantly reduces the amount of waste available for upgrading to higher value products."[106]

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101 Q 81.

102 Peter Jones OBE.

103 Q 97.

104 Solvert.

105 Royal Society of Chemistry.

106 Centre for Process Innovation.

65. Government policy on extracting value from waste lacks coherence and certainty. We agreed with Dan Rogerson MP, Parliamentary Under Secretary of State for water, forestry, rural affairs and resource management, when he told us that:

> "We think the Government has a role in tackling barriers and in setting the conditions that allow the market, businesses, local authorities and individuals to make the changes and move us towards an economy in which waste is valued as a resource."[107]

66. At the moment, however, it is not clear to us that the Government are sufficiently seized of the role that they articulate. It would be unfair to dismiss out of hand the various initiatives and strands of policy but there is a lack of a strategic lead. Stakeholders do not currently think that policy and regulation are sufficiently aligned and that cross-departmental co-ordination is optimal; there is a need for greater co-ordination and long-term policy stability. The following examples are indicative:

> "… whilst there are elements which support growth, existing policy and regulation, the uncertain regulatory environment and the lack of long-term stability of Government incentives does not support the growth of this area effectively."[108]

> "If there was more co-ordination across government departments so that the Department for Transport work was part of a considered cross-departmental approach, that would make it easier for the people who want to access this support and gain clarity as to how they could take this forward."[109]

> "The difficulties of the current framework reflect the multiplicity of Government Departments involved, across Agriculture, Waste, Food, Forestry, Energy, Local Government, Business and Skills."[110]

> "Wider bioenergy sector development would benefit from greater coordination and integration between key Government departments such as DECC and DEFRA, on issues such as land use and sustainability." [111]

> "A secure and long-term policy and regulatory framework is needed that reaches beyond 2020 to at least 2030 to provide certainty and stability for researchers and companies seeking to exploit bio-waste as a feedstock."[112]

67. In contrast, it is unclear whether any particular Government department or Minister is leading on the development of a waste-based, high value bioeconomy. Dr Church, Director, Resource, Atmosphere and Sustainability, Defra, told us that:

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[107] Q 144.

[108] Water UK.

[109] Q 78 (Dr Tattam, Director of Operations, Chemistry Innovation Knowledge Transfer Network).

[110] Peter Jones OBE.

[111] Energy Technologies Institute (ETI).

[112] Royal Society of Chemistry.

> "In this particular concept, I would not say that there is a department that takes the lead on it … We work together. We each try to align our objectives with the objectives of the other departments."[113]

68. This approach may mean that it is difficult for industry to know where to turn. As Ms Munday, Director of Advanced Manufacturing and Services, Department for Business, Innovation and Skills, told the Committee:

> "I would very much say to companies in that position, 'Come in and talk to our three departments'. We have various instruments, we know about how the Government systems work and we would certainly hope to navigate them through to a suitable vehicle."[114]

69. This does not suggest that there is a clear policy framework or departmental lead to encourage industry investment and provide certainty. Protecting the environment from the harmful effects of waste will continue to be of utmost importance and we recognise the important functions undertaken by Defra and the Environment Agency in achieving this. We also recognise that Government departments already work together on waste policy, but consider that given the potential value of waste as a resource, there is a need for far greater coordination.

70. We have heard that there are significant opportunities for the development of a waste-based, high-value bioeconomy in the UK. Given the right conditions, the market will be able to seize these opportunities. We are deeply concerned, however, that the Government does not have a coordinated, joined-up approach that would enable the potential of a waste-based bioeconomy to be realised. Considering the potential economic opportunities on offer, we consider that BIS should provide the strategic lead in this area, and ensure that a strategy is put in place to make the very most of waste as a resource.[115] BIS should ensure that policies are coordinated across departments to enable waste to be effectively used as a resource and to allow maximum value to be extracted from it, whilst at the same time ensuring that environmental impacts are carefully evaluated.

71. **We recommend that a Minister in the Department for Business, Innovation and Skills (BIS) is given responsibility for the development of a waste-based, high value bioeconomy. The Minister should be a champion for waste as a high value resource and should coordinate activities across Government. The Minister responsible should ensure the production of a long-term plan, with at least a 15 year horizon, to support the development of a high value waste-based bioeconomy. This plan should be produced by early 2015.**

72. The evidence we received suggested that other countries are currently ahead of the UK in terms of extracting value from waste. The Research Councils, for instance, noted that the UK is some way behind the US and Brazil in using waste to manufacture biofuels.[116] Solvert told us that despite significant

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[113] Q100.

[114] Q112.

[115] We note that a recent report has called for a re-adjustment in how the Government perceives and values the waste sector. The report argues that: "waste as a government policy area should be renamed 'resources' and moved from DEFRA to BIS. From BIS it could be given strong sectoral support as a commercial opportunity." 2020 Productivity and Efficiency Group (2014) *Sweating our Assets—Productivity and Efficiency Across the UK Economy*.

[116] RCUK.

demand, the UK has no domestic production of n-butanol or acetone from renewable sources.[117] Meanwhile, Brazil and China have both installed large production facilities. These various approaches may or may not be appropriate for the UK—as noted above, we would be very concerned if it were thought prudent for the UK to replicate Germany's deployment of anaerobic digestion facilities—but we are concerned that the Government do not appear to monitor the approach in other countries to making use of waste as a resource.[118]

73. We believe that important lessons can be learnt from the approaches taken in other countries, which the UK will wish either to follow or avoid. The UK lags behind some other European countries in that it continues to send waste to landfill, and also exports waste as it lacks sufficient infrastructure to extract value from it. Although this currently represents a problem, as stated earlier, it also represents an opportunity. Whilst some other countries have over capacity in energy from waste facilities or anaerobic digestion, the UK has the opportunity to develop infrastructure which can deliver higher value products from waste. In essence, the UK has the opportunity to leap-frog the mistakes made elsewhere.

74. **In developing a long-term plan for a high value waste-based bioeconomy, we recommend that the Department for Business, Innovation and Skills examines the strategies used by other countries to extract maximum value from waste, both successes and failures, and identifies approaches which would afford the UK the greatest economic opportunity.**

Research and Development

75. Throughout this inquiry, we have heard that the UK has key strengths in its research base, which would allow it to excel in developing a waste-based bioeconomy. As Research Councils UK (RCUK) told us:

> "The UK is also fortunate in that it has highly competitive academic groups and a range of dynamic small companies able to develop ideas rapidly. In addition, the UK has significant strengths in the new bioscience technologies that will underpin future developments in IBBE [Industrial Biotechnology and Bioenergy]."[119]

76. Professor Shah from Imperial College London expressed similar views, but noted that a shift is needed to expand effectively into new disciplines:

> "We have in the UK a fantastic bioscience and bioprocessing community, but that research and industrialisation has been oriented around healthcare and the pharmaceutical sector. It is more or less the same skills, together with process engineering and chemistry physical science skills that can orient themselves around this sector. It is getting those different experts mobilised and especially working on industrialisation rather than discovering new things."[120]

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[117] Solvert.

[118] Q 102 (Dr Church).

[119] RCUK.

[120] Q 66.

77. We nonetheless heard many examples of exciting areas of research currently underway at universities, institutes and in businesses around the UK. Support from the Research Councils and the Technology Strategy Board is essential to nurture success in this area.[121] RCUK indicated that research relevant to waste and the bioeconomy is funded through programmes across different research councils. Industrial biotechnology and bioenergy is identified as a key area in the Biotechnology and Biological Sciences Research Council's (BBSRC) strategic plan. In addition, the sustainable use of natural resources is identified in the Natural Environment Research Council's strategic plan. The Engineering and Physical Sciences Research Council (EPSRC) have joint programmes for synthetic biology with both BBSRC and the Technology Strategy Board (TSB). Separately, the EPSRC funds doctoral training centres in Industrial Biotechnology at UCL and Newcastle University. Although there is much promising R&D underway, only a proportion is focused on the use of waste as a feedstock, or on the development of high value products.

78. The TSB funds pre-market research in collaboration with industry. It funds research relevant to waste and the bioeconomy through its industrial biotechnology, resource efficiency and synthetic biology programmes.[122] As well as its research programmes, the TSB also funds Catapult Centres and Knowledge Transfer Networks, described later in this chapter. As with the Research Councils, the TSB informed us that their programmes:

> "… do not directly focus on waste, but use whatever feedstock is available at the required quantity, quality and cost. The focus is on using biological systems in manufacturing to access novel products and processes, not on the exploitation of waste. However, a number of projects we have funded do use various forms of waste or low value biomass …"[123]

79. Whilst noting that there has been reasonable cohesion between the funding bodies, the Industrial Biotechnology Leadership Forum told us that:

> "The funding strategy to date has been focussed on the technology required to process feedstocks (e.g. industrial biotechnology) or on final product targets (e.g. bioenergy/biofuels) and therefore a single co-ordinated funding strategy for waste valorisation does not exist."[124]

80. Much of the research described in the evidence we received is related to the use of biomass, but not specifically to making use of waste. The evidence suggested that mechanisms for funding research into the exploitation of waste should be strengthened:

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[121] There are seven Research Councils with responsibility for different disciplines who invest in research. These are: the Science and Technology Facilities Council (STFC), the Natural Environment Research Council (NERC), the Medical Research Council (MRC), the Economic and Social Research Council (ESRC), the Engineering and Physical Sciences Research Council (EPSRC), the Biotechnology and Biological Sciences Research Council (BBSRC) and the Arts and Humanities Research Council (AHRC). The Technology Strategy Board (TSB) is a non-departmental public body, sponsored by BIS, which provides the primary means through which Government incentivises business-led technology innovation. The majority of the funding provided by TSB is matched by business.

[122] TSB.

[123] TSB.

[124] IBLF.

> "Currently, there does not appear to be any effective mechanisms in place for funding cross disciplinary research between the Research Councils and the Technology Strategy Board that would underpin the science and technology for the exploitation of bio-wastes. The Research Council (RC) supports blue skies research whilst Technology Strategy Board (TSB) and Government are more related to applied research with close to market applications. There needs to be more joined up effort to coordinate funding with priority given and greater focus on bio-waste exploitation."[125]

> "The Technology Strategy Board manages a number of grant calls to support technology commercialisation activities. As these are not exclusive to waste processing technologies they have only supported a handful of projects at sub commercial scale."[126]

81. The evidence indicated that there may be benefits from opening a specific funding stream for multidisciplinary projects which bring together waste and the bioeconomy. The Royal Society of Chemistry stated:

> "Greater multidisciplinary collaboration between scientists across disciplines should be enabled by bespoke funding sources. A big challenge for the chemical science community is that some chemists lack awareness of the many research opportunities in biomass conversion nor do they have an understanding of where they can play a role."[127]

82. In January 2014, applications opened for the new Industrial Biotechnology Catalyst.[128] The Catalyst is co-funded by BBSRC, TSB and the EPSRC and will allocate £45 million of funding to multidisciplinary research and development projects in industrial biotechnology. It is intended to "accelerate the translation of Research Council-funded research into commercial products and processes."[129] This is an important development in terms of maximising the potential of industrial biotechnology as a whole and we welcome this investment.

83. We believe that it is important that there is a shift from funding energy projects towards projects focusing on the development of higher value products. While we do not recommend that a specific funding stream is opened to ensure that the challenges of using waste as a feedstock are thoroughly researched, we would hope that the Research Councils and the TSB are alive to the burgeoning opportunities which we set out in this report. The two areas—waste and the bioeconomy—need to be brought together effectively if the UK is to succeed in exploiting this opportunity.

84. **We therefore recommend that the Research Councils and the Technology Strategy Board should collaborate to ensure that the funding environment nurtures research on extracting high value from waste and developing a bioeconomy in the UK.**

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125 End-O-Sludg.

126 Solvert.

127 RSC.

128 See: http://www.bbsrc.ac.uk/news/industrial-biotechnology/2014/140120-n-industrial-biotechnology-catalyst.aspx.

129 TSB.

Information on Waste

Data on waste

85. The evidence indicated that considerable quantities of waste are produced, which could potentially be used as a resource for the bioeconomy. As noted in Chapter 2 of this report, however, there is sub-optimal information on exactly how much waste is available, where it arises, its quality, and the potential value which could be extracted from it. In addition, information about the environmental impacts of different uses of this waste could be improved.

86. The Chartered Institution of Wastes Management (CIWM) told us that: "waste data collection in the UK tends to have concentrated on monitoring specific issues."[130] We heard that the amounts of waste which are generated by households are well recorded, whilst for other sectors, far more limited information is available. Dr Church from Defra told us:

> "Household waste is about 13% by mass of waste generated in the country. We have quite good data about that because local authorities have a reporting obligation and they are the ones who generally collect that material through a system called waste dataflow."[131]

87. WasteDataFlow is an online tool which allows local authorities to report municipal waste data to the Government.[132] In addition, Defra provide funding to WRAP to undertake research and data analysis on the composition and fates of waste from a range of different sources. CIWM told us, however, that the message from Government to local authorities was not to undertake waste composition analysis for municipal waste.[133] This is concerning as it is important for local authorities to have reliable information on waste arisings in their area and the Government should support local authorities in achieving this. On food waste, WRAP told us that:

> "Whilst we now have a much better picture of where waste is arising within businesses and premises where food is prepared and served, we have a less clear picture on where the waste is consigned to in terms of disposal or recovery. WRAP has an ongoing work programme in this area …"[134]

We note that the current House of Lords EU Agriculture, Fisheries, Environment and Energy Sub-Committee inquiry on food waste prevention has heard that there is a need for improvement in data collection in some areas.

88. As noted by Dr Church, limited information is available on waste from commercial and industrial sources:

> "For commercial and industrial waste, the data is much, much, much less good. We effectively have three data points for surveys that have been done for businesses over the past 10 or so years. They are

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130 CIWM.

131 Q 98.

132 See: http://www.wastedataflow.org/.

133 CIWM.

134 WRAP.

> incredibly expensive surveys to run and even then you only touch perhaps 2,000 or 3,000 or 6,000 businesses. But still, compared to the 5 million or whatever it is businesses, it is a very small number. They do not tend to be compositional analyses. We understand and believe that the large waste management companies probably have far better data than we do and we have made several attempts to get them to share it with us and we continue to do so."[135]

89. In their written evidence, CIWM referred us to a recent speech from their president, Mr. Beadle, in which he commented on the paucity of data on commercial and industrial wastes:

> "… on a wave of poor data and understanding, and a tide of failure to plan or secure feedstocks, we are sailing steadily towards a market failure to recover resources or value from up to 15 million tonnes per year of wastes from businesses in the UK and Ireland. Failure to secure adequate C&I [commercial and industrial] infrastructure will lock us into either continued landfill or reliance on export markets which may or may not be there in the future … publicly available data is poor and patchy, course grained, gathered for different purposes and hard to compare from source to source. It throws into stark relief how poorly informed we are as a sector to make robust, strategic decisions about the future delivery of waste infrastructure."[136]

90. We note that waste management firms may consider that holding exclusive access to data on waste helps to put them at a competitive advantage. The result, however, is a fragmented picture whereby no firm has a complete overview of waste arisings, which would allow it to develop an approach to maximise the value of waste as a resource. A recent report for the CIWM stated that a lack of reliable data is a key barrier in convincing financial backers that a proposed facility will be viable.[137] This report noted that stakeholders have concerns that at present public data on commercial and industrial waste takes too long to become available, quickly becomes out of date, is of limited accuracy, and is rarely available at the subregional level.

91. In January 2014, a new online tool for recording waste from business, called 'edoc', was launched.[138] Edoc provides an alternative to the current requirement for businesses to fill in waste transfer notes to record the disposal of their waste, lightening the regulatory burden. It also makes it easier for businesses to obtain information about the waste they are producing. As noted by Mr. Beadle, the president of CIWM:

> "Edoc data can be interrogated at a strategic level without disclosing commercially confidential detail, and making sure that businesses understand this protection is vital to gaining broad uptake across the industry."[139]

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135 Q 98.

136 CIWM: David Beadle Presidential Inauguration speech http://www.ciwm.co.uk/web/FILES/PressRelease/David_Beadle_speech_transcript_final_151013.pdf

137 CIWM (2013) *Commercial and Industrial Waste in the UK and Ireland*.

138 See: http://edoconline.co.uk/.

139 CIWM: David Beadle, Presidential Inauguration speech.

92. As we heard during the inquiry, the roll-out of edoc creates an opportunity for improving information on waste.[140] The use of edoc is voluntary, and businesses can continue to use the previous system, and so its success will depend on levels of uptake. We therefore encourage businesses and waste management firms to make use of this system. As this will be a key tool for monitoring commercial and industrial waste, the Government will wish to monitor uptake closely.

93. The CIWM report notes concern from some stakeholders that edoc may not provide sufficiently accurate information on waste.[141] It will be important for businesses and the Government to work together to make sure edoc delivers useful information on waste as a resource. As it will take a number of years for data from edoc to accumulate, there would also be benefits from the waste management industry working with the Government to share existing data and establish improved historic data sets.

94. It is necessary to be able to measure waste effectively in order to manage it as a resource. To enable the maximum value to be extracted from waste, a more robust baseline of waste produced by different sectors is needed. This should comprise information on sources of waste, quantities, composition, location and changes over time. It may also comprise information on the potential energy or value which can be extracted from waste resources. This information should be made easily available to potential users. It should provide sufficient detail so that waste management companies and other potential investors can make informed decisions about where to site a facility and what kind of facility to put in place in order to extract maximum value from waste.

95. Creating a comprehensive pool of data on waste would have great benefits in enabling waste to be more effectively used as a resource. Information about the location and timing of waste arisings would help inform the siting of facilities and allow economies of scale to be realised. It would reduce uncertainty about the availability of waste and so reduce the risks of investment. If all waste management firms contributed to such a data source, all could benefit.

96. The Government will need to determine how this could best be achieved and who should take ownership of providing this information as a publicly available resource. Dr Wylie, co-founder and chairman of WHEB, a sustainability-focused investment firm covering private equity, listed equities and infrastructure projects, told us that what was needed was, "a unified resource collecting all the information and that WRAP could be very useful in a recharge-type role, a more proactive role."[142] As we heard, it is also important that this information on waste is embedded as part of holistic mapping of material flows across the economy and is used to inform circular economy approaches.[143]

97. It is clear that improved data collection and data analysis will help to support the Government in evidence based policy making. Making this information publicly available, easily accessible and possible to interrogate will help

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140 Q 141 (Peter Jones OBE), Q 98 (Dr Church), Q 153 (Rt Hon Dan Rogerson MP).

141 CIWM (2013) *Commercial and Industrial Waste in the UK and Ireland*.

142 Q 130.

143 Peter Jones OBE, International Synergies Limited.

businesses to make investment decisions. Whilst there are some encouraging signs, and the work of WRAP, CIWM and others is to be commended, further work is needed to improve the information available on waste in order to help open up the market to potential investors. We suggest that WRAP may be well positioned to take ownership of providing holistic information on waste resources. In this regard, we are concerned that recent reductions in its budget may not leave it well placed to do so.[144]

98. Defra has indicated that it intends to step back from policy work "in areas such as commercial and industrial waste and construction and demolition waste."[145] We are aware that in a resource constrained environment it is necessary for the Government to prioritise and it is right that industry should be expected to take a greater role. There are clear benefits to industry in taking steps which will enable waste to be used as a resource and we would encourage industry to grasp this opportunity. The evidence we have received indicated that the availability of reliable data is of key importance. We consider that the Government needs to play a catalytic role in developing a framework for the provision of data and bringing industry together.

99. **We recommend that the Department for Business, Innovation and Skills takes steps to ensure that information on both domestic and non-domestic waste streams is collated in a way which enables it to be used as a resource. Information on sources of waste, quantities, composition, location and changes over time needs to be made available in a way which allows industry to make informed investment decisions on how to extract maximum value from waste resources. Industry needs to engage with the Department for Business, Innovation and Skills as a matter of urgency to agree ways in which this can be achieved for non-domestic waste streams. A clear owner needs to be identified to collate, and make available, such holistic information on waste as a resource. This may be an evolution of the functions of the Waste and Resources Action Programme (WRAP). The Department for Business, Innovation and Skills should draw upon this improved information in producing the long-term plan for a high value waste based bioeconomy.**

Whole Systems Analysis

100. Several witnesses told us that there is a need for improved whole systems analysis of the economic and environmental impacts of processes and products. As seen in Chapter 2 of this report, there are challenges with Life Cycle Assessment—using different approaches can deliver different results.

101. We received many different estimates of the environmental and economic potential of different technologies. In order to be able to compare evaluations of different uses of waste, independent audit is needed. Richard Barker from Biogen, a company specialising in the anaerobic digestion of food waste, was asked about who should take ownership of whole systems analysis. He stated:

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144 Defra (2013) Review of Defra funding for WRAP.

145 Letter to stakeholders from the Rt Hon Dan Rogerson MP, Parliamentary Under Secretary for Water, Forestry, Rural Affairs and Resource Management https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/255508/waste-stakeholder-letter-131106.pdf.

> "It should not be industry because there are a lot of biases that are introduced to that system view. … Taking a step back and providing a system view is not best left in any of the particular industry groups that clearly favour their own membership."[146]

102. Mr Barker considered that the Government or a Government sponsored independent institution needed to be responsible for whole systems analysis to ensure that industry was not favouring its own technology. Mr Jones called for the Government to take a role in benchmarking the scientific credibility of processes, referring to economic and environmental impacts.[147] From an investment perspective, Dr Wylie did not consider this necessary, stating that the customers' view of the market place would be more important.[148] If the Government wishes, however, to use incentives to support the adoption of greener technologies, they will need to take ownership of common approaches to whole systems analysis to avoid distorting the market. Incentives, including the development of standards for bio-based products, are discussed further later in this chapter. It is important that claims of environmental benefits, used to support planning decisions or standards for bio-based products, can be independently audited.

103. **We recommend that the Department for Business Innovation and Skills takes steps to ensure that consistent approaches to whole systems analysis are adopted to ensure that the environmental impacts of processes and products can be compared effectively.**

Availability of Waste

Waste collection and planning

104. The policies of local authorities on waste collection and the planning of waste infrastructure impact on the availability and quality of the waste resource and the possible economic returns from its use. Although household waste is only about 13% by mass of waste generated, it is nevertheless a valuable resource. Policies vary markedly and it is not clear that waste is always collected and treated in a way that maximises its economic value. Moreover, a complex picture emerged in terms of responsibilities, divided between Government departments and local authorities.

105. In essence, local authorities are responsible for putting in place strategies for domestic waste collection which are appropriate for their areas. Mr Woodruff, Chair, National Association of Waste Disposal Officers and Head of Waste Services, London Borough of Bromley, explained:

> "Broadly, we collect what households no longer want and try to do the most beneficial thing that we can find to do with it, in line with the waste hierarchy and other drivers, and as economically beneficially as we can."[149]

106. Defra told us that they work with local authorities by funding WRAP:

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146 Q 31.

147 Q 138 (Peter Jones OBE).

148 Q 138.

149 Q 115.

> "… we part-fund WRAP. We fund it entirely in England. WRAP works with local authorities to help them understand the costs and benefits of taking that kind of action. It shows good practice: this council over there did it and this is what it cost them; that council over there did it and that is what it cost them, and so on. We also have provided money through, as I said earlier, the weekly collection support scheme that DCLG ran."[150]

107. In November 2012, the Department for Communities and Local Government (DCLG) announced £250 million of funding to incentivise local authorities to put in place weekly waste collection and separate food waste collection. In January 2014, DCLG published its *Guidance on Weekly Rubbish Collections* describing how "councils can and should deliver weekly rubbish collections." [151] DCLG also has a role in waste planning:

> "… the planning system is like an anchor because it provides the waste management facilities of the right type, in the right place and when they are most needed. In doing so, planning legislation puts the emphasis very much on local authorities to put in place robust plans setting out their vision for the next 10 to 15 years about waste management arisings and how to deal with it. What we do in DCLG is create the framework for doing so through the National Planning Policy Framework and, for the moment, Planning Policy Statement 10, which sets out the key principles that local authorities must have regard to when preparing their spatial vision for their area."[152]

108. For a waste based bioeconomy to thrive, waste needs to be collected and treated in a way which maximises its potential to be used as a resource. Mr John Woodruff, Chair, National Association of Waste Disposal Officers and Head of Waste Services, London Borough of Bromley, told us how collection practices had developed:

> "I noticed in a previous session that there was a question about why local authorities collect stuff in the way they do and why it is different everywhere. It is a common question. I think it is a very valid question. Is there a single best way of doing it? There might be. We are working towards it. Generally, if you will forgive the unintended pun, local authority schemes tend to have grown organically to where they are and from where they started. Their nature very much depends on when and where they started."[153]

109. At present, different approaches across local authorities in England result in a complex landscape for potential investors wishing to use waste as a resource:

> "The waste supply chain is fractured in nature. Different approaches to recycling and the use of green waste result in differing pictures as to the reliability of waste sources and uncertainty from the point of view of investors."[154]

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150 Q 104.

151 DCLG (2014) *Guidance on Weekly Rubbish Collections*.

152 Q 117.

153 Q 115.

154 Wilson Steam Storage.

> "Half of English local authorities now collect household food waste but only 50% of these collect food waste as a separate collection. The other 50% collect food waste with green waste. Where food waste is separately collected it will be treated at anaerobic digestion plants to generate energy and fertiliser. Where it is collected with green waste the collected material is composted."[155]

110. In general, less energy is required to extract value from homogenous wastes than from mixed wastes. In this regard, separate collection is therefore preferable, although as noted by a Defra official, there are costs associated with this and also practical implications:

> "On the food waste question, I fundamentally disagree … that there is a single right way to do it because, apart from anything else, I do not know where you live, I know where I live … I have the ability to store dozens of bins if I wanted to. Down the street from me is a set of properties straight on to the street that are flats, they have little or no storage space. How you store, collect, separate, sort and deal with the waste from those two properties is not the same if you want to get good separation. That is why I fundamentally disagree … that there is one single right way of doing that thing."[156]

111. This argument, however, rather begs the question of how many 'right ways' there may be of collecting waste. There may be no single, universal, collection method which all local authorities can apply, but both greater consistency and ambition should be aimed for. In addition to DCLG's *Guidance on Weekly Rubbish Collections*, we also note the recent letter from Lord De Mauley, Parliamentary Under Secretary of State at Defra, to local authorities. This letter reminded local authorities of new regulations coming into force in January 2015 affecting the separate collection of waste paper, plastic, glass and metal.[157] It will be important that local authorities are encouraged to be ambitious and are well supported in implementing separate collection of these wastes and also biowastes, and are provided with clear guidance to support them in doing so. We note that targets incentivising local authorities to collect greater volumes of recyclables do not automatically incentivise higher value uses.

112. It would be useful to find effective ways of engaging those with an interest in extracting value from waste so that they can articulate needs in terms of composition of waste. This, along with the needs of local communities, should inform approaches to the collection and treatment of waste. If value can be extracted from waste, this should help to make improved collection practices financially viable.

113. The Anaerobic Digestion and Biogas Association noted large differences in waste collection practices between England and the devolved administrations:

> "While 95% of Welsh councils have separate food waste collections and all non-rural Scottish local authorities will do by 2015, only 27% of English local authorities have separate food waste collections. This is

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155 WRAP.

156 Q 109.

157 See: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/250013/waste-seperate-collection-201310.pdf.

> helping to contribute to the situation today whereby only 7% of food waste is being treated through AD, while 35% is still landfilled."[158]

114. This variability raises questions as to why the devolved administrations have been able to put in place more ambitious policies on waste collection. Mr. Woodruff told us that progress was being made with waste collection in England:

> "On the collection side, where we used to drive around and collect stuff in dustcarts, you can now have a collection vehicle that has two, three or four compartments that allows you to collect multiple materials on the same journey, which is far more effective. So we are changing what we do. We are searching for the best way of doing it."[159]

115. In addition to waste collection practices, the availability of waste is also influenced by the type of contracts local authorities put in place with waste management, treatment or disposal firms:

> "County or Unitary Authorities tend to commit to long term commercial waste treatment agreements to secure the significant infrastructure investment required for the chosen waste treatment solutions and to provide fundable long term economic certainty for their waste management requirements."[160]

116. Others also told us that the availability of waste is affected by long contracts.[161] A proposal to use waste as feedstock to create chemicals, biofuels and energy in the Tees Valley notes the impact of long term contracts on the availability of waste and the need to import waste to make sure enough is available.[162] Long term contracts are important for local authorities in securing investment and for business in making investment decisions. We note, however, that long term contracts for lower value uses of waste may also act as a barrier as technologies to make higher value use of waste come on line. It will be important that local authorities are well supported in keeping abreast of developments in technology and in making sound decisions, which enable the highest possible value to be extracted from waste in the long term. In some cases, it may be necessary to consider the renegotiation of existing contracts to allow higher value uses of waste resources.

117. In their written evidence, CIWM referred us to a recent speech from their president, Mr. Beadle, in which he stated:

> "We have poor or poorly defined co-ordination between planning authorities, again especially here in England. Planning guidance is currently being reviewed [by DCLG] but CIWM remains concerned that we have lost some of the bigger picture in looking at wastes as resources at a regional or sub-regional level. We need to get it back."[163]

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158 ADBA.

159 Q 115.

160 Solvert.

161 INEOS Bio, ETI.

162 Tees Valley Unlimited (2012) *Creation of an Integrated Energy/Bioresources/Petrochemicals Cluster in the Tees Valley*.

163 CIWM.

118. Whilst DCLG provide the planning framework, we heard that Defra provides advice to local authorities, through WRAP, as to which type of waste facility would be most appropriate.[164] It will be important that, in providing advice to local authorities, the Government remains fully appraised of recent and future developments in technology for extracting value from waste.

119. While welcome progress on waste collection has been made, and while we note some of the practical difficulties for households in sorting waste, it is not clear why there cannot be greater consistency in waste collection by local authorities in England when this has been achieved in Wales and Scotland. We note the £250 million of funding provided by DCLG, along with their recent guidance advocating weekly bin collections. Such funding is welcome, but might be usefully diverted towards collection practices which enable the waste to be most effectively used in a high value bioeconomy, rather than focussing on weekly collection practices. Funding and guidance for local authorities should be informed by a robust evidence base taking account of social, environmental and economic needs.

120. **The Department for Business, Innovation and Skills, in developing a long-term plan for a high value waste-based bioeconomy, should ensure that waste is collected in such a way as to enable it to contribute fully to a high value waste-based bioeconomy. To this end, we recommend that the Department for Environment, Food and Rural Affairs and the Department for Communities and Local Government adopt a far more ambitious approach to waste collection in order to ensure that waste is collected and treated in a way that maximises the potential for it to be used as a resource. To enable this, we recommend that local authorities are offered further guidance to enable them to put in place waste collection facilities, and make planning decisions on waste infrastructure, which maximise the value which can be extracted from waste. We recommend that a long-term policy goal should be the creation of a more standardised system of waste collection across local authorities which views waste as a valuable resource.**

Export of waste

121. The UK exports a large amount of waste. The evidence suggested that the export of waste from the UK to Europe represents a lost opportunity for the bioeconomy. INEOS Bio told us that:

> "The amount of SRF [Solid Recovered Fuel—an engineered fuel produced from household and commercial wastes and meeting a defined specification] that the UK exported in 2012 to other European Member States for use in energy from waste plants was 739,535 tonnes. This number is increasing year on year. If this material were to be used in the UK, rather than be exported, it would result in around 150,000 tonnes of bioethanol. It would create skilled UK jobs in the emerging bioeconomy, reduce CO_2 emissions from UK transport, and reduce our need for imported fuels and energy."[165]

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[164] Q 119 (John Woodruff, Chair, National Association of Waste Disposal Officers and Head of Waste Services, London Borough of Bromley).

[165] INEOS Bio.

122. Air Products PLC expressed similar concerns:

> "… rapidly increasing rates of refuse-derived fuel (RDF) exported to the continent are hindering the development of UK energy-from-waste facilities and pose a significant risk to the viability of future projects. The increase in RDF export (from 0 to almost 900,000 tonnes per year in the last 5 years) has been caused by rising landfill costs in the UK, the slow development of UK waste conversion capacity and the rapid expansion of the Northern European incineration capacity. The export of RDF from the UK is clearly currently a commercially attractive option which is depressing gate fees[166] in the UK and causing concern for Air Products given that up to a third of our project revenue is expected to arise from gate fees. This trend is not only undermining the development of energy-from-waste infrastructure in the UK, it is also effectively exporting valuable green jobs and renewable energy resource."[167]

123. Air Products PLC told us that they had been in communication with Defra about the export of waste, but reported delays in the Department proposing and consulting on a way forward. The export of waste represents a lost opportunity for nurturing a bioeconomy in the UK. The Energy Technologies Institute argued that a lack of UK market opportunities was leading to a rapidly growing export market in UK Refuse Derived Fuel (RDF) going to European energy from waste (combustion) plants:

> "This may have increasing undesirable social, political and environmental consequences, such as the increased greenhouse gas emissions associated with transporting and disposing of 'our waste' abroad, and will certainly lead to competition for domestic feedstock markets as they develop. Therefore there is an opportunity for future policy and regulatory frameworks to encourage the more sustainable 'local' treatment and conversion of domestic waste in the UK."[168]

124. We agree that it must make sense, both environmentally and for UK businesses, for policy and regulation to be directed, if at all possible, at ensuring that UK waste is treated and converted in the UK. As we were drafting this report, the Government acknowledged concerns about the growing export market in RDF:

> "We are aware of concerns about the recent increase in exports of refuse-derived fuel and its effect on gate fees in the UK. We intend to publish a call for evidence shortly that will seek evidence on the market for refuse-derived fuel and the extent to which a market failure might exist. This will enable us to assess the effect of increased exports on the UK market for refuse-derived fuel, including its impact on gate fees."[169]

125. **We look forward to this consultation and recommend that the Department for Business, Innovation and Skills, in developing a long-term plan for a high value waste-based bioeconomy, takes its findings into account.**

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166 The cost payable to waste management companies for handling waste.

167 Air Products PLC.

168 Energy Technologies Institute.

169 HC Deb, 11 February 2014, col. 578W.

126. We note that were BIS to enable a waste-based bioeconomy to flourish in the UK, as we recommend, it is likely that less waste would be exported.

Stimulating Investment

Reducing risk

127. Reducing the risks of investment is vital if pioneering research is to be brought to the market place. One of the most challenging, costly and risky stages of technology development is the scaling up of processes to the commercial scale. The Government, through the Technology Strategy Board, has invested in facilities to support this scaling up and so reduce commercial risk. Crucial in the context of this inquiry is the Centre for Process Innovation (CPI—see Box 3 below), one of the seven centres that make up the High Value Manufacturing Catapult. This is the largest of the Catapult centres recently set-up by the Technology Strategy Board. The Catapult centres aim to help turn innovative ideas into commercial realities by bridging the gap between universities, research institutions and industries. As such, the CPI works to transfer technology concepts from research to proven market ready commercial processes and technologies. This activity involves moving products and technologies across the so-called valley of death between technology readiness levels (TRLs) 3 and 7.[170] The CPI offers open access to facilities so that industry can rigorously test and refine their new products.

BOX 3

Centre for Process Innovation

The Centre for Process Innovation (CPI) hosts equipment and provides expertise to help industry partners develop and scale up processes and prove new products prior to commercialisation. Partners are able to develop whole processes, from the treatment of raw feedstocks, such as waste, right through to the final product. CPI has a range of equipment which can be used in various combinations to identify problems and eliminate poor processes, before developing a final process plant, which can be used in commercial production. CPI therefore reduces risk for its partners by reducing the cost and increasing the speed of development programmes. CPI has over £80m of open access assets for process development and proving. Partners use this to develop and commercialise new products and processes. CPI owns and operates the two scale-up and proving plants that make up the National Industrial Biotechnology Facility as well as having a dedicated bioprocess development laboratory. It also has a Thermal Technology Centre in collaboration with Tata Steel. This centre uses high temperature processes for the creation of value from wastes. This equipment can help companies scale processes up to 10 tonnes a day so they can prove their processes on a commercial scale.[171]

128. The CPI is regarded as having been successful in supporting industry to test, develop and scale up products and processes, and we were told in November 2013 that the CPI's biological facility was fully booked up until Easter

[170] TRLs are a technology management tool that provides a measurement to assess the maturity of evolving technology.

[171] CPI.

2014.[172] While this is to be welcomed, it implies that potential partners are being denied access. The CPI told us that it is underfunded compared to other countries:

> "… the UK still needs to invest more in integrated innovation systems if it is to increase the value created from its investment in the chain. Currently the HVM Catapult and CPI are underfunded relative to similar centres in the UK's competitor countries. Significant further benefit could be secured by increasing investment in the innovation chain."[173]

129. Dr Hillier, Director of Strategy & Futures, Centre for Process Innovation & CTO, High Value Manufacturing Catapult, stressed the importance both of funding and the TSB having a sufficiently long horizon:

> "We need our research councils and we need the TSB to be joined up to be able to fund these things, and that means TSB funding is probably inadequate to do the amount of things it needs to do. Also the horizon that Will [Dr Barton, Head of Manufacturing, Technology Strategy Board] and his team can see forward is much too short. I was on the Centre for Doctoral Training panels last week, and they were giving grants that were going to last for five years to create a cohort of people that can go into manufacturing and make things happen. That is fantastic. But if the TSB does not always have that five-year horizon in front of it as well, it is going to be very difficult because it takes 10 to 15 years to get from a research idea in the lab through to something where you can build a factory that is going to manufacture something."[174]

130. Support for such facilities is critical to UK plc. RCUK, for example, observed a lack of large companies with the financial backing to develop the *whole process* from waste feedstock to high value product:

> "Whilst the UK has many excellent academic groups and active small companies developing new technological approaches, the UK appears to lack sufficient numbers of large companies in this area who have the financial backing to develop a whole "process", integrating a range of technology platforms, taking feedstocks to end product(s)."[175]

131. In addition to the Catapult Centres, the provision of demonstration facilities across the piece, we were told, is vital. Dr Philp from the OECD, but speaking in an individual capacity, explained:

> "Demonstrator plants are larger than pilot plant but smaller than full-scale production plants. Many of the technical, supply chain and economic issues become apparent, and can therefore be addressed, at the demonstrator phase. It is therefore a vital stage to prevent very expensive mistakes at the full-scale production phase. And yet demonstrator plants are notoriously difficult to fund, and this calls for public intervention, ideally through public-private partnerships (PPPs)."[176]

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[172] Q 26 (Dr Hillier, Director of Strategy & Futures, Centre for Process Innovation & CTO, High Value Manufacturing Catapult).

[173] CPI, Q 26.

[174] Q 20.

[175] RCUK.

[176] Dr Philp, OECD (acting as an individual). Please also see: http://ec.europa.eu/dgs/jrc/downloads/events/20130425-ket-sme/20130425-ket-sme-crean.pdf.

132. We heard concerns about the provision of demonstration facilities. Dr Green, Founder and Chief Scientific Advisor, Green Biologics, told us:

> "We have benefited greatly from TSB support for early stage research and development, but our challenge now is how can we get technology out of the lab and into demonstration projects. We have had to do this outside the UK because demonstration facilities simply do not exist in the UK. More could be done to support process demonstration, which is a vital thing … to derisk the whole process and to get the investment for a commercial project."[177]

133. Dr Green informed us that new demonstration facilities were reasonably imminent but it had taken some time for them to come to fruition:

> "There are at least two new things that are coming up. One is through the Department for Transport. They are looking to fund advanced biofuel demonstration projects, and that is something that will be greatly beneficial for us. Also, there is a pan-European initiative as well that is going to fund demonstration projects that we could tap into. Those are two examples where funding is starting to come through but it has taken a while."[178]

134. British Airways stressed the importance of Government support to reduce the risk of high capital intensive projects:

> "There is a strong need for government support to get demonstration scale technologies into operation as well as to help finance first-of-a-kind projects at commercial scale. Although the Green Investment Bank is tasked with helping renewable projects get to financial close, there is still a reluctance to move away from traditional waste treatment technologies such as incineration. Advanced gasification is almost twice as efficient at converting the valuable carbon contained in waste into energy than the traditional incinerators it will replace. High capital expenditure projects that have not been successfully demonstrated at commercial scale require government support."[179]

Dr Philp told us:

> "We have all said that the demonstrators are totally crucial. Anybody from the oil and gas business will tell you: you make your mistakes at demonstrators before you go to full scale. It might look great on the bench and you build a full-scale plant, but something economic or technical does not work."[180]

135. Knowledge Transfer Networks (KTNs) are also very important in this area. There are 15 KTNs which are funded by the Technology Strategy Board. KTNs facilitate networking, communication and collaboration between UK businesses, research organisations, universities and technology organisations working in specific areas.[181] KTNs highlight recent developments, events and funding opportunities through the connect on-line portal. They are also able to provide advice to the Government on the technological needs of the sector

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[177] Q 52.

[178] Q 53.

[179] British Airways.

[180] Q 92.

[181] See TSB website: https://www.innovateuk.org/-/knowledge-transfer-networks.

and specific issues which either enhance or inhibit innovation. The TSB has announced that it is setting up a new body, from 1 April 2014, to continue and invigorate the work of the KTNs. Knowledge Transfer Network Ltd "will bring the previously separate KTN communities together under one umbrella, to enable greater opportunities for collaboration, provide even more invigorating networking opportunities and make cross-cutting activity across disciplines easier."[182]

136. Our attention was also drawn to the work of the Green Investment Bank (GIB). The GIB provides funding for sustainable projects and waste has been chosen as a priority sector for investment.[183] BIS confirmed to us that, with respect to waste, the Green Bank was currently mainly funding anaerobic digestion projects. Dr Wylie, co-founder and chairman of WHEB, a sustainability-focused investment firm covering private equity, listed equities and infrastructure projects, urged the Government to take further steps to: "build on what you have already with organisations to catalyse investment such as the Green Investment Bank."[184] It is early days for the GIB and it will be some time before its success can be adequately measured, but we heard that it has made a sound start.

137. **We recommend that the Department for Business, Innovation and Skills (BIS) ensures that sufficient funding is given to knowledge transfer and near market research and that there is adequate capacity in demonstration facilities across the UK. In particular, BIS should regularly review whether the capacity of the High Value Manufacturing Catapult continues to be sufficient to support projects, particularly at later Technology Readiness Levels. In addition, we note that the Green Investment Bank has made a promising start in helping to reduce the risk of high capital intensive projects. To this end, we recommend that successive Governments support its mission.**

Incentives

BOX 4

Incentives

The Renewables Obligation requires UK electricity suppliers to source a specified proportion of electricity from renewable sources.[185] Generators of renewable electricity are issued with Renewables Obligation Certificates (ROCs), which they sell to energy suppliers. There is no fixed price for a ROC. The number of ROCs awarded to an electricity generator depends on the technology used to generate the renewable electricity. For example, electricity produced from AD currently receives 2 ROCs per megawatt hour, the highest possible number.[186] Energy from waste with combined heat and power receives 1 ROC per megawatt hour.

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182 See TSB website: https://www.innovateuk.org/-/non-executive-chair-announced-for-new-knowledge-transfer-network-ltd-.

183 See: http://www.greeninvestmentbank.com/what-we-do/waste/default.html.

184 Q 142.

185 See: Gov.uk website. *Increasing the use of low carbon technologies. The Renewables Obligation* https://www.gov.uk/government/policies/increasing-the-use-of-low-carbon-technologies/supporting-pages/the-renewables-obligation-ro.

186 See: Gov.uk website. *Table summarising the banding levels for the banding review period (2013–17) in England and Wales* https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/211292/ro_banding_levels_2013_17.pdf.

The Feed-In Tariffs scheme aims to promote the uptake of small scale renewable and low carbon electricity generation technologies. Registered small scale generators are paid for the electricity produced by licensed electricity suppliers.[187]

The Renewable Heat Incentive[188] provides financial incentives for the uptake of renewable heat. Participants in the scheme are paid for generating and using renewable energy to heat their buildings. Different technologies are paid different amounts per kilowatt hour and there are incentives for biomass units and anaerobic digesters.

The Renewable Transport Fuel Obligation (RTFO) requires transport fuel suppliers to incorporate a specified percentage of fuel from renewable sources, which meet defined sustainability criteria, or pay a financial penalty.[189] Owners (at the point of duty) are awarded one Renewable Transport Fuel Certificate (RTFC) per litre of biofuel or kilogram of biomethane. Biofuels produced from certain feedstocks, including wastes and residues, receive double the amount of RTFCs. The evidence we received suggested that the effectiveness of the RTFO is reduced as fuel is taxed by volume rather than energy content.[190]

In addition to these incentives, funding is also provided directly to support specific technologies. For example, Government has provided funding for AD, advanced gasification projects and facilities for energy recovery from residual waste.

138. We heard that the plethora of incentives, as described in Box 4, was distorting the market and pushing waste towards lower value uses.[191] Sector specific incentives for heat, biofuel and energy are contributing to an unstable policy environment overall. The Government maintain that they do not and should not back certain technologies,[192] but the miscellany of incentives, encouraging energy generation rather than higher value uses, makes us call this into question. Different industries are offered different incentives, favouring some, discriminating against others:

> "The legislative and fiscal dynamics are currently pulling in different directions. Industries such as power production from anaerobic digestion are heavily subsidised to the point where chemical production, which would compete for the same feedstock in a non-subsidised market, only provides marginal returns and is therefore unlikely to see the investment due to the additional technical and commercial risk, even though in the long-term it provides the best economic solution for UK Plc. … there are currently no incentives for the production of green

[187] See: Gov.uk website. *Increasing the use of low carbon technologies. Feed-in Tariffs scheme* https://www.gov.uk/government/policies/increasing-the-use-of-low-carbon-technologies/supporting-pages/feed-in-tariffs-scheme accessed November 2013.

[188] See: Gov.uk website. *Increasing the use of low carbon technologies. Renewable Heat Incentive* https://www.gov.uk/government/policies/increasing-the-use-of-low-carbon-technologies/supporting-pages/renewable-heat-incentive-rhi.

[189] See: Gov.uk website *Renewable Transport Fuels Obligation* https://www.gov.uk/renewable-transport-fuels-obligation.

[190] INEOS Bio.

[191] This issue was alluded to in the opening section of this chapter; here it is elaborated upon.

[192] Q 109.

chemicals and therefore most activity is towards the heavily incentivised energy from waste market."[193]

139. Dr Hillier, Director of Strategy & Futures, Centre for Process Innovation & CTO, High Value Manufacturing Catapult, put it to us that:

> "We have focused a lot on the fact that you need this integrated technology chain to get things through to the end, but when you get to the end, if you do not have the funding, the incentive, the users, the long-term support from the regulatory system you will not succeed, even if you have the best technology in the world, you are never going to invest in it in the UK. This whole focus on how you join up the technology chain and the delivery of the new technology into the market is vital. This is particularly true if we are talking about biowaste. There is a need to incentivise the diversion away from incineration into added value. It is an important factor in the success making it all happen because technically we can do it."[194]

140. Solvert, a company specialising in the development of technology to produce renewable chemicals from sustainable raw materials, specifically the organic fraction of waste, stated:

> "There are currently no incentives for the production of green chemicals and therefore most activity is towards the heavily incentivised energy from waste market."[195]

141. The Centre for Process Innovation argued that if a bioeconomy was to be grown, then current incentives must be looked at:

> "This market would grow significantly more quickly if incentives were created to encourage production of high value products. The current incentives to use wastes for energy production and the lack of incentives for high value chemical production, combined with long-term waste processing agreements distort the market and make it unattractive for significant investment in high value chemical production. … policy instruments remove feedstock that could be used for the bio-economy from the available pool and destroy it. If there is a strong desire to grow the bio-economy then the incentives and funding environment needs to be changed to support it."[196]

142. British Airways told us that the aviation sector was excluded from incentive mechanisms:

> "A significant challenge to the aviation sector is that it is often excluded from incentive mechanisms—for example road transport fuels in the UK are eligible for Renewable Fuels Transport Certificates that can be traded, whereas aviation fuels are not. This has been addressed by some governments, for example, the US Renewable Fuels Standard allows both fuels to earn these types of credits."[197]

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193 Solvert.

194 Q 27.

195 Solvert.

196 CPI.

197 British Airways.

143. In addition to hearing widespread concern that current incentives were distorting markets, we also heard that even where support mechanisms were in place, incentives were not aligned across a sector:

> "A range of support mechanisms exist to incentivise and enable bioenergy utilisation (the Renewable Obligation, Renewable Heat Incentive and Renewable Transport Fuel Obligation). However, these mechanisms are not fully aligned across bioenergy uses and the market does not yet have the confidence that they will offer sufficient support levels in the period required for significant R&D investments."[198]

144. We were told that whilst an array of incentives for heat, energy and biofuel were in place, there were no incentives for bio-based products such as plastics or chemicals. We heard that standards for bio-based products were needed. Bio-based standards—something similar to a kite-mark—would help to enhance market transparency by providing common reference methods and requirements in order to verify claims about products (e.g. bio-degradability, bio-based content, sustainability). Certifying a product as 'greener' could help to enhance its desirability and increase its market value relative to equivalent products. The Industrial Biotechnology Leadership Forum told us:

> "… more could be done by Government to support innovation in waste minimisation and utilisation. One such idea could be the introduction of a UK scheme similar to the 'Biopreferred'[199] programme used in the USA, which actively endorses and promotes the purchase of biobased products, particularly across Government departments. This could certainly act as a stimulant for research and development in this area."[200]

145. Such standards are being pursued at an EU level. We note this development and the University of York's assertion that: "Future European standards on bio-based content will encourage greater use of bio-feedstocks."[201] British Airways called for further work to develop sustainability standards for biofuel.[202] This would give biofuels produced from waste, or from sustainably sourced biomass, an advantage.

146. Again, adopting common approaches to LCA will be important in developing meaningful standards for bio-based products. As seen in chapter 2, there are currently challenges in that LCA can deliver different results depending on the approach used. It is important that the Government take an active role in supporting the development of standards for bio-based products at the EU and international level.

147. It is clear to us that there is considerable concern and uncertainty about the range of incentives currently offered. The system is complex and may well be distorting the market, and working against the production of high value products. We believe that the tax structure should be clear, fair and not inhibit any business sectors.

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198 Energy Technologies Institute.

199 See: http://www.biopreferred.gov/.

200 IBLF.

201 University of York Green Chemistry Centre in collaboration with the regional Biovale initiative.

202 British Airways.

148. **We recommend that the Department for Business, Innovation and Skills, in producing a long-term plan for a high value waste-based bioeconomy, reassesses the current approach of providing incentives to support specific sectors. The approach to the taxation and incentive structure should focus on providing policy stability, ameliorating market distortions and not inhibiting the extraction of high value from waste.**

CHAPTER 4: SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

The Opportunity

149. The information we received indicated that there are likely to be considerable amounts of waste which could be used as a resource in a bioeconomy. There is, however, no single source of this information and it has proved very difficult to get a clear picture of the quantities available for use. In our view, there is therefore an urgent need for improved information on the availability, quantities and quality of waste now and in the future. (paragraph 41)

150. We conclude that there are promising signs that a waste based bioeconomy could deliver substantial economic returns and support a considerable number of jobs. While there is clearly uncertainty in these predictions, it seems, however, that there is significant promise and the Government, industry and academia should take steps to further characterise this opportunity and ensure its full potential is realised. (paragraph 47)

151. Although it can be difficult to provide a precise evaluation of environmental impacts, the evidence we received suggested that in general there are environmental benefits from making use of waste as a resource. We conclude that more consistent approaches for analysing environmental benefits are needed so that the size of the opportunity can be better understood. (paragraph 57)

Government strategy

152. We recommend that a Minister in the Department for Business, Innovation and Skills (BIS) is given responsibility for the development of a waste-based, high value bioeconomy. The Minister should be a champion for waste as a high value resource and should coordinate activities across Government. The Minister responsible should ensure the production of a long-term plan, with at least a 15 year horizon, to support the development of a high value waste-based bioeconomy. This plan should be produced by early 2015. (paragraph 71)

153. In developing a long-term plan for a high value waste-based bioeconomy, we recommend that the Department for Business, Innovation and Skills examines the strategies used by other countries to extract maximum value from waste, both successes and failures, and identifies approaches which would afford the UK the greatest economic opportunity. (paragraph 74)

Research and Development

154. We therefore recommend that the Research Councils and the Technology Strategy Board should collaborate to ensure that the funding environment nurtures research on extracting high value from waste and developing a bioeconomy in the UK. (paragraph 84)

Information on Waste

155. We recommend that the Department for Business, Innovation and Skills takes steps to ensure that information on both domestic and non-domestic

waste streams is collated in a way which enables it to be used as a resource. Information on sources of waste, quantities, composition, location and changes over time needs to be made available in a way which allows industry to make informed investment decisions on how to extract maximum value from waste resources. Industry needs to engage with the Department for Business, Innovation and Skills as a matter of urgency to agree ways in which this can be achieved for non-domestic waste streams. A clear owner needs to be identified to collate, and make available, such holistic information on waste as a resource. This may be an evolution of the functions of the Waste and Resources Action Programme (WRAP). The Department for Business, Innovation and Skills should draw upon this improved information in producing the long-term plan for a high value waste based bioeconomy. (paragraph 99)

156. We recommend that the Department for Business Innovation and Skills takes steps to ensure that consistent approaches to whole systems analysis are adopted to ensure that the environmental impacts of processes and products can be compared effectively. (paragraph 103)

Availability of Waste

157. The Department for Business, Innovation and Skills, in developing a long-term plan for a high value waste-based bioeconomy, should ensure that waste is collected in such a way as to enable it to contribute fully to a high value waste-based bioeconomy. To this end, we recommend that the Department for Environment, Food and Rural Affairs and the Department for Communities and Local Government adopt a far more ambitious approach to waste collection in order to ensure that waste is collected and treated in a way that maximises the potential for it to be used as a resource. To enable this, we recommend that local authorities are offered further guidance to enable them to put in place waste collection facilities, and make planning decisions on waste infrastructure, which maximise the value which can be extracted from waste. We recommend that a long-term policy goal should be the creation of a more standardised system of waste collection across local authorities which views waste as a valuable resource. (paragraph 120)

158. We look forward to this consultation and recommend that the Department for Business, Innovation and Skills, in developing a long-term plan for a high value waste-based bioeconomy, takes its findings into account. (paragraph 125)

Stimulating Investment

159. We recommend that the Department for Business, Innovation and Skills (BIS) ensures that sufficient funding is given to knowledge transfer and near market research and that there is adequate capacity in demonstration facilities across the UK. In particular, BIS should regularly review whether the capacity of the High Value Manufacturing Catapult continues to be sufficient to support projects, particularly at later Technology Readiness Levels. In addition, we note that the Green Investment Bank has made a promising start in helping to reduce the risk of high capital intensive projects. To this end, we recommend that successive Governments support its mission. (paragraph 137)

160. We recommend that the Department for Business, Innovation and Skills, in producing a long-term plan for a high value waste-based bioeconomy, reassesses the current approach of providing incentives to support specific sectors. The approach to the taxation and incentive structure should focus on providing policy stability, ameliorating market distortions and not inhibiting the extraction of high value from waste. (paragraph 148)

APPENDIX 1: MEMBERS AND DECLARATIONS OF INTEREST

Members:

Lord Dixon-Smith
Baroness Hilton of Eggardon
Lord Krebs (Chairman)
Baroness Manningham-Buller
Lord O'Neill of Clackmannan
Lord Patel
Baroness Perry of Southwark
Lord Peston
Lord Rees of Ludlow
Earl of Selborne
Baroness Sharp of Guildford
Lord Wade of Chorlton
Lord Willis of Knaresborough
Lord Winston

Declared Interests

Lord Dixon-Smith
Farming

Baroness Hilton of Eggardon
None

Lord Krebs
Principal, Jesus College, Oxford

Baroness Manningham-Buller
Chair, Council of Imperial College London

Lord O'Neill of Clackmannan
None

Lord Patel
None

Baroness Perry of Southwark
None

Lord Peston
None

Lord Rees of Ludlow
None

Earl of Selborne
Director, Blackmoor Estate Ltd (a farming enterprise)

Baroness Sharp of Guildford
None

Lord Wade of Chorlton
None

Lord Willis of Knaresborough
Council Member, Natural Environment Research Council (NERC)

Lord Winston
Fellow, Royal Academy of Engineering
Fellow, Academy Medical Sciences

Employee of Imperial College London

A full list of Members' interests can be found in the Register of Lords Interests: http://www.publications.parliament.uk/pa/ld/ldreg.htm

Ian Shott CBE FREng, Specialist Adviser

Managing Partner, Shotttrinova LLP—consultancy agreements with Nottingham University, Chemoxy International Ltd, Bio Cats Ltd and KFS Ltd
Chairman, Industrial Biotechnology Innovation Centre—Scotland
Chairman and shareholder, Kiln Flame Systems Ltd
Chairman and shareholder, THLW Ltd
Member, Governing Board of Technology Strategy Board (TSB)
Chairman, Royal Academy of Engineering Enterprise Committee
Member, Strategic Advisory Board of Imperial College School of Chemical Engineering
Member, Chemistry Growth Partnership Council (co-chaired by Neil Carson(CEO Johnson Matthey) and Michael Fallon MP)

APPENDIX 2: LIST OF WITNESSES

Evidence is published online at www.parliament.uk/hlscience and available for inspection at the Parliamentary Archives (020 7219 5314)

Evidence received by the Committee is listed below in chronological order of oral evidence session and in alphabetical order. Those witnesses marked with * gave both oral evidence and written evidence. Those marked with ** gave oral evidence and did not submit any written evidence. All other witnesses submitted written evidence only.

Oral evidence in chronological order

**	QQ 1–14	Non-Food Crops Centre (NNFCC)
*		Institute for European Environmental Policy
**	QQ 15–27	Professor Greg Tucker, University of Nottingham
*		Centre for Process Innovation (CPI)
*		Technology Strategy Board (TSB)
*	QQ 28–43	Dr Prab Mistry, Economic and Human Value (EHV) Engineering
**		Branston Ltd
**		Biogen
**	QQ 44–54	Professor Iain Hunter, Strathclyde University
**		Ingenza Ltd
**		Green Biologics
**	QQ 55–69	TMO Renewables
*		Professor James Clark, University of York
**		Professor Nilay Shah, Imperial College London
**	QQ 70–79	Chemistry Innovation Knowledge Transfer Network
*		INEOS Bio
*		Dr Mike Goosey
**	QQ 80–92	Friends of the Earth
*		Dr Jim Philp, OECD (Organisation for Economic Co-operation and Development)
**		Professor Richard Murphy, University of Surrey
*	QQ 93–113	Department for Business, Innovation and Skills (BIS)
*		Department for Environment, Food and Rural Affairs (Defra)
*		Department of Energy and Climate Change (DECC)
*	QQ 114–128	Environment Agency
**		National Association of Waste Disposal Officers

**		Department for Communities and Local Government (DCLG)
*	QQ 129–142	Peter Jones OBE
**		Dr Rob Wylie, WHEB
*	QQ 143–158	Rt Hon Michael Fallon MP, Minister of State for Business and Energy and Minister of State for Energy, Department for Business, Innovation and Skills (BIS) and Department of Energy and Climate Change (DECC)
*		Dan Rogerson MP, Parliamentary Under Secretary of State for water, forestry, rural affairs and resource management, Department for Environment, Food and Rural Affairs (Defra)
*		Rt Hon Gregory Barker MP, Minister of State for Climate Change, Department of Energy and Climate Change (DECC)

Alphabetical list of all witnesses

AD Fertiliser Technologies Limited (ADFerTech)

Advanced Plasma Power (APP)

Air Products PLC

Anaerobic Digestion and Biogas Association (ADBA)

* Rt Hon Gregory Barker MP, Minister of State for Climate Change, Department of Energy and Climate Change (DECC) (QQ 143–158)

** Biogen (QQ 28–43)

Biotechnology and Biological Sciences Research Council's (BBSRC) Sustainable Bioenergy Centre (BSBEC)

** Branston Ltd (QQ 28–43)

British Airways

Calysta Energy

* Centre for Process Innovation (CPI) (QQ 15–27)

Centre for Resource Efficiency & the Environment, University College London (CREE UCL)

Chartered Institution of Wastes Management (CIWM)

** Chemistry Innovation Knowledge Transfer Network (QQ 70–79)

* Professor James Clark, University of York (QQ 55–69)

College of Science and Engineering, University of Edinburgh

* Department for Business, Innovation and Skills (BIS) (QQ 93–113)

** Department for Communities and Local Government (DCLG) (QQ 114–128)

* Department of Energy and Climate Change (DECC) (QQ 93–113)

* Department for Environment, Food and Rural Affairs (Defra) (QQ 93–113)

* Department for Transport (DfT)

END-O-SLUDG

Energy Technologies Institute (ETI)

* Environment Agency (QQ 114–128)

Environmental Resource Recovery Solutions (EVRS)

* Rt Hon Michael Fallon MP, Minister of State for Business and Energy and Minister of State for Energy, Department for Business, Innovation and Skills (BIS) and Department of Energy and Climate Change (DECC) (QQ 143–158)

Food and Environment Research Agency (Fera)

** Friends of the Earth (QQ 80–92)

Friends of the Earth, Derbyshire Branch

* Dr Mike Goosey (QQ 70–79)

** Green Biologics (QQ 44–54)

Dr Adam D Hughes, Scottish Association for Marine Science

** Professor Iain Hunter, Strathclyde University (QQ 44–54)

Industrial Biotechnology Leadership Forum (IBLF)

* INEOS Bio (QQ 70–79)

** Ingenza Ltd (QQ 44–54)

* Institute for European Environmental Policy (IEEP) (QQ 1–14)

International Synergies Limited

* Peter Jones OBE (QQ 129–142)

Kielder Forest Products Ltd

LanzaTech

Mineral Products Association Ltd (MPA)

* Dr Prab Mistry, Economic and Human Value (EHV) Engineering (QQ 28–43)

** Professor Richard Murphy, University of Surrey (QQ 80–92)

** National Association of Waste Disposal Officers (QQ 114–128)

** Non-Food Crops Centre (NNFCC) (QQ 1–14)

Dr Jagroop Pandhal, University of Sheffield

* Dr Jim Philp, OECD (QQ 80–92)

Research Councils UK (RCUK)

* Dan Rogerson MP, Parliamentary Under Secretary of State for water, forestry, rural affairs and resource management, Department for Environment, Food and Rural Affairs (Defra) (QQ 143–158)

Royal Society of Chemistry (RSC)

** Professor Nilay Shah, Imperial College London (QQ 55–69)

Solvert Ltd

* Technology Strategy Board (TSB) (QQ 15–27)

** TMO Renewables (QQ 55–69)

** Professor Greg Tucker, University of Nottingham (QQ 15–27)

University of Nottingham

* University of York Green Chemistry Centre in collaboration with the regional Biovale initiative

Virgin Atlantic Airways (VAA)

Warwick Centre of Industrial Biotechnology and Biorefining, University of Warwick

Water UK

Wilson Steam Storage (WSS)

WRAP (the Waste and Resources Action Programme)

** Dr Rob Wylie, WHEB (QQ 129–142)

APPENDIX 3: CALL FOR EVIDENCE

25 July 2013

The House of Lords Science and Technology Committee, under the Chairmanship of Lord Krebs, is conducting an inquiry into waste and the bioeconomy. The Committee invites interested individuals and organisations to submit written evidence as part of the inquiry.

Scope

The inquiry focuses on the technology used to exploit bio-waste and waste gases in order to generate high-value products. Bio-waste is produced by agriculture (crops and livestock), forestry, food processing and households. Waste gases arise from heavy industry and large chemical complexes. Approaches are being developed using, for example, biotechnology and green chemistry, to make use of these waste sources and extract high-value products. These high value products include chemicals, polymers, bio-materials and bio-fuels.

The Committee would welcome written submissions on the type of activities currently underway in this area from basic research through to commercialisation. The inquiry aims to collect evidence on the potential for this technology to enable bio-waste and waste gas to replace current feedstocks and the potential contribution this could make to a bioeconomy.

The inquiry will look at whether there is a clear route to allow the potential of this technology to be realised, whether the UK is making the most of the opportunities presented by this technology and how it can be competitive within Europe and internationally. The Committee will consider whether more should be done to promote basic and applied research and development or to remove regulatory or market barriers to commercialisation. It is timely to examine whether Government has a joined-up strategic approach to funding, policy and regulation in this area. The deadline for written evidence submissions is **Friday, 27 September 2013**.

Questions:

The Committee invites submissions on the following points, with practical examples where possible. Please only answer the questions of relevance to you. Please also do draw the Committee's attention to any relevant issues not captured in the specific questions below:

Science and technology

- What research is underway to enable high-value products to be derived from bio-waste and waste gas feedstocks and what problems could this help to solve?
- Where does the waste come from and is there a reliable supply?
- Is it environmentally and economically viable to make use of such technologies using waste as a feedstock?
- How strong is the UK's research base in this area relative to the rest of the world?

Commercial exploitation and the bioeconomy

- How large is the current market and what types of products generated from bio-waste and waste gas are currently commercially available? How does this compare to elsewhere in the world?
- Are there appropriate mechanisms in place to facilitate commercialisation?
- Which types of products will be on the market in five, ten and twenty years from now and which factors will influence this?
- What is the potential contribution of this technology to a bioeconomy?

Governance

- Do Government, the Research Councils and the Technology Strategy Board have a co-ordinated funding strategy for this area? Are effective mechanisms in place for funding cross disciplinary research?
- Does Government have a joined up approach to policy and regulation, which effectively supports the growth of this area?

APPENDIX 4: SEMINAR HELD AT THE HOUSE OF LORDS

22 October 2013

Members of the Committee present were Lord Dixon-Smith, Baroness Hilton of Eggardon, Lord Krebs (Chairman), Baroness Manningham-Buller, Lord O'Neill of Clackmannan, Lord Patel, Baroness Perry of Southwark, Lord Peston, Earl of Selborne, Baroness Sharp of Guildford and Lord Willis of Knaresborough.

Presentations were heard from:

- Philip Webster, Manager in Arthur D. Little's Technology & Innovation Management Practice;
- Dr Celia Caulcott, Biotechnology and Biological Sciences Research Council's (BBSRC) Director for Innovation and Skills;
- Professor Nigel Minton, Professor of Applied Molecular Microbiology, University of Nottingham;
- Graham Rice, Business Development Manager for Europe, Middle East, Africa and India, INEOS Bio; and
- Matthew White, Head of Innovation, AB Sugar

APPENDIX 5: ABBREVIATIONS AND ACRONYMS

AD	Anaerobic Digestion
ADBA	Anaerobic Digestion and Biogas Association
AHRC	Arts and Humanities Research Council
BIS	Department for Business, Innovation and Skills
BBSRC	Biotechnology and Biological Sciences Research Council
BSBEC	BBSRC Sustainable Bioenergy Centre
CHP	Combined Heat and Power
CIWM	Chartered Institute of Waste Managers
CPI	Centre for Process Innovation
DCLG	Department for Communities and Local Government
DECC	Department of Energy and Climate Change
DEFRA	Department for Environment, Food and Rural Affairs
DfT	Department for Transport
EA	Environment Agency
EPSRC	Engineering and Physical Sciences Research Council
ESRC	Economic and Social Research Council
ETI	Energy Technologies Institute
EU	European Union
GHG	Greenhouse Gas
GIB	Green Investment Bank
IBBE	Industrial Biotechnology and Bioenergy
IBLF	Industrial Biotechnology Leadership Forum
KTNs	Knowledge Transfer Networks
LCA	Life Cycle Assessment
MBT	Mechanical and Biological Treatment
MRC	Medical Research Council
MwH	Megawatt Hours
NERC	Natural Environment Research Council
OECD	Organisation for Economic Co-operation and Development
PPP	Public-Private Partnerships
RC	Research Council
RCUK	Research Councils UK
RDF	Refuse Derived Fuel
ROC	Renewables Obligation Certificate
RSB	Roundtable of Sustainable Biomaterial

RSC	Royal Society of Chemistry
RTFC	Renewable Transport Fuel Certificate
RTFO	Renewable Transport Fuel Obligation
SRF	Solid Recovered Fuel
STFC	Science and Technology Facilities Council
TRL	Technology Readiness Level
TSB	Technology Strategy Board
UN	United Nations
WRAP	Waste and Resources Action Programme

APPENDIX 6: RECENT REPORTS FROM THE HOUSE OF LORDS SCIENCE AND TECHNOLOGY COMMITTEE

Session 2007–08

1st Report	Air Travel and Health: an Update
2nd Report	Radioactive Waste Management Update: Government Response
3rd Report	Air Travel and Health Update: Government Response
4th Report	Personal Internet Security: Follow-up
5th Report	Systematics and Taxonomy: Follow-up
6th Report	Waste Reduction
7th Report	Waste Reduction: Government Response

Session 2008–09

1st Report	Systematics and Taxonomy Follow-up: Government Response
2nd Report	Genomic Medicine
3rd Report	Pandemic Influenza: Follow-up

Session 2009–10

1st Report	Nanotechnologies and Food
2nd Report	Radioactive Waste Management: a further update
3rd Report	Setting priorities for publicly funded research

Session 2010–12

1st Report	Public procurement as a tool to stimulate innovation
2nd Report	Behaviour Change
3rd Report	Nuclear Research and Development Capabilities
4th Report	The role and functions of departmental Chief Scientific Advisers
5th Report	Science and Heritage: a follow-up

Session 2012–13

1st Report	Sports and exercise science and medicine: building on the Olympic legacy to improve the nation's health
2nd Report	Higher Education in Science, Technology, Engineering and Mathematics (STEM) subjects
3rd Report	The implementation of open access

Session 2013–14

1st Report	Regenerative Medicine
2nd Report	Scientific Infrastructure