House of Commons

Innovation, Universities, Science and Skills Committee

Engineering: turning ideas into reality

Fourth Report of Session 2008–09

Volume I

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00.01hrs on Friday 27 March 2009

HC 50-I

House of Commons

Innovation, Universities, Science and Skills Committee

Engineering: turning ideas into reality

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Volume I

Report, together with formal minutes

Ordered by the House of Commons to be printed 18 March 2009

HC 50-I
[Incorporating HC 470-i-iii, 640-i-iii, 599-i-iii, 1064-i, 1202-i, 1194-i, Session 2007-08]
Published on 27 March 2009
by authority of the House of Commons
London: The Stationery Office Limited
£0.00

The Innovation, Universities, Science & Skills Committee

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

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The current staff of the Committee are: Sarah Davies (Clerk); Glenn McKee (Second Clerk); Dr Christopher Tyler (Committee Specialist); Dr Joanna Dally (Committee Specialist); Ana Ferreira (Senior Committee Assistant); Camilla Brace (Committee Assistant); Anna Browning (Committee Assistant); Jim Hudson (Committee Support Assistant); and Becky Jones (Media Officer).

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Summary

The Secretary of State for Business, Enterprise and Regulatory Reform, Lord Mandelson recently said: "If you really want to change the world—choose a career in engineering. And I mean real engineering, not financial engineering." His comment encapsulates the spirit of our Report. In the current economic climate, engineering has come under the spotlight because it is a critical component of our national economy and of society in general.

We have found engineering to be one of the UK's great strengths and were pleased to discover that UK engineering and engineers are highly regarded internationally, more than they are at home. We are convinced that the strength of the UK's engineering base means that the UK can play a major part in solving global problems such as climate change, food and water supply, energy security and economic instability.

Engineering cuts across every aspect of the work of DIUS—skills, higher education and innovation—as well as other departments. It encompasses research and development, design, production, distribution and services. We decided to take a case study approach, exploring key themes through the lenses of nuclear engineering, plastic electronics engineering, geo-engineering and engineering in Government.

Nuclear engineering: The Government's recent enthusiasm for nuclear power has raised important questions about the UK's capacity to deliver a new generation of nuclear power stations. We discovered that there are significant skills shortages, which could affect plans to bring new plants online by 2020. We argue that there should be a master roadmap for all major engineering projects, including nuclear new build.

Plastic electronics: This case study highlighted the potential opportunity afforded to the UK through the support of emerging, innovative industries. Hailed as a disruptive technology, the UK research base in this area of plastic electronics is world-class. We are concerned, however, that the UK is likely to miss out on the economic return associated with translating the findings of research into commercialised technologies, and call for a serious revision of the structures used to support the growth of fledgling industries.

Geo-engineering: The global nature of many engineering challenges was highlighted during our discussion of geo-engineering research. During this case study we considered the implications of a new engineering discipline for UK policy-making. It became clear that, if the Government is to be an informed actor in the development of any future international policy relating to geo-engineering, it is essential that the views of the science, engineering and social science communities be seen as complementary sources of expertise, and their advice actively sought and considered.

Engineering in Government: Our final case study went further and demonstrated that engineering advice and scientific advice offer different things, and that this should be recognised in the policy process. Government, in key policy areas of several departments, does not have sufficient in-house engineering expertise to act as an intelligent customer and engineering advice is frequently not sought early enough during policy formulation. We were shocked to discover that engineering advice had been lacking in the formulation of policies as important and diverse as eco-towns, renewable energy and large IT projects.

We suggest that there should be a greater level of engineering expertise in the generalist civil service as well as more engineering policy specialists. As a starting point, the

Government should at least know what expertise it has in the civil service. It should also recruit more people into the Science and Engineering Fast Stream, distribute them more widely and provide real opportunities in career progression while retaining specialist skills. And it should also strengthen links between the public and private sector through secondments.

We argue that there is a need for better trans-departmental management of engineering policy. To help achieve this, we have suggested a reorganisation of the high level advisory structures in Government. The GCSA should be renamed the Government Chief Scientific and Engineering Adviser (GCSEA). This person would be the head of profession for science, engineering and social science and should have a more senior role in the Government with direct access to the Prime Minister. The GCSEA would head up the Government Office for Science and Engineering, which should be placed in the Cabinet Office. Beneath the GCSEA should be a Government Chief Engineer, a Government Chief Scientist and a Government Chief Social Scientist. Additionally, departments should either have a Departmental Chief Engineering Adviser (DCEA), or a Departmental Chief Scientific Adviser (DCSA), and in some cases they should have both.

Our overall conclusions link our case studies together and are relevant to the engineering sector as a whole. As stated above, we argue that there is a need for better trans-departmental management of engineering policy. The Government should adopt a practice of formulating and following roadmaps for each major engineering programme with co-ordination between each of them. And the Government should be more strategic in its support for emerging industries and policy areas. To achieve these goals, the Government would benefit from having senior officials with appropriate skills and experience tasked to oversee engineering roadmaps and strategic plans. These officials should also manage engineering advice in a civil service with more specialised engineering expertise throughout.

The recent economic crisis has presented the Government with a once-in-a-generation opportunity to restructure the economy by building on the existing substantial strengths of UK engineering. Our report suggests how that could be achieved.

1 Introduction

> Engineers are essential to all things in life.[1]
>
> The Professor the Lord Broers

Why engineering?

1. From the stone age to the computer age, engineering innovations have facilitated a sustained improvement in the quality of life possible for humankind. Engineers design and construct the infrastructure that supports civilisation (buildings, roads, bridges, sewers, electricity and communication grids, satellites), the vehicles we use to get around (cars, ships, aeroplanes), power plants that give us energy (nuclear power plants, coal and gas stations, wind farms, hydroelectric plants), the products we use in everyday life (food, clothes, medicines, cleaning products, televisions, computers and mobile phones) and so much more. The ubiquity of engineering influence in modern life is undeniable, yet, perversely, "the extent and nature of engineers' and engineering's contribution go largely unrecognised, with people failing to make the connection between the technology they enjoy and the role of engineering".[2]

2. It is the combination of engineering's generic importance and the public's vague understanding of it that led us to conduct this inquiry. It fits neatly within our remit to scrutinise the policy, administration and expenditure of the Department for Innovation, Universities and Skills (DIUS) [3] and the Government Office for Science, which supports the Government Chief Scientific Adviser in his role to ensure that scientific and engineering advice across Government is sufficiently embedded in policy. Engineering cuts across every aspect of the work of DIUS—skills, further/higher education and innovation—as well as other departments.

What is engineering?

3. Our impetus for conducting an inquiry into engineering was partly the fact that engineering means—and engineers are—many things to many people. According to the Engineering and Technology Board the general perception of engineering is clouded by an outdated view and a lack of clarity—even within the profession—about what it constitutes.[4] It is easy to understand why: over the past few decades, the breadth of disciplines has ballooned so rapidly that many are hardly recognisable as engineering. It takes 36 professional institutions in the UK to represent such extraordinary diversity of activity. Coupled with this is engineering's deep value chain: research and development, design, production, distribution and services. Engineering is all of these things.

4. So how should we define engineering? A common definition is that engineering is the 'appliance of science': that "engineering translates science into realities".[5] This is certainly the case for much modern engineering, but engineers do not always need to be prompted by science or even need to understand the science behind a problem in order to come up

1 Q 68 [Ev 732]: Several sequences of oral evidence were taken during this inquiry (reflecting the case study approach). For ease of reference we include the evidence page number alongside the Q number.

2 Ev 169 [Engineering and Technology Board]

3 A Glossary is annexed to this Report.

4 Ev 169

5 Q 474 [Ev 67] [Mr Pamenter]

with a solution. For example, the engineers who built the first watermills knew nothing about fluid dynamics, nonetheless they built very effective mills. Engineers solve problems, and the end, not the means, is the motivating factor. As one witness put it: “scientists know and engineers do”.[6] So we prefer a more general interpretation of engineering: that ‘engineers turn ideas into reality’. It is perhaps a little simplistic, but we believe that it reflects both the motivation, creativity and breadth of engineers and engineering.

The profession

5. The engineering sector has developed in an ad hoc manner according to opportunity and historical conditions. Prior to the middle of the 18th century, engineering was almost exclusively a military endeavour, but the industrial revolution meant that civilians could increasingly make a living—and sometimes a fortune—from being an engineer. In 1818, the Institution of Civil Engineers was formed to make ‘civil engineering’ a profession in its own right. The Institute of Mechanical Engineers was founded in 1847, which was a reaction to a growing tendency to associate civil engineering purely with the construction side of the industry. The increasing importance of electricity and electrical engineers prompted the formation of the Society of Telegraph Engineers in 1871, which became the Institution of Electrical Engineers in 1884. The IEE has since merged with the Institution of Incorporated Engineers to form the Institution of Engineering and Technology in 2006. A complete list of professional institutions is provided in Table 1.

Table 1. A list of institutions registered with Engineering Council UK

Professional institution	Established
Institute of Acoustics	1974
Royal Aeronautical Society	1866
Institution of Agricultural Engineers	1938
Chartered Institution of Building Services Engineers	1897
Institute of Cast Metals Engineers	1904
Institution of Chemical Engineers	1922
Institution of Civil Engineers	1818
British Computer Society	1957
Energy Institute	1927
Institution of Engineering Designers	1945
Institution of Engineering and Technology	1871
Society of Environmental Engineers	1959
Institution of Fire Engineers	1918
Institution of Gas Engineers and Managers	1863
Institute of Healthcare Engineering & Estate Management	1943
Institute of Highway Incorporated Engineers	1965

6 Q 2 [Ev 721] [Professor Kelly]

Institution of Highways & Transportation	1930
Institution of Lighting Engineers	1923
Institute of Marine Engineering, Science and Technology	1889
Institute of Measurement and Control	1944
Institution of Mechanical Engineers	1847
Institute of Materials, Minerals and Mining	1869
Institute of The Motor Industry	1920
Royal Institution of Naval Architects	1860
British Institute of Non-Destructive Testing	1954
Nuclear Institute	1959
Society of Operations Engineers	1945
Institute of Physics	1874
Institute of Physics & Engineering in Medicine	1960
Chartered Institute of Plumbing and Heating Engineering	1906
Institution of Railway Signal Engineers	1912
Institution of Royal Engineers	1923
Institution of Structural Engineers	1908
Chartered Institution of Water and Environmental Management	1895
Institution of Water Officers	1945
Welding Institute	1923

Source: www.engc.org.uk/institutions/institutions.aspx

6. One of the key roles of these 36 professional institutions is to provide professional accreditation to practicing engineers. Setting professional standards for engineers and technicians and granting licences to organisations to allow them to register engineers is the responsibility of the Engineering Council UK (ECUK). ECUK grants three levels of engineering status, which are protected by law and can only be used by registrants: Chartered Engineer (CEng), Incorporated Engineer (IEng) and Engineering Technician (EngTech). Finally, there are the Royal Academy of Engineering, which was formed in 1976 to bring together eminent engineers to promote excellence, and the Engineering Technology Board, which was formed in 2001 to promote engineering and technology in society.

7. These are all representative bodies, working to promote and support engineering. The real engineering takes place in industry, universities and Government and its agencies. The engineering profession provided us with a joint submission, in which it pointed out that engineering's contribution to the UK economy is considerable:

> Engineering, with approximately 0.5 million professional engineers, brings technology, products and services to market and in doing so directly contributes (through SET-intensive sectors) approximately £250 billion, 27% of the total UK

GDP (2002). In 2006 engineering services directly contributed £3.2bn in exports to the Balance of Payments.[7]

8. There are over 250,000 students in further education studying engineering, manufacturing and technology courses. Around 90 higher education institutes in the UK have engineering departments,[8] teaching over 140,000 students, 100,000 of whom are undergraduates.[9] In Government, there are several departments and agencies that have an engineering role. The Health and Safety Executive, for example, employs 135 professionally registered engineers and the Ministry of Defence around 650.[10]

9. Co-ordinating the existing workforce's training requirements and promoting the next generation of engineers are a number of Sector Skills Councils and National Skills Academies. There are ten Sector Skills Councils that directly represent the engineering sector and five active Skills Academies. These are employer-led initiatives, providing the training and professional development support that industry needs. Working adjacent to these skills initiatives are a number of charities whose missions are to inspire the next generation of engineers and to improve the diversity of the engineering profession.

10. During the course of our inquiry we heard several complaints that the multitude of engineering institutions created a cacophony, out of which a clear and common message was often difficult to distinguish. For example, Lord Broers, the former President of the Royal Academy of Engineering, partly attributed the Academy's often muted voice to "a lot of competition from the institutions who want their voice heard as well".[11] Clearly the engineering community would prefer to provide a public voice that was more harmonious and focussed, and we are pleased to report that this inquiry has shown that this can be achieved. **The engineering community's approach to this inquiry has been coherent and co-ordinated, with the institutions working together to communicate a common message with and through the Royal Academy of Engineering. The Academy must take forward and formalise its leadership role, so that the engineering community can communicate—and co-ordinate—more effectively.**

The inquiry

Terms of reference

11. Witnesses to this inquiry were asked to provide evidence on the following points:

— the role of engineering and engineers in UK society;

— the role of engineering and engineers in UK's innovation drive;

— the state of the engineering skills base in the UK, including the supply of engineers and issues of diversity (for example, gender and age profile);

— the importance of engineering to R&D and the contribution of R&D to engineering; and

7 Ev 186

8 Guardian University Guide 2005

9 Higher Education Statistics Authority (HESA) 2006/07

10 Ev 788–790

11 Q 78 [Ev 735]

— the roles of industry, universities, professional bodies, Government, unions and others in promoting engineering skills and the formation and development of careers in engineering.

Conduct of inquiry

12. This was a wide-ranging inquiry. Over the course of 13 evidence sessions, we heard from a panel of young engineers, senior representatives from the engineering community, including the Royal Academy of Engineering, the Engineering and Technology Board, the engineering institutions and Engineering Council UK, charities promoting engineering, skills bodies, funding bodies, industry representatives, including large and small employers, venture capitalists and Government bodies, including four Ministers, two Chief Scientific Advisers and the Government Chief Scientific Adviser.

13. We also made a number of visits to inform our work. We visited Sizewell B on 15 July 2008 and in October 2008 we visited Shanghai, Beijing and Tokyo. We found these visits to be extremely useful and were struck by the high esteem in which UK engineering is held overseas. The Chairman and some members of the Committee went on a number of informal visits in September 2008, including Sellafield, Westlakes Research Institute, the Department of Physics and Molecular Vision at Imperial College London, Culham Research Institute; Research Councils UK, the Technology Strategy Board and the Printable Electronic Technologies Centre.

14. We conducted two e-consultations. The first, 'Engineering in the UK', which ran for six weeks in September and October 2008, was aimed at engineering employers who might otherwise not have had the opportunity to contribute to the inquiry. It sought out opinion on the future of UK engineering and what role the Government could play in promoting the sector. The second, 'Young engineers', set out to explore what young engineers thought about engineering as a profession and to find out why they had decided to pursue, or were contemplating, a career in engineering. A summary of both e-consultations is printed with the submissions we received.[12]

15. We would like to thank everyone who submitted written evidence, all our witnesses, those who helped organise and who we met on visits and all those people who contributed to our e-consultations for their invaluable contributions.

16. Finally, we would like to thank the specialist advisers who assisted the Committee throughout this inquiry. Professor Mike Gregory, Head of the Institute for Manufacturing at the University of Cambridge, and Dr Hayaatun Sillem, Head of International Activities at the Royal Academy of Engineering, were our primary advisers, and their tireless enthusiasm and expert advice helped to maintain a keen focus on the key issues in a challengingly broad inquiry. We would also like to thank the other advisers who contributed on the case studies: Dr Paul Howarth, Executive Director of the Dalton Nuclear Institute, University of Manchester; Professor Peter Liss, University of East Anglia; Professor Donal Bradley, Deputy Principal of the Faculty of Natural Sciences, Imperial College London; and Professor Sir Roy Anderson, Rector of Imperial College London.

Structure of report

17. The challenge of conducting an inquiry on such a broad and cross-cutting topic is that the inquiry itself becomes unwieldy. We therefore decided to take a case study approach.

12 Ev 792-799

To open the major inquiry, we held some exploratory sessions in which we identified key themes that we would seek to address. The first themes we chose to prioritise were skills and innovation. The following questions were raised:

- *on skills:* Is there a shortage of engineering skills? If so, what impact does this have on national engineering programmes? What roles do Government, universities, FE colleges and industry play in providing training? What can be done to raise the public awareness of engineering and engineers?

- *on innovation:* How could the Government best support commercialisation of emerging technologies and innovation? Is the Government sufficiently strategic in supporting engineering research? How does the UK capitalise on the economic potential of the engineering sector?

18. To explore these issues in some detail we chose two case studies. For the skills issues we conducted an inquiry on nuclear engineering (Chapter 2). For the innovation issues we conducted an inquiry on plastic electronics engineering (Chapter 3).

19. During the course of these case studies, further questions arose. For example, what factors need to be taken into consideration when looking at a new policy area? How does the international context of engineering impact national decisions on engineering policy? How do we inspire the next generation of engineers? How does engineering advice inform policy making in Government? To explore these issues in more detail, we conducted two further case study inquiries on geo-engineering (Chapter 4) and engineering in Government (Chapter 5). The terms of reference for all four case studies can be found in Annex 2.

20. Following the completion of the case studies, we held two wrap-up sessions, in which we attempted to broaden out the inquiry again and check that our detailed analysis held across a range of sectors (Chapter 6). In the time, and given the subject, it was impossible to be comprehensive in our coverage. However, we have tried to draw as many broad conclusions as possible and hope that they find agreement across the full range of engineering stakeholders.

21. During the course of this inquiry, the world economy went into recession. The severity of the economic crisis has made this subject all the more important as the international community reassesses the foundations of economic health. The UK Government has, like other nations, announced measures to protect and support its manufacturing base (announcing a package of support for the UK car industry potentially worth up to £2.3 billion, for example). Lord Mandelson, Secretary of State for Business, Enterprise and Regulatory Reform, has called for Government to engage in ‘industrial activism’, and to develop, as core national objectives, policies to improve the UK’s skills base, national infrastructure and regulatory stability. He added, with reference to the role of engineering in relation to the recession, “For the future, Britain needs an economy with less financial engineering and more real engineering”.[13]

13 HL Deb, 27 January 2009, col 178

2 Nuclear Engineering—Skills

> I think it is important to recognise that there is a skills gap, not only in nuclear engineering which it clearly is, but in engineering in general.[14]
>
> Dr Stephen Garwood, Director, Engineering & Technology-Submarines, Rolls-Royce

Background

22. Prior to starting this inquiry, we heard from multiple sources that the engineering sector was concerned about a skills time-bomb. Here is a small selection of the many facts, figures and opinion we received on this issue:

— the total number of registered engineers and technicians has declined from 263,999 in 1997 to 242,530 in 2006, which represents a fall of 8%;[15]

— there has been a 22% decline in the numbers of Chartered Engineers in all age groups under 55 years, a two-thirds decline in the numbers of Incorporated Engineers; and a 50% decline in Engineering Technicians;[16]

— one in ten organisations in the SEMTA footprint have had difficulties recruiting;[17]

— around 13% of graduates leave university with the most valuable science, technology, engineering or maths degrees and this needs to rise to at least 25% if the UK is to match the predicted growth in jobs;[18]

— "As engineering populations age and vacancies are 'booming' worldwide, the result is the visibility of the shortfall of young people entering the engineering profession. The result for many companies is a true shortage of engineers that is (and will continue) to endanger their growth and in some cases their existence."[19]

— 40% of National Grid's workforce will reach retirement age over the next 10–15 years.[20] The UK faces a "crucial skills shortage from 2015 to 2025 that will make power supplies less reliable and more expensive".[21]

23. This final point drives home one potential impact of a skills shortage. We decided to explore the skills issues in more depth by way of a case study on nuclear engineering.

24. The Prime Minister announced in July 2008 that Britain must build several new nuclear power stations over the next 15 years to replace ageing plants and contribute to a post-oil economy, with the first of the new reactors coming online in 2017.[22] Our reaction, like other interested observers, was concern that there might be a gap between the PM's

14 Q 49 [Ev 375]

15 *Engineering UK 2007*, p 60

16 *Engineering UK 2007*, p 63

17 2006 Labour Market Survey of the GB Engineering Sectors, April 2007, p 11

18 Ev 335 [CBI]

19 From the e-consultation 'Engineering in the UK' , Ev 792-799

20 Ev 131

21 Ev 150

22 www.guardian.co.uk/environment/2008/jul/14/nuclearpower.gordonbrown

desire for a rapid ‘nuclear renaissance’ and the UK’s capacity to deliver such a programme. We address this question in the following sections of the report.

Nuclear engineering in the UK

25. Extensive nuclear investment programmes in the 1950s created a world-class nuclear engineering capability in the UK. This was reflected in the building of nuclear power stations, reprocessing facilities, a nuclear defence capability, and world class R&D and university programmes. The UK is one of the few countries to have fully developed a closed nuclear fuel cycle with the ability to reprocess and recycle fuel as well as to deploy prototype fast reactors for breeding fuel. Additionally, fusion research in the UK is world leading. However, the ‘dash for gas’ in the late 1970s and 1980s meant that nuclear energy received less investment. The UK moved away from fast reactor technology, R&D programmes were cut, and eventually the teaching of nuclear engineering and related courses in universities declined. Eventually the Government decided to break up and sell BNFL.

26. As international recognition has converged on the need to reduce carbon emissions and increase security of supply, so has international enthusiasm for nuclear energy reignited. Worldwide, there are over 436 power reactors contributing about 15% of the world’s electricity.[23] As of January 2009, 43 new reactors were under construction around the world, 106 were being planned and 266 proposed.[24] Currently, many countries are revising their energy policy to include nuclear as part of a diversified mix. Countries with a legacy of nuclear energy that are committed to new build include: the US, France, Japan, Russia, China and South Korea. Many other countries are exploring or progressing new nuclear build, including Sweden, Finland, South Africa, Canada, Italy and Belgium. In addition, countries keen to use nuclear energy in the future include Thailand, Mexico, Argentina, Philippines, Qatar and Jordan.

27. There are 10 nuclear power plants operating in the UK,[25] but only three are planned to operate beyond 2020 (see Table 2).[26] Nuclear energy provides 15% of the UK’s electricity, but planned closures of nuclear power stations means that this figure will decrease over the next 10 years at the same time as the Government attempts to increase the amount of electricity produced per unit of carbon. If the UK is to maintain or grow nuclear energy’s contribution to the national electricity requirement, new nuclear power stations have to come online quickly.

23 www.world-nuclear.org/info/reactors.html

24 www.world-nuclear.org/info/reactors.html

25 Most of the power stations have 2 reactors. There are a similar number of reactors associated with the naval nuclear propulsion programme.

26 Ev 421 [British Energy]

Table 2. Nuclear power stations in the UK

Station	Owned by	Commissioned	Current Closure Date
Oldbury	Magnox	1967	2008
Wylfa	Magnox	1971	2010
Hinkley Point B	British Energy	1976	2016
Hunterston B	British Energy	1977	2016
Hartlepool	British Energy	1984	2014
Heysham 1	British Energy	1984	2014
Dungeness B	British Energy	1985	2018
Heysham 2	British Energy	1988	2023
Torness	British Energy	1989	2023
Sizewell B	British Energy	1995	2035

28. Clearly, nuclear new build is a significant engineering challenge, which, if it is to be completed quickly and safely, will require many engineers with relevant expertise and experience, as well as a fully connected supply chain. Even without new build in the UK, the entire nuclear industry employs over 18,000 graduates and skilled people, and that number will have to increase if the closing power stations are to be decommissioned. A study of Nuclear and Radiological Skills by the DTI in 2002 reported that the power, fuel, defence and clean-up sub-sectors of the nuclear industry would require approximately 1,000 graduates a year until 2017.[27] Of these, about 700 would be replacements for retirements and 300 in response to the growth in nuclear clean-up. In 2001, the year preceding the report, these sub-sectors were estimated to be recruiting about 560 graduates a year.[28] In addition to nuclear new build and decommissioning, the UK will have to consider legacy waste management, next generation naval propulsion and retention of a deterrent capability, not to mention the many other major civil engineering programmes that will be taking place nationally and internationally. In short, there will be significant competition for engineering skills.

The process for nuclear new build in the UK

29. The new build process has been summarised by the Dalton Nuclear Institute: "At the start of the project an intelligent buyer and regulatory capability is needed." The 'regulatory capability' in the UK begins with the Generic Design Assessment (GDA) process, previously known as 'pre-licensing'. The GDA process was devised by the nuclear regulators (HSE, the Environment Agency and the Scottish Environment Protection Agency) to assess the safety of nuclear plant designs. The Dalton Nuclear Institute continues:

27 This is a conservative estimate: the National Skills Academy for Nuclear estimates that 1,500 people need to be replaced each year, with an additional 11,500 over the next 20 years to complete the task of decommissioning, and 6,500 in other civil/defence sectors, which includes new build (Ev 431).

28 Ev 464 [Institution of Engineering and Technology]

> [T]he construction phase is very much akin to normal civil construction associated with any major infrastructure projects. Based on a new nuclear build programme being a £2bn per annum commitment, this represents a small fraction of the existing construction industry. Approximately 80% of the list items for a nuclear plant could be sourced in the UK, and the value of these components is approximately 50% as expensive [as] items sourced from overseas. […]
>
> With regards to decommissioning […], the end process may simply be bulldozing an historic building. As for nuclear power plant construction, this doesn't need any significant nuclear expertise. Where the nuclear engineering expertise is required is in understanding how facilities can be decommissioned.[29]

The state of play

30. In May 2007, the Government invited vendors of nuclear reactors interested in building nuclear plants in the UK to have their designs assessed against a set of eligibility criteria for the first stage of the assessment process. In July 2007, four such designs were declared eligible for the first stage of GDA: Atomic Energy of Canada Ltd submitted the ACR 1000; EDF-Areva submitted the EPR; GE-Hitachi submitted the GE ESBWR; and Toshiba-Westinghouse submitted the AP 1000.[30]

31. In January 2008, the Government published Meeting the Energy Challenge: A White Paper on Nuclear Power in which it announced that "it would be in the public interest to allow energy companies the option of investing in new nuclear power stations".[31] The Health and Safety Executive and the Environment Agency have completed the initial stage of the GDA process and concluded that "they could see no shortfalls at this stage—in terms of safety, security or the environment—which would prevent any of the designs from ultimately being constructed on a licensed site in the UK".[32] However, since then, Atomic Energy of Canada has dropped out of the process[33] and GE-Hitachi has temporarily suspended its application leaving only EDF-Areva and Toshiba-Westinghouse as potential players in the first round of new build.[34]

32. On 23 June 2008, *The Guardian* reported on a letter to BERR from Dr Mike Weightman, HM Chief Inspector of Nuclear Installations:

> Government plans for a new generation of nuclear power stations risk delays [and rising costs] after warnings by its own inspectors that no decision can be made on reactor designs because of a shortage of skilled engineers.[35]

Dr Weightman confirmed in oral evidence that he was struggling to recruit sufficient inspectors. He told us in July 2008 that he had 153¼ full-time equivalent inspectors and was expecting to recruit about 20 more people. He bleakly noted, however, that: "For existing predictive business *excluding new build* I need 192" [emphasis added].[36] The Minister confirmed that there "are some issues around skills capacity" in relation to the

29 Ev 416–417

30 www.hse.gov.uk/nuclear/reactors/index.htm

31 BERR (2008) 'Meeting the Energy Challenge: A White Paper on Nuclear Power', p 10

32 Health and Safety Executive website, UK Nuclear Regulators New Reactor Assessment, www.hse.gov.uk/newreactors.

33 www.hse.gov.uk/newreactors/index.htm

34 www.world-nuclear-news.org/print.aspx?id=23046

35 www.guardian.co.uk/world/2008/jun/23/nuclear.greenpolitics

36 Q 174 [Ev 394]

GDA process.[37] However, when we asked him if the Government will complete the GDA process on time, he optimistically—although not confidently—answered: "We believe we can".[38]

33. **The Generic Design Assessment (GDA) process is important and requires highly skilled inspectors. The Government should make available sufficient resources to the Health and Safety Executive and the Environment Agency so that they can recruit enough staff to complete the GDA process in a timely fashion and to the high standards required. A clear timetable should be published by the end of 2009.**

Skills shortages in nuclear engineering

34. We found plenty of evidence to suggest that there are very real skills shortages in the nuclear industry. As described above, it is the Generic Design Assessment and licensing of the nuclear technologies that creates the most immediate demand.[39] There are also shortages of HSE inspectors, safety case specialists, and project managers with nuclear experience.[40] However, across the nuclear engineering sector as a whole there is an oversupply of people qualified at S/NVQ Level 1 and below and S/NVQ Level 4 and above. It is those jobs for which S/NVQ level 2 and 3 qualified people are required—who account for 53% of the nuclear industry—where the deficit exists (see Figure 1).[41]

37 Q 240 [Ev 404]

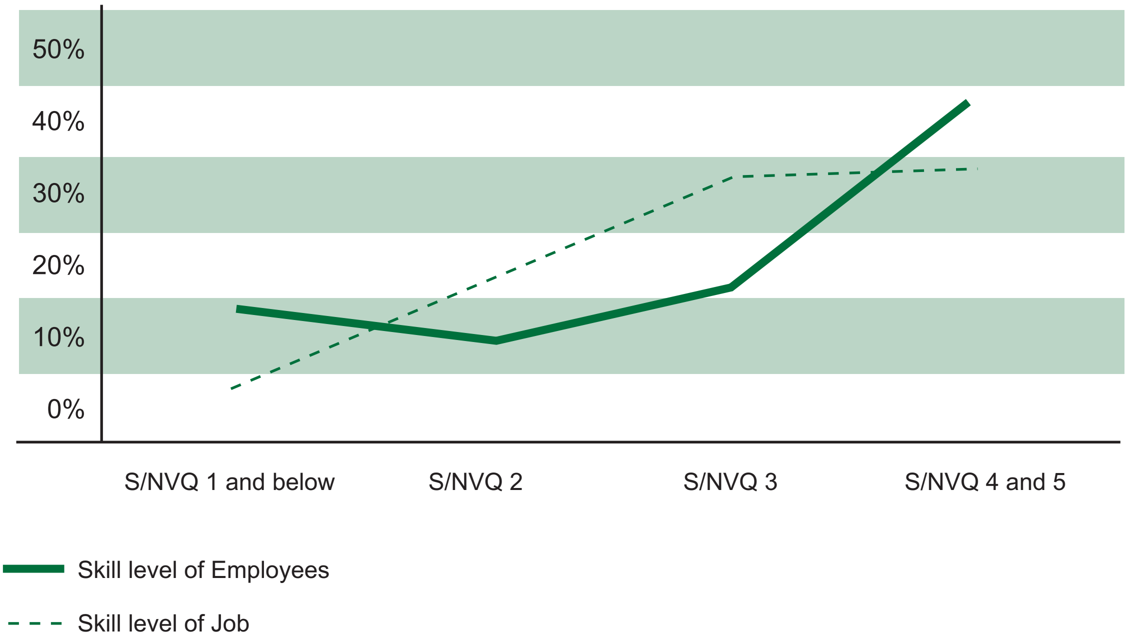
38 As above.

39 Ev 410 [BERR & DIUS]; Ev 454 [RAEng]

40 Ev 436 [Cogent & NSAN]

41 Ev 438 [Cogent & NSAN]. Cogent, in collaboration with other Sector Skills Councils, Skills Academies and Government bodies, has started a new labour market intelligence survey to update data across the nuclear industry, including new build and capturing the full capability in the nuclear defence sector.

Figure 1. Percentages of employees in the nuclear industry with S/NVQ levels 1–4 against required S/NVQ levels. From Cogent fact sheet, June 2008



35. Additionally, the nuclear industry has an ageing employee base:

> The SET [science, engineering and technology] workforce has a more ageing profile than the overall industry. 11% are due to retire over the next 10 years, but this could rise as high as 20% if early retirements at age 60 occur. Certain areas were found to have an older workforce, e.g. 44% of process & machine operatives are aged over 45. While overall demand for this group may be declining this is outstripped by the rate of retirements. Nuclear heat generation has an ageing profile with 18% due to retire over the next 10 years; however this could rise up to 33% if early retirements occur.[42]

36. Some concern has been raised that these problems in the nuclear sector will be problematic come the commencement of a new build programme. In particular, the already skills-short sector could be further damaged by internal competition for talent, between decommissioning, the military and civil new build.[43] However, the Royal Academy of Engineering noted that:

> There is nothing technically difficult in the decommissioning of the UK's graphite reactors. It does not require nuclear engineering because once the reactors have been defuelled there is no fissile material and hence no nuclear or criticality threats. […] Hence, there is no urgency requiring the diversion of nuclear engineering expertise to the task of decommissioning.[44]

Expert opinion on the feasibility of delivering new build

37. Despite reservations about the speed of the GDA process and skills shortages, we heard from academics, industry and the Government that the timetable for getting new

42 *Nuclear Employers Survey*, Cogent, 2005, p ii

43 Ev 451 [University of Central Lancashire]; Q 79 [Ev 380] [Clive Smith]

44 Ev 454

nuclear power stations up and running in ten years time is tight but achievable. Both Professor Jonathan Billowes, from Dalton Nuclear Institute, and Dr Stephen Garwood, from Rolls-Royce, agreed that the UK has not "missed the boat".[45] Alex Walsh, from BAE Systems, noted:

> We are heavily recruiting at the moment and we are heavily training. There are certain contractions happening in other areas of the aerospace industry, for instance, where there are very good structural welding engineers, aeronautical engineers, who have skills which are transferable with a degree of cross-skilling. It is addressable.[46]

38. When asked "is it doable", Fiona Ware, from AMEC, answered:

> Yes, I think so. We now have long-term visibility for the plans for a number of the programmes: the decommissioning programmes, the new build programme. Having that long-term visibility enables AMEC and other parts of the supply chain to plan to respond to that. We are doing an awful lot of recruitment. We are working with universities and working with schools, trying to encourage people into science and engineering, to make sure that we have the right resources available when we need them.[47]

39. We also heard from Robert Davies, from AREVA, and Adrian Bull, from Westinghouse, both of whom were in agreement. As Mr Bull put it:

> ***Mr Bull:*** This is one occasion where the timescales that the nuclear industry works to, which are quite long, actually help us out rather than the other way round. […] It is probably going to be of the order of five years before somebody puts a spade in the ground to start construction work on the first UK plant, whatever design that might be. Even if somebody were to sign a contract today, they would have to get through all of the licensing and site specific approval processes before they could start construction. There will be a significant lead time when supply chain companies know that there is a project there that they have to resource up to deal with. Like Areva, we are talking to a number of the supply chain companies and we have got a number of arrangements in place at one level or another. People will have that foresight. When we start to look to operation, it is another five years beyond that. When somebody puts the first spade in the ground then the operators of that plant will know that the clock starts ticking and in five years' time they need to have the appropriate number of trained and skilled operators.
>
> **Chairman:** So you are confident you can deliver?
>
> ***Mr Bull:*** Yes.[48]

40. Despite the general optimism, we did come across some warnings. The Institution of Mechanical Engineers told us that "the UK's capacity to build a new generation of nuclear power stations is uncertain".[49] And the Royal Academy of Engineering pointed out that, irrespective of whether the UK can deliver new nuclear power stations by 2018, "the UK could by no means be *self-sufficient* in the building of a new generation of nuclear power stations in the timescales required" (emphasis added).[50] The Government did not agree

45 Q 10 [Ev 369]

46 Q 94 [Ev 383]

47 Q 96 [Ev 383–384]

48 Qq 186–187 [Ev 395]

49 Ev 419

50 Ev 453

with this analysis and argued that "There is no reason to believe that we need to bring in any significant levels [of engineers] from abroad".[51]

41. **We note the Government's optimism that delivering new nuclear power stations within ten years is possible. However, we are not convinced that the skills shortage in nuclear engineering can be bridged quite as easily as some have suggested. In particular, the Generic Design Assessment, which kick-starts the whole process, is already running slower than expected, and the remaining workforce is ageing. The Government must continue its investment in engineering and nuclear engineering skills and produce a clear skills plan by the end of 2009 (see Paragraph 33), to ensure its nuclear new build ambitions can be met.**

The nuclear skills sector

42. Our report *Re-skilling for recovery* argued that the UK skills sector is overly complicated. It bemoaned "the multiplicity of planning organisations", which led to "duplication, confusion and employer fatigue".[52] We were therefore unsurprised to discover a typically diffuse set of organisations charged with promoting skills in the nuclear engineering sector, let alone the engineering sector as a whole.

43. There are ten Sector Skills Councils (SSCs) that directly represent the engineering sector (see Table 3). Although Cogent is directly responsible for nuclear, in the context of new build, ConstructionSkills, Energy & Utility Skills and SummitSkills are also directly relevant. The SSCs exist to reduce skills gaps and shortages by boosting the skills of existing workforces and promoting learning in each of their sectors.[53] To do this, they work with employers to develop, review and revise National Occupational Standards,[54] and to produce apprenticeship frameworks.

51 Q 243 [Ev 404]

52 Innovation, Universities, Science and Skills Committee, First Report of Session 2008-09, *Re-skilling for recovery: After Leitch, implementing skills and training policies*, HC 48-I, para 98

53 Skills 'gaps' and 'shortages' mean different things to skills specialists. Skills gaps exist when an existing workforce requires additional training: skills shortages require recruitment.

54 National Occupational Standards describe what an individual needs to do, know and understand in order to carry out a particular job role or function.

Table 3. Sector Skills Councils representing the engineering sector

Sector Skills Council	Representing…
Cogent	Chemicals and pharmaceuticals, oil and gas, nuclear, petroleum and polymer industries
ConstructionSkills	Construction industry
e-skills uk	IT and telecoms industries
Energy & Utility Skills	Electricity, gas, waste management and water industries
GoSkills	Passenger transport industries
Improve Ltd	Food and drink manufacturing and processing
Proskills	Building products, coatings, extractives, glass and print industries
Semta	Science, engineering & manufacturing technologies
Skillfast-UK	Design, manufacturing and servicing of clothing, footwear and textile fabrics
SummitSkills	Building services engineering

44. Working alongside the SSCs are National Skills Academies, which are employer-led centres of excellence that deliver training at all levels. The National Skills Academy for Nuclear (NSAN) is "focusing primarily on addressing the acute gap in technical and vocational skills".[55] This is in contrast to the National Nuclear Laboratory (NNL)—which describes itself as "the only commercially run organisation in the UK with a specific government remit to preserve and grow nuclear engineering skills"[56]—which is charged with maintaining the 'skills pipeline' at the other end of the spectrum: post-graduate and professional nuclear engineering. In between NSAN (vocational training) and NNL (postgraduate training) are the universities, which train young people in general engineering and in some cases specifically in nuclear engineering; for example, MSc courses such as the Birmingham University Physics & Technology of Nuclear Reactors or the Nuclear Technology Education Consortium (N-TEC) Course.

45. Although this brief description of the nuclear skills sector is a simplification, it is useful to outline the general areas of responsibility. During the course of the inquiry, we were not presented with such a description. It would have been of benefit, not only to us, but also to the Minister, who, relatively new in post, did not seem to know which institution has responsibility for each area of skills provision:

> We have the National Skills Academy for Nuclear and that is helping to develop […] the capacity in universities with degrees—Masters degrees in particular.[57]

46. Perhaps the reason for confusion is that although NSAN currently focuses on NVQ levels 2 and 3, it could (should the industry demand it) develop stronger links with universities and the NNL, which provide training at levels 4, 5 and above. Such employer-led flexibility is important, but is undermined in the absence of—at least we found no evidence for—a master plan for the provision of skills: how many people were needed at

55 www.nuclear.nsacademy.co.uk/about-us/about-skills-academy

56 Ev 498

57 Q 239 [Ev 404]

each NVQ level and in which field to deliver on the Government's nuclear ambitions. For example, as Professor Billowes put it:

> [W]e are going to need operators to operate plant[s] from 2018, and they should be in the educational system now and they need a career path; they have got to be suitably qualified and experienced, and getting experience takes years.[58]

47. **We welcome the formation of the National Skills Academy for Nuclear: employer-led training is the best way to ensure that industry gets the skills it requires. However, we also believe that there should be greater clarity from industry and Government about which institutions do what in terms of skills provision.**

R&D and skills capacity in nuclear engineering

48. Between the various programmes in civil and military nuclear fission and nuclear fusion, the UK has a strong research base in nuclear physics and engineering. The UK's fusion research is world-class. Researchers and engineers at UKAEA, Culham, look after JET[59], the world's largest tokamak[60] reactor, on behalf of the European fusion R&D community. Knowledge gained through research at Culham is directly contributing to ITER, the international collaboration to build a prototype commercial fusion reactor. The UK also has strength in nuclear fission engineering. In particular, as Dr Garwood from Rolls-Royce put it:

> There is a very strong strength on design still in [the UK]. [Rolls-Royce] has been designing pressurised water reactors for 50 years. [It has] 850 nuclear engineers in the broader sense working today on that activity and that is a continuing skill. There is also […] a very strong capability out in the supply chain and in certain industries in the nuclear area.[61]

49. Professor Billowes, Dalton Nuclear Institute, agreed that the UK "has a lot of expertise in different reactor systems",[62] but warned that research in this area is under threat since "we cannot get research money from EPSRC […] because there is the perception that the United Kingdom is no longer supporting advanced reactor R&D".[63] This perception is at least in part due to the UK's absence from several of the international research projects on fourth generation reactors. For example, in October 2006, the former Department of Trade and Industry (DTI) withdrew the UK from active membership of the Generation IV International Forum (Gen-IV or GIF) charter. The GIF programme was started in 2000 by nine countries, including the UK,[64] and is currently considering six reactor types. Although the UK retains GIF membership, it is a 'non-active' partner. The UK's withdrawal has been explained as a refocusing of DTI's priorities following the Energy Review towards near term objectives, and means that BERR will no longer provide the annual funding of up to £5 million for UK researchers to participate in GIF.[65] The Government said:

58 Q 9 [Ev 369]

59 Joint European Torus

60 A torus-shaped magnetic chamber

61 Q 5 [Ev 369]

62 Q 11 [Ev 370]

63 Same as above.

64 Introduction to Generation IV Nuclear Energy Systems and the International Forum, www.gen-4.org/PDFs/GIF_introduction.pdf

65 Ev 475 [Royal Society]

> We took a view that there were other areas that we wanted to prioritise. As you know, this technology and experimental work is unlikely to produce significant, commercial development until after about 2030. The aim is to ensure that we focus on other areas of research. We are involved in [Torus] and we are encouraging university research.[66]

However, we note AMEC's opinion:

> Participation in international collaborative R&D projects has proven to be a valuable training ground in maintaining and developing UK nuclear skills. For example, AMEC has been able to maintain a competent reactor physics capability to assess new reactor designs, rather than just provide ongoing support to existing designs. This has been achieved through participation in Generation IV programmes. The UK Government's withdrawal of support to these programmes is viewed negatively by industry and by our international partners as reducing the UK's standing in the international nuclear community and removing a vital industrial training route. AMEC strongly urges the Government to reconsider its support to these activities.[67]

We also note Professor Jonathan Billowes' comment:

> it is not just the Gen-IV programme. There are other [research programmes] in Europe [where] the UK is the only country missing from the table, like the accelerator-driven systems and energy amplifier systems. We do not seem to be engaging even with Europe in nuclear engineering areas.[68]

50. **The design of fourth generation nuclear reactors will go ahead with or without UK participation, and it is likely that the UK will want to start building fourth generation power stations in the future. The UK should avoid positioning itself so that it has little expertise in the very nuclear systems it needs in the future. In a post-oil economy, nuclear power will be a major player in the energy market and the UK should grasp enthusiastically the opportunity to take a lead role in the international nuclear industry.**

51. We estimate that it would only cost an additional £9 million per year to maintain and improve UK knowledge, capability and international involvement in nuclear engineering R&D projects. For example, Europe has an ambitious plan for a demonstration fast reactor by 2020 and the UK has capability in this area. However, unless UK researchers are able to contribute to the EU and GIF programmes, the UK runs the risk of being sidelined in future EU energy policy. Involvement in this research area would cost £1 million per year. Our full breakdown of areas in which the UK would benefit from research investment is given in Table 4.

Table 4. Proposed Annual Investment Requirement in Advanced Reactors & Fuel Cycle for UK to Maintain Knowledge, Capability and International Involvement

Research area	Estimated cost per annum	Consortia	Benefit/Reason
High temperature reactors	£2.0 m	Gen IV, EU, PBMR, NGNP	Small reactors for hydrogen economy and non-electricity use. Reactors well suited to deep-burning UK

66 Q 266 [Ev 408]

67 Ev 426–427

68 Q 35 [Ev 374]

			plutonium stockpile. Keeps UK knowledge of graphite developed for safety case support to existing Magnox and AGR Reactors.
Sodium Cooled Fast Reactors	£1.0 m	EU, Gen IV	Europe has an ambitious plan for demonstration fast reactor by 2020. The UK has capability in this area and unless UK researchers contribute, the UK risks being sidelined on future EU energy policy.
Fuel Cycle Technology	£2.5 m	EU, Gen IV, AFCI	Advanced fuel cycles are integral part of advanced reactors, but novel fuel 'treatment' technology is needed. There is a significant number of applications of novel fuel cycle technology to support treatment of legacy waste at Sellafield.
Novel LWRs	£1.0 m	EU, IAEA, IRIS	This R&D directly supports skills and capability for existing reactors, lifetime extension and the deployment of new Gen III systems.
Gen III R&D	£2.0 m	UK domestic	This is predominantly a domestic UK programme to support the establishment of the right capability, skills pipeline associated with the 'novel' aspects of Gen III systems that the UK needs to ensure it has intelligent customer capability, for example, thermal hydraulics, control and instrumentation, and safety systems.
International Engagement	£0.5 m	IAEA / OECD	The UK should ensure it plays a key role in international initiatives such as those coordinated by the IAEA or OECD. Otherwise the UK will lose influence in international nuclear energy development, industry and policy.
TOTAL	**£9.0 m**		

52. **The Government should consider which research programmes—including the Generation IV programme, EURATOM, and IAEA and OECD research programmes—are required to support its nuclear activities. We strongly recommend that the Government commission the National Nuclear Laboratory to conduct a cost-benefit analysis on what international R&D offers the UK in relation to maintaining UK nuclear engineering capability and ensuring future UK energy policy is supported.**

A way forward for nuclear engineering

53. During our visit to China and Japan, we were impressed by both administrations' approach to large scale engineering projects. The most impressive characteristic of the Chinese and Japanese Governments—in stark contrast to the UK—was an unwavering confidence that whatever was decided should be done would be done, on time and to budget. We noticed that the Chinese and Japanese officials referred to engineering projects with confidence in part because each project is accompanied by a detailed roadmap for delivery. Such roadmaps form the bedrock of the policy formulation and project delivery process—and their existence is linked to an unambiguous emphasis on the provision of

skills and also the importance of engineering advice that exists in those administrations (an issue to which we return later). If a person worked in an environment in which each project has a comprehensive plan for delivery that is acted upon and is always met, he or she would become confident in the ability of that administration to deliver complex engineering projects. This is not something that happens in UK Government. We have outlined above our concerns regarding uncritical optimism regarding the provision of skills for nuclear new build. Further, when we asked the Minister on the Government's plan to deliver an 80% reduction in carbon emissions, he said of the role of nuclear power:

> We do not have a statistical 'we want this percentage generation' but we have dropped over the last few years from about 19 per cent to about 15 per cent. We certainly would want to replace that sort of area with nuclear generation of electricity.[69]

54. When asked if he wanted eight stations as a hard and fast number, as had been reported in the newspapers, he replied:

> No. What we are looking at is how we can get a number of nuclear power stations going. Whether we get to the target we are aiming for will depend on a number of factors. You have already seen the significant announcement of EDF and British Energy which suggests we will get some development fairly quickly. By "fairly quickly" we are talking about 2017/2018.[70]

55. The Chairman summarised the Minister's performance during oral evidence: "With respect, you have not said a single thing about what you are actually going to do, other than that you are going to do it."[71]

56. Despite the lack of a plan, there is an acceptance that there should be a plan:

> **Mr Boswell:** Just to pursue the various players in this orchestra: the National Skills Academy for Nuclear, the National Nuclear Laboratory, the Nuclear Decommissioning Authority, Cogent, the Royal Academy of Engineering […], the universities […] and […] the new Nuclear Institute which is going to be formed out of the Institution of Nuclear Engineers and the British Nuclear Energy Society. You have added in two new bodies […]: the Office for Nuclear Development and the Nuclear Development Forum. How on earth is the Government going to conduct this particular orchestra, make sure it is all playing in tune and gets to the end of the piece at the right time?
>
> ***Mr O'Brien:*** Because we have set up the OND, the Office for Nuclear Development, it is their job in a sense to ensure that the conducting of the orchestra is done in a way that produces the tune that we want.
>
> **Mr Boswell:** They are in the driving seat?
>
> ***Mr O'Brien:*** They are essentially there to make sure everything works effectively. I demur slightly from being in the driving seat, they do not directly control companies or anything like that. It is their job to say, "This is where we are. That is where we want to be. This is how we get there." If somebody is going off at the wrong angle, then we tell ministers and ministers will have the job of pulling them back.[72]

69 Q 264 [Ev 408]

70 Q 237 [Ev 404]

71 Q 245 [Ev 405]

72 Qq 255–256 [Ev 406–407]

57. **We support the formation of the Office for Nuclear Development, but remain concerned about the lack of a clear and detailed plan for delivering the next generation of nuclear power stations. There should be a master roadmap for all major engineering projects, including nuclear new build. The Office for Nuclear Development should take ownership of the roadmap for nuclear. The roadmap should include consideration of: what skills are required over time and what will be needed to deliver the skills capacity ahead of time; other general engineering programmes and nuclear engineering programmes, both national and international; potential bottlenecks in the supply chain; and who is responsible for the delivery of each part of the roadmap. There should be six-monthly progress reports against the roadmap. The roadmap should be in place by the end of 2009.**

Case study conclusion: skills

58. The exploration of skills issues through the lens of nuclear engineering has proved a useful exercise. The key points we took out of this case study relating to skills were that:

— the consideration of skills shortages is a critical issue for the nuclear engineering sector;

— the Government must continue its investment in engineering and nuclear engineering skills and maintain a watching brief on the development of skills pertinent to its nuclear new build ambitions; and

— there should be better clarity from industry and Government across each engineering sector about which institutions do what in terms of skills provision.

59. Skills requirements will vary from sector to sector and we consider broader skills issues for the engineering community in Chapter 6. We are particularly mindful of the fact that the nuclear engineering sector has a long history of skills provision and that that is not the case in all engineering sectors. In the next chapter we consider an emerging industry that does not have such a history in skills provision: plastic electronics. The chapter focuses on issues relating to innovation and commercialisation; skills issues in relation to plastic electronics are considered in Chapter 6.

3 Plastic electronics engineering—innovation and commercialisation

> The message that I picked up when I started my life as a physicist is that one should never under-estimate the power of engineering to convert something that appears not necessarily to be promising into something that is spectacularly good.[73]
>
> Professor Sir Richard Friend, University of Cambridge

Background

60. Our decision to undertake this case study partly arose from comments by Professor Sir David King, former Government Chief Scientific Adviser (GCSA), on the potential for plastic electronics to disrupt global markets for electronic devices: "In Britain we have a world-leading position in a technology that could wipe out silicon chip technology and could convert photovoltaics into easily accessible materials at a much cheaper price, and I am talking about plastic electronics".[74]

61. As an emerging industry, the plastic electronics sector provides us with an opportunity to examine the transition of a technology from the research laboratory to the market place. Further, Professor King's assertion that plastic electronics is a sector in which the UK could lead the world provides for an opportunity to explore how the Government supports innovative industries, a discussion made all the more timely given that Lord Drayson, Minister for Science and Innovation (DIUS), has committed to leading "a serious debate about the areas of focus for this country in the future"[75]:

> I think that we need to look at the global environment, we need to note that the countries with whom we are competing have made strategic choices about the areas in which they believe they are best placed to focus.
>
> I think it would be actually good for the country to get a clear sense of what it is we think we can lead the world in over the next ten years.[76]

62. The Prime Minister has also alluded to the potential for Government to strategically support areas of scientific and technological strength, but made clear that he did not see this as a return to the industrial policies of the 1960s and 1970s where the Government attempted to pick winners:

> The picking winners strategy was about taking one company or a second company and saying that we were going to back this single company to the hilt, and it led, of course, to some of the problems of the old industrial policies. This is a policy of saying, look: there are sectors where we have got great genius. Biosciences, life sciences, is one; advanced sections of information technology is another; the creative

73 Q 19 [Ev 510]

74 Oral evidence taken before the Innovation, Universities, Science and Skills Committee on 5 December 2007, HC (2007–08) 115-i, Q 22

75 Uncorrected transcript of oral evidence taken before the Innovation, Universities, Science and Skills Committee on 26 January 2009, HC (2008–09) 169-i, Q 6

76 Uncorrected transcript of oral evidence taken before the Innovation, Universities, Science and Skills Committee on 26 January 2009, HC (2008–09) 169-i, Q 16

> industries are another. Let us back the development of skills and research in these sectors. That is what we are talking about.[77]

63. We would not advocate that the Government back individual companies. However, while the Prime Minister has recognised that “it is vital that our portfolio of early-stage, high-value businesses survive the downturn to secure our long-term future competitive advantage”, we are unconvinced that at the current time a disruptive technology could ever flourish in the UK. If this is to change, the Government must not only have the technical capacity to identify such innovations, but also design a mechanism for providing targeted financial support when required. We note that other nations have adopted the approach of very strong support for pre-competitive R&D via Government-funded institutions that engage closely with the industrial base at all levels and via Ministry-convened industrial consortia. This is especially true of Japan, Korea and Taiwan but is also evident within the German Fraunhofer Institutions and related consortia activities. We discuss these issues in further detail during this chapter and welcome, in principle, Lord Drayson's commitment to debate the future form and focus of UK science and engineering policy.

Plastic electronics

64. Semiconductor devices—electronic components made of semiconductor materials—are essential in modern electronic devices (mobile phones and computers, for example). Today, an inorganic material, silicon (Si) is used to create the majority of semiconductor devices used in commercial applications (with the exception of light emitting devices where III-V semiconductors are used[78]). Professor Sir Richard Friend, University of Cambridge, told us that plastic electronics research presents an opportunity to “use materials that one would call ‘plastics’, that is more correctly polymers, [… to] provide the semi-conducting behaviour”.[79]

65. ‘Plastic electronics’ can be broadly defined as the branch of electronics encompassing semiconductor devices, both organic and inorganic, fabricated by methods compatible with high throughput, and low temperature processes.[80] The difference between traditional electronics and plastic electronics is not necessarily one of electronic principles, but of materials and fabrication methods.[81] For instance, while silicon semiconductors normally need to be manufactured on rigid substrates, usually at high temperatures, plastic electronics offers the potential to print active semiconductor devices—such as thin film transistors (TFTs)—on non-conventional flexible substrates (plastic, metal or paper, for example). Professor Friend outlined the potential for increased manufacturing flexibility to impact on device functionality:

> At the moment, in order to make a circuit with electronic devices in it, you really have to make it on a very stable, expensive substrate—a slice of a silicon crystal, or a sheet of very expensive glass—and that means that these are prized items that have to be placed carefully and used carefully. If, on the other hand, we can have

77 Uncorrected transcript of oral evidence taken before the Liaison Committee on 12 February 2009, HC (2008–09) 257-i, Q 40

78 Semiconductor alloys made from elements from Group III and Group V on the periodic table, such as Gallium Arsenide (GaAs).

79 Q 13 [Ev 509]

80 Note that the Plastic Electronics sector is also referred to as ‘organic electronics’, ‘printed electronics’, and flexible electronics.

81 Q 13 [Ev 509]

functionality painted or printed everywhere, then there are huge ranges of applications for semi-conductors that are currently not served.[82]

66. Increased functionality is not the only benefit that plastic electronics can offer electronic devices relative to conventional technologies. Other advantages include waste reductions during manufacture through the use of biodegradable substrates and ultra-thin layers of material, and reduced energy consumption during manufacture and device use.[83] In developing products, the benefits offered by organic semiconductors must be weighed against the superior durability offered by silicon chips.

Niche technology or global opportunity?

67. Disruptive technologies function to create new technological markets, or transform or eliminate established ones. Past technological disruptions include telephony, the digital camera, and the computer. The potential for plastic electronic technologies to disrupt current markets was raised by Professor Sir David King when he told us that plastic electronics could "wipe out silicon chip technology" and that "it is exactly the sort of technology that will completely sweep aside existing technologies".[84] Technologies in development, and potential applications, are outlined in Table 5.

Table 5. Plastic electronic technologies

Technology	Benefits	Functionality
Organic Light Emitting Diode (OLED): Thin-film device with an organic layer that emits light when a current flows through it.	Relative to LCDs: lower weight, thickness and power consumption; readability from every direction; wide operating temperature; ultra-fast switching speed. Relative to conventional light technologies: longer life; lower environmental impacts; reduced energy consumption.[85]	Displays: mobile phones; MP3 players; televisions. Lighting: potential to displace conventional light sources such as fluorescent and incandescent lights.
Organic photovoltaic (OPV) cells: Light shone on OPV cells generates a current.	Lightweight, flexible and can be manufactured on a roll-to-roll web.	Contribute to renewable electricity generation, especially in the context of local generation where no grid infrastructure exists.[86]

82 Q 4 [Ev 507]

83 Ev 567, 578, 581

84 Oral evidence taken before the Innovation, Universities, Science and Skills Committee on 5 December 2007, HC (2007–08) 115-i, Q 22

85 Fluorescent lamps contain mercury.

86 Ev 547, 597

Radio-frequency identification (RfID): Wireless recognition technology that store and allows remote retrieval of data.	Potential for radical cost reduction through all-printed or 'chipless' RfID.[87]	RfID tags can be applied to or incorporated in objects for the purpose of identification
Non-light-emitting Displays: Reflective or transmissive properties of a material are changed locally via the action of an electric field.	Displays can be produced on flexible plastic, metal or even paper substrates.	Products include: an LCD display that can be rolled out of a mobile phone; e-readers; e-books.[88]
Sensors	Depositing plastic electronics circuits onto a surface using ink-jet (and other) printers would make it possible to produce cheap electronic 'chips'/sensors.	Intelligent packaging to display: if food or liquid is "off"; time during storage/transport.[89] Medical sensors: monitor/diagnose health conditions. [90] Flexible patches for localised photodynamic therapy for the cure of certain skin cancers.[91]

68. Estimates of growth in the plastic electronics market appear to support Professor King's view of the sector's potential. IDTechEx—a company that provides global analysis of the printed electronics industry—estimated that the worldwide market for printed electronics will increase from $1.18 billion in 2007 to $48 billion by 2017 and $330 billion by 2027, and technology analysts suggest that new markets in the sector could be valued at hundreds of billions of dollars in twenty years time.[92]

69. Rapid growth in the global plastic electronics market was expected by some of our witnesses.[93] For example, Dr Keith Rollins, Dupont Teijin Films (a manufacturer of plastic substrates), told us that "this industry is on the brink of explosive growth",[94] and Professor Friend identified plastic electronics as having "all those indicators to say that it can be disruptive".[95] However, Dr Ian French (who works on a silicon-based technology) and M-Solv (a company working on a technology that is competitive to plastic electronics) were more cautious, the latter stating that: "it is simply not the case […that] OLED [Organic Light Emitting Diodes] and plastic transistors will be the dominant electronic system to supplant inorganic (silicon) technology for the foreseeable future".[96]

70. The potential for plastic electronics research to create new products, and even entire new industries, was identified by the Council for Science and Technology (CST) in its

87 Ev 552

88 Ev 547, 552, 564, 573, 578

89 Ev 581

90 Ev 557, 581; www.molecularvision.co.uk

91 Ev 557, 581; www.molecularvision.co.uk, www.lumicure.com

92 Ev 562, 595, 597

93 Q 5 [Ev 507], Q 118 [Ev 526], Q 128 [Ev 527]

94 Ev 589

95 Q 2 [Ev 507] [Dr Ian French]; Ev 600 [M-Solv]

96 Ev 600

2007 report, '*Strategic decision making for technology policy*'.[97] To enable the UK to take a strategic view of where to concentrate support mechanisms, and to capture as much value as possible from this developing market, CST recommended that the Government undertake a comprehensive value chain analysis of the plastic electronics sector. Asked whether it intended to implement this recommendation, DIUS reported that the project had been completed by BERR, in collaboration with UK Trade and Investment (UKTI), and the outcomes published in '*Plastic Electronics in the UK—A guide to UK capability*'.[98]

71. We do not believe the content of the BERR/UKTI report equates to the 'value chain analysis' called for by CST. Rather than identifying where the potential value in the sector lies, and how the UK might capitalise on these opportunities, the report describes plastic electronic technologies and catalogues the interests of university and businesses active in the sector. DIUS highlights work conducted by Dr Zella King, University of Reading, as a further effort to analyse the UK's plastic electronic sector.[99] In June 2008, Dr King produced a 'Competence Matrix' intended to "aid understanding about how near we are to bringing products to market in the UK, what kinds of markets the UK might be able to dominate, and the feasibility of collaboration to bring technologies to market".[100] Although valuable, this research does not provide a comprehensive roadmap for taking the industry forward.

72. **The UK is well placed to capitalise on the economic potential of the growing plastic electronics industry. However, we are concerned that without a clear understanding of how best to build on and market the UK's strengths in this sector this opportunity might not be fully realised. We urge BERR to engage with the Technology Strategy Board, UK Trade and Investment, UK Displays and Lighting Knowledge Transfer Network and the plastic electronics community to develop a technology roadmap. In constructing this roadmap it is essential that stakeholders across the sector be consulted, from spin-out companies to multinationals.**

Research infrastructure

Funding

73. Professor Sue Ion, Royal Academy of Engineering, told us that "Access to capital is a key issue to get you from good laboratory scale work through to a prototype that you can then industrialise".[101] UK-based research relevant to the development and application of plastic electronic technologies is supported by both public and private finance. We review funding sources, their interrelationships and their potential to support innovative research below.

Research Councils

74. The Engineering and Physical Sciences Research Council (EPSRC) is the principal public funder of plastic electronics research.[102]

97 Council for Science and Technology, *Strategic decision making for technology policy*, November 2007

98 BERR, *Plastic Electronics in the UK: a guide to UK capability 2008–09*, April 2008

99 Ev 604

100 www.printedelectronics.net/PlasticElectronicsintheUK.htm

101 Q 6 [Ev 508]

102 Note that Dr Zella King's research was funded by the ESRC.

75. EPSRC invests a total of around £740 million per annum in research and training activities, of which £68.2 million is spent on research, training and knowledge transfer activities of "direct relevance to the area of plastic electronics".[103] 42% of this investment is provided to universities through investigator-led research, 38% is spent on projects in collaboration with industrial partners and other stakeholders, and 3.8% of the total is invested in the training of postgraduate students.[104]

76. While we welcome EPSRC's investment in plastic electronics research, we note that the funding level it reports is for projects that are "playing within the plastic electronics space".[105] Consequently, these funds might also be counted as supporting other research areas (for example the development of micro- and nano-technologies or more fundamental synthesis and molecular modelling activities).

77. We recognise that the multidisciplinary nature of plastic electronics research may make it difficult to identify those projects specific to the sector, and believe this makes EPSRC's investments in centres such as the Cambridge Integrated Knowledge Centre and the Organic Materials Innovation Centre (based in Manchester)—which provide support for plastic electronics research—even more valuable. We note also that since starting this inquiry, EPSRC has announced: (a) a programme for joint funding of Japanese-UK co-operative research projects in the area of "Oxide Electronics, Organic Electronics and Spintronics";[106] and (b) the establishment of a Doctoral Training Centre focused on the science and application of plastic electronic materials.[107] We welcome these developments.

The Technology Strategy Board

78. The Government established the Technology Strategy Board through the former Department for Trade and Industry (DTI) in 2004. As a business-focused organisation, the Technology Strategy Board is charged with stimulating "technology-enabled innovation in the areas which offer the greatest scope for boosting UK growth and productivity".[108] It has operated at arm's length from Government as a non-departmental public body (NDPB) since 1 July 2007.

79. As at June 2008, the total value of plastic electronics projects supported by the Technology Strategy Board was £52 million, of which £27 million is provided by industry.[109] When asked about the value of the Technology Strategy Board's funding programmes, Richard Price told us that his spin-out company, Nano e-Print, had found them to be "incredibly important":

> Firstly, it brings together consortia that would not necessarily have come together unless there was government support to share the risk. Secondly, it helps us in terms of our cash flow and enables us to further develop before we have to go back to the market for more investment. It also helps us build relationships with some of the

103 Ev 584

104 As above.

105 Q 40 [Ev 585]

106 Spintronics is an emerging technology that harnesses the spin of particles. www.epsrc.ac.uk/CallsForProposals/Archive/JSTCollaborativeCall.htm

107 A collaboration between Queen Mary University of London and Imperial College London. www.epsrc.ac.uk/PostgraduateTraining/Centres/NewCentres.htm

108 www.innovateuk.org/aboutus.ashx

109 Ev 560

> knowledge transfer networks and to grow organically some of our networks within industry.[110]

80. **We welcome the support for plastic electronics research and development provided by EPSRC and the Technology Strategy Board, and believe sustained support by these organisations is vital to the growth of the industry.**

A Managed Programme in plastic electronics

81. Set up by the then DTI, the UK Displays & Lighting Knowledge Transfer Network (UKDL KTN) was established "to support the disparate needs of the Displays and Lighting communities in the UK including small and medium-sized enterprises (SMEs), OEMs [Original Equipment Manufacturers] and academics".[111] Since its establishment, UKDL KTN's role and remit has evolved, and the network now provides a forum within which the plastic electronic community can "meet and cross-fertilise ideas, to encourage innovation in the field".[112]

82. In 2006, the former DTI and UKDL KTN engaged with the UK plastic electronic community to develop a comprehensive analysis of the sector's opportunities for growth, and to identify specific needs for targeted support. Logystyx UK Ltd told us that this process resulted in a proposal for a Managed Programme that would ring fence £50 million funding for R&D investment into plastic electronics over a period of up to 5 years:

> [T]he proposal was centred on the premise that the PE [plastic electronic] community is best positioned to assess its own progress and to identify its own needs for short- and medium-term research activities. It was planned that an investment panel comprising a representative selection of companies and academics would identify the particular technology hurdles that needed to be addressed at any time, and would run a mini-competition to solicit project proposals against those topics. The Panel, together with DTI would agree projects to be selected for support, and the projects would then be funded under the normal rules. This proposal was very well received but coincided with the split of DTI into DIUS & BERR. The structural change prevented the proposal for a Managed Programme being taken forward.[113]

83. During this inquiry, we heard support for the planned introduction of the Managed Programme, and disappointment that the project had not been taken forward. Dr Stuart Evans, co-founder of Plastic Logic, said:

> Chris Williams [Director of UKDL KTN] has done a great job at building the UKDL [KTN] into something quite cohesive, but there is a step further to go I think, and that would be a very desirable outcome, and I think if we had had the managed programme where essentially there had been a commitment to spend the money, which is being spent anyway, industry would have had more control over that and I think that would have been very helpful.[114]

84. Asked whether he hoped to revive plans for this project, Chris Williams, Director of UKDL KTN, told us that while "the concept of a managed programme is essential for this

110 Q 165 [Ev 534]

111 www.ukdisplay.net

112 Ev 562

113 Ev 579

114 Q 177 [Ev 536]

nascent industry", neither BERR or the Technology Strategy Board was receptive to the proposal. He explained that the latter:

> Have their own interpretation of innovation: they have their innovation platforms, they have the collaborative research programme, they have the knowledge transfer networks […] but at the same time they have no vehicle in position today to run a managed programme in the way the DTI used to do—they have no facility at all—and it would be very valuable for our sector, and I am quite sure it would be the same for other sectors, if that were added to their armoury of tools.[115]

85. Asked why his organisation had not honoured the former DTI's commitment to a Managed Programme, Mike Biddle, Technology Strategy Board, told us the £38 million investment made in plastic electronics, some of it in conjunction with Research Councils, "is not a million miles away from that £50 million that was discussed as part of that investment programme".[116] Further, he asserted that it was not just a case of "throwing money at the problem", but about bringing people together and "attracting new thinking into the area" in order to leverage an investment for the benefit of the UK. [117]

86. Although we welcome the financial support provided to the plastic electronics community by the Technology Strategy Board, we do not see the vehicles used to deliver R&D funding as comparable to the Managed Programme proposed by UKDL KTN and the former DTI. The Managed Fund proposed to fund research projects at 100% of cost. By contrast, the Technology Strategy Board funds academic collaborators for up to 80% of their Full Economic Costs, industry partners for 50% of eligible project costs, and SMEs for up to 60% of project costs.[118]

87. The Technology Strategy Board's funding schemes target two forms of collaborative working: science-to-business (a university/business partnership) and business-to-business. Engaging in a science-to-business collaboration may be an attractive prospect for a start-up/spin-out company. However, as universities are unlikely to provide significant levels of project funding, the brunt of any financial commitment would most likely be borne by the fledgling SME. We are concerned that together these factors combine to put the financial commitment required to apply for a grant beyond the reach of many start-up companies, and that, rather than support innovative work by fledgling businesses and grow a new industry, the Technology Strategy Board's grant schemes principally act to support established concerns.

88. Finally, we do not consider the Technology Strategy Board to be unique in its ability to bring people together. As we outlined previously, UKDL KTN is appreciated for just this ability. Indeed, Dr Rollins told us that there is "a strong sense of community around this space [plastic electronics] with the KTN playing an important role".[119]

89. **We do not believe that the Technology Strategy Board's grant schemes and the Managed Programme proposed by UKDL KTN and the former-DTI are mutually exclusive forms of support. UKDL KTN champions the needs of the plastic electronic community, and as such we urge BERR and the Technology Strategy Board to engage with it, and to reconsider the deployment of a Managed Programme in this area.**

115 Q 107 [Ev 524]

116 Q 44 [Ev 515]

117 As above.

118 www.technologyprogramme.org.uk/site/Documents/default.cfm

119 Ev 590

Venture capital

90. Venture Capital (VC) has provided significant levels of financial support to a number of UK companies involved with plastic electronics. Lord Drayson of Kensington, Minister for Science and Innovation (DIUS), told us that the very fact these companies have raised significant VC is "the best evidence that one can take for the independent assessment of this area of technology having a high impact".[120]

91. The largest single VC investment in Europe was raised by Plastic Logic. Plastic Logic raised $50 million between 2000 and 2006 to develop its technology, and more than $100 million in 2007 to build its first factory in Dresden, Germany.[121] However, the Institute of Physics told us companies attempting to repeat Plastic Logic's fundraising success "experience difficulty in obtaining private funding".[122] Nano e-Print believed that commercial investment in plastic electronics, particularly VC, needs to be increased.[123]

92. One factor that may limit VC investment in this sector is that investors are unlikely to see a return on their investment in the short-term. However, Dr Tom Taylor, Printable Electronic Technology Centre (PETeC), identified a wider problem, suggesting that the UK investment sector tends to be 'risk ignorant' when it comes to financing technological development or advising on investment decision making:

> The city institutions understand financial risk. They need to engage with bodies which can help them appreciate the technology risk […] that is something where there has historically been a gap.[124]

93. The need to address this information deficiency and drive up private investment in the sector was underlined by Professor King, and his belief that financial backing from the Treasury alone would be insufficient to allow a 'winning technology' to fulfil its potential:

> [I]t is not just government funding I am looking for, it is stimulating that wonderful city [City of London …] to understand the opportunity on its front door step.[125]

94. We asked the Minister whether, given the global economic downturn, it was realistic to expect the City of London to support innovative industries such as plastic electronics. His response provided us with some optimism that such investment would be forthcoming:

> These are really challenging times for business generally, clearly, but if one looks at the opportunity for hi-tech, high-growth businesses in the context that those are the businesses which are going to deliver the growth in the future, it is very important both for the private and the public sector not to eat the seedcorn during a time of difficulty. […] I am actually quite optimistic that there will be a renewed look at venture capital investments as an alternative for hedge funds. I have already seen some anecdotal evidence […] I am really quite optimistic.[126]

95. **The future success of the UK plastic electronics industry not only lies in its ability to lever public and private finance, but also in the co-ordination of funding sources.**

120 Q 187 [Ev 538]

121 Ev 572

122 Ev 598

123 Ev 555

124 Q 116 [Ev 525]

125 Q 121 [Ev 526]

126 Q 188 [Ev 539]

We recommend that BERR, the Technology Strategy Board and UKDL KTN take immediate steps to increase the understanding of technological risk in the private sector, and to review the funding landscape.

Research centres

96. There are five centres in the UK that provide support to the plastic electronics industry (Table 6). To ensure these organisations function as a co-ordinated national resource, each Centre is represented on its counterparts' board. Chris Williams, UKDL KTN, told us he believed this co-ordinated working has functioned to create a "multi-legged support platform" for UK industry while allowing each Centre to maintain a speciality focus.[127]

127 Q 133 [Ev 528]

Table 6. The five research centres supporting UK plastic electronics research, development and demonstration

Facility	Background
Welsh Centre for Printing and Coating (WCPC)	• Based at Swansea University. • Expertise in preparing and characterising functional electronic inks and pastes, and a variety of sheet-fed and roll-to-roll printing processes.
Printable Electronics Technology Centre (PETeC)	• Located in Sedgefield. • National open-access prototyping institute for the development and commercialisation of printed electronics. • Customers of the centre will be able to test design concepts and novel materials for a variety of products including Thin Film Transistors (TFT) for flexible displays including e-paper, organic photovoltaic cells (OPVs) and solid state lighting (SSL) applications.
Centre for Process Innovation (CPI)	• Based in the North East. • Process services include: integrated demonstrations and assessments of new bio, chemo and physical transformations; atomic layer deposition and reel-to-reel vacuum coating; printable electronics prototyping; development and testing of alternative energy applications. • Provides consultancy services. • Engages in 'development partnerships' with organisations such as DuPont and Oxford Instruments. • CPI is part of the same organisation as PETeC and the Centre of Excellence for Nano, Micro and Photonic Systems (Cenamps).
Organic Materials Innovation Centre (OMIC)	• Based in Manchester. • Government supported the University Innovation Centre for speciality organic materials and polymer industries (principally EPSRC funded). • Facilities for the synthesis and purification of the chemicals required for innovative organic materials chemistry. • Works with industry to define and execute research and technology programmes into organic materials and their application.
Cambridge Integrated Knowledge Centre (CIKC)	• Principally EPSRC funded. • Established to develop advanced devices and related manufacturing technologies.

Printable Electronics Technology Centre

97. Located in Sedgefield in the North East of England, PETeC was established with a joint investment of £6.3 million from OneNorthEast and County Durham Economic Partnership (including around £5 million from Northern Way). A further £3.8 million of capital investment was sourced from European Regional Development Funds, and the Technology Strategy Board contributed £2.1 million towards the first platform of equipment installation in the Centre.

98. Professor Ion, Royal Academy of Engineering, told us that the Centre—an incubator for SMEs—provided a valuable opportunity for technology developers to "plug in and play",[128] making available access to capabilities around substrate preparation, materials formulation, device modelling, process development and process integration using

128 Q 29 [Ev 512]

advanced printing techniques. However, throughout this inquiry PETeC attracted significant criticism in three areas: geographical location; proposed business model; and provision of services. We deal with each of these concerns below.

99. The suggestion that PETeC may not be "geographically correct"[129], appeared to be based on its distance from those academic research groups engaged in cutting edge research (University of Cambridge and Imperial College London, for example).[130] In defending the Centre's location, Nigel Perry, Chief Executive Officer of the Centre for Process Innovation (CPI), made two points. First, that the skill-set in the region is "significant" (we note that Siemens had a facility nearby until recently), and second, that people needed to "stop thinking about the UK regionally and start thinking about the UK operating together as a whole", arguing that the five centres, distributed around the UK represent the assembly of a national capability.[131]

100. **PETeC's location is a function of the fact that it was established as a regional initiative. It is an open question whether PETeC would have been sited elsewhere had it been founded as a national resource, something that it undeniably is. However, we do not see further discussion on this issue as constructive or worthwhile, and wish to see a line drawn under the debate.**

101. The second criticism levelled at PETeC centred on the nature of its business model. Plastic Logic told us that rather than supporting UK entrepreneurial activity, PETeC's business model appeared to be revenue driven with a significant focus on contract research for "a small number of giant Asian electronics companies", and that the Centre had "struggled to define and articulate a compelling vision of how it will benefit the UK plastic electronics community as a whole".[132]

102. We put the concerns of Plastic Logic to Dr Tom Taylor and Nigel Perry. They explained that, at the current time, overseas custom was vital to the sustainability of the centre for three reasons. First, PETeC's funding arrangements require the Centre to have transitioned from being publicly financed to financial self-sustainability within five years. Economic activity in the UK plastic electronics sector is, however, currently insufficient to meet this demand. Second, to qualify for grants under publicly funded research competitions, such as those run by the Carbon Trust, it is necessary to match the public funding sought with private funding. Without overseas custom, PETeC may be unable to raise the finance necessary to participate in these competitions. Finally, engaging with overseas investors allows PETeC to prove its competence and improve its business credentials.[133]

103. We asked Mike Biddle, Technology Strategy Board, whether he agreed that the requirement for Centres to become financially self-sustainable over the relatively short-term detracts from supporting innovative UK research. He disagreed, reporting that it "creates a dynamic tension", and that, while there was a line to walk between supporting UK and overseas customers, interaction with the Far East is "almost a badge of honour".[134]

104. **We are sympathetic to PETeC's need to generate income in order both to assure its future survival and to allow it to participate in UK grant competitions. The**

129 Q 6 [Ev 508]

130 Q 27 [Ev 512]

131 Q 148 [Ev 531]

132 Ev 574

133 Q 147 [Ev 531]

134 Q 74 [Ev 519]

Technology Strategy Board and OneNorthEast should review whether the requirement for self-sustainability within five years is realistic.

105. The third, and final, concern focused on the services PETeC intends to offer. For example, Dr French reported the Centre to be focusing on one particular research capability (roll-to-roll processing), a decision he considered to be high-risk in terms of ensuring the Centre's sustainability. However, Dr Taylor reported this to be:

> [M]isunderstanding the complexity of the situation. People see the very impressive roll technology that we have assembled at Wilton in combination with Dupont Teijin. We have not been able to show people all the new technology that is emerging in PETeC, I think it is probably fair to say, but it is diverse. It has to be.[135]

106. **We urge PETeC to continue developing its relationships with other Research Centres, and to liaise with these Centres to ensure national capability in facilitating R&D across the spectrum of plastic electronic technologies.**

University research base

107. The UK has a strong academic base in plastic electronics, with world-class research activity at a host of universities.[136] A number of university-based activities are now substantially larger in scope than the Centres that support the sector. For example, the Imperial programme comprises some 70 people, whereas the Welsh Centre for Printing and Coating employs 15 staff, has 6 PhD students and 2 visiting students, and PETeC expects to recruit 12 staff.[137]

108. In order to support high-quality research, Plastic Logic believed it was essential for UK-based academics to be able to access high quality research facilities and equipment:

> [I]f academic groups have access to plastic electronics devices made in state-of-the-art industrial facilities (rather than university labs) they are more likely to generate breakthrough insights that will improve manufacturing effectiveness.[138]

109. We were therefore disappointed to hear that despite the UK's network of publicly funded centres, UKDL KTN's academic members:

> [C]ommented that with few exceptions, they seldom get to perform research work on state of the art materials and devices, or to use the latest metrology equipment. They are concerned that their research activities can go largely unnoticed by industry, which may not readily interpolate the improvements that would be seen if the work was conducted on the best available materials/equipment.[139]

110. During a visit to Imperial College London, academics told us that capital equipment used for plastic electronics research in UK university laboratories was not globally competitive. In particular, Swiss, US and German research groups were considered to be better provided for, and several researchers maintained collaborations with research groups in other EU countries such that their students could access state-of-the-art equipment.

135 Q 146 [Ev 530]

136 Universities of Cambridge, Durham, Hull, Imperial College London, Liverpool, Manchester, Oxford, QMUL, Sheffield, St Andrews, Surrey and UCL.

137 www.ukpetec.com/pages/about/faqs.htm#6

138 Ev 574

139 Ev 582

111. Some of the initiatives launched to support plastic electronics research in countries such as the United States and Germany are outlined in Table 7.[140]

Table 7. Initiatives to support the plastic electronics industry

Country	Support
United States	Public support for plastic electronics research in the United States comes principally from the Division of Materials Research, National Science Foundation (NSF). NSF funds 14 Materials Research Science and Engineering Centres (MRSECs). The University of Minnesota MRSEC is the primary centre for plastic electronics research and has received about $14.9 million over the past seven years. The Center for Organic Photonics and Electronics at Georgia Tech Centre will receive $8.1 million over the next six years.
Germany	The Federal Research Ministry (BMBF has promoted plastic electronics research through a number of public-sector funding initiatives). These include: €100m to promote pre-competitive research and development of OLEDs; €360 public-private-partnership initiative in the area of OPV. The Federal Government, the Free State of Saxony and the European Union have invested a total of €25m in the Centre for Organic Materials and Electronic Devices Dresden. Fraunhofer Institute for Photonic Microsystems (IPMS) has an annual budget of €23m (including €14m from the public sector). The Government of the Free State of Saxony has allocated a total of €9.2m to R&D projects in the area of polymer electronics.
Japan	The New Energy and Industrial Technology Development Organisation (NEDO) is conducting two research programmes in the area of organic electroluminescence: ‘Basic technology for next generation large OLED display (2008/12, £173 million programme); and ‘High-efficiency Lighting Based on Organic Light-Emitting Devices’ (2007/09, £6 million programme).[141]

112. **The plastic electronics industry is likely to grow substantially over the next few years. Although the UK’s research base puts it in a unique position to capitalise on this growth, we must not be complacent as countries such as Germany and the USA are becoming increasingly competitive. We recommend that the Research Centres supporting UK plastic electronics R&D engage with the academic research base to ensure state-of-the-art facilities are accessible to the academic community.**

Bringing products to market

Commercialisation

113. Devices utilising plastic electronics components are currently on the market. For example, OLED displays are used in some mobile phones and MP3 players. Sony brought the first television with an OLED display to market in December 2007, and during our visit to Japan we learned about the next generation of OLED technology in the form of a Sony television with a screen just 0.9 mm thick.

114. The UK is leading in the early commercialisation of many first-generation plastic electronic applications. Elumin8 manufactured the large electroluminescent display in the First Class lounge at British Airways’ new Terminal Five—although this company has

140 Ev 354-364

141 Myoken Y., *Overview of organic electroluminescence R&D in Japan*, British Embassy, Japan, 2008

since ceased trading—and Pelikon manufactures electroluminescent displays for high-end Universal Remote Control Units at its factory in South Wales.[142]

115. The Council for Science and Technology (CST) identified the UK as having the potential to be a world-leader in the plastic electronics supply chain, but cautioned that:

> The risk is that key parts of the value chain move outside the UK, or that spin-out companies are bought up by major IT multinationals at such an early stage that the plastic electronics industry never fully develops a manufacturing and product infrastructure in the UK.[143]

116. We are concerned that what the CST perceived as a risk in 2007 is now, in fact, a reality. In Table 8, we highlight the origins, and current status, of spin-out companies commonly cited in evidence submitted to this inquiry. Since the inquiry began, several of these companies have entered into administration or ceased trading. One of these companies, MicroEmissive Display, cited the "severe slowdown in the demand for consumer electronics" as negatively impacting on the conversion of interest in their business to sales and revenue.[144]

142 Ev 575

143 Council for Science and Technology, *Strategic decision making for technology policy*, November 2007

144 www.eetimes.eu/germany/212100996

Table 8. UK companies in plastic electronics

Company	Spin out from	Founded	Focus	Current status
Plastic Logic	University of Cambridge	2000	The use of flexible plastic substrates for readable displays.	Headquarters in California, USA. Manufacturing based in Dresden, Germany.
Cambridge Display Technologies (CDT)	University of Cambridge	1992	Development of display technologies using solution processable polymer organic light emitting diodes (P-OLEDs).	Bought by Sumitomo Chemical Company in November 2007.
MicroEmissive Displays	University of Edinburgh	1999	P-OLED microdisplay technologies for head-mounted displays.	Entered administration in November 2008.
OLED-T	South Bank University	1999	Materials development.	Ceased trading in September 2008.
Molecular Vision	Imperial College London	2001	The integration of microfludic chips and organic semi-conductor light sources to develop low-cost diagnostic devices.	In November 2008, Acrongenomics Inc became a shareholder in Molecular Vision.
Lumicure	St Andrews University		Light sources for use in photodynamic therapy.	Lumicure is an early stage, privately held company.
Nano e-Print	University of Manchester	2006	Development of one-step printing process for the production of electronically-enabled labels.	Secured $1M in 2007 from Manchester Technology Fund and an undisclosed private investor.

117. The Minister rightly pointed out, however, that the UK's failure to sufficiently support spin-outs to grow into established SMEs was a problem that preceded the current 'credit crunch':

> The problem has been our ability to convert those increasingly large numbers of start-up companies into a sufficiently large number of really substantial businesses, and I think that there are a number of reasons for this. One of the key reasons is the economic environment, nothing to do with the credit crunch; the credit crunch is making it dramatically more difficult now and bringing all of this into focus, but we have seen that our high technology companies which have been built on our science base have tended to get to a certain size, comparably smaller than you would see, for example, in the United States, and then have been acquired or have stagnated.[145]

145 Uncorrected transcript of oral evidence taken before the Innovation, Universities, Science and Skills Committee on 26 January 2009, HC (2008–09) 169-i, Q 15

118. In the current economic climate the financial pressures felt by SMEs are only set to intensify. We were therefore heartened by the Minister's commitment to work with financial institutions to ensure that, over the next six to nine months, adequate capital is available in the £200,000 to £200 million range of funding.[146] However, a thorough review of the support offered to businesses as they transition from early stage R&D to manufacture may be required if UK companies are to be world-leading in production rather than just research.

119. In addition to technology based companies, the UK plastic electronic sector has started to see the emergence of service-based enterprises. For example, Cintelliq provides consultancy services to the organic semiconductor industry, and C-Change consults on the science, technology, and application of plastic electronics.

120. **The UK academic research base should be applauded for its strong record in 'spinning out' start-up companies. Focused support, however, is needed to ensure these businesses grow into world-class enterprises. We recommend that the Technology Strategy Board, BERR and UKTI consult with UK business, from start-ups to multinationals, to identify how best to support the growth of innovative businesses in emerging industries.**

Device manufacture

121. Plastic electronic devices can be produced through ink-jet printing at room temperature and pressure. By contrast, the manufacture of silicon semiconductors is only possible in fabrication plants with clean room facilities.[147] Consequently, whilst fabrication plants for the manufacture of many conventional electronic devices and displays can require capital resource in excess of $1 billion, plastic electronic devices can be manufactured in plants with a construction cost within the reach of many SMEs.

122. The Royal Academy of Engineering informed us that, in terms of "producing semiconductors adapted for plastic electronics, there is the capacity for manufacturing in the UK".[148] Although we agree that the nature of the plastic electronics industry means that manufacturing is not irreversibly destined to migrate to Asia, the evidence we have received does not give us hope that spin-out companies will choose to base their manufacturing operations here in the UK: MicroEmissive Displays and Plastic Logic built their manufacturing plants in Dresden, Germany, despite having spun out of UK universities (the former from the University of Edinburgh [initially manned by a large contingent from Sheffield University], and the latter from the University of Cambridge).

123. We asked Dr Hermann Hauser, Amadeus Capital Partners, why Plastic Logic decided to manufacture its products in Dresden. He explained that Dresden's success was, at least in part, down to a strategic decision on their behalf:

> When we arrived in Dresden we were met by the Burgermeister, the Mayor, and all his team. He said: "We really want you here. We want plastic electronics. It is a key strategic imperative for us to have this here—what do you want?"[149]

146 Q 189 [Ev 539]

147 Clean rooms are an area where the environment is controlled to eliminate all dust, dampened against vibration and climate controlled.

148 Ev 560

149 Q 52 [Ev 516]

124. Dr Hauser went on to list three other factors as critical to the decision. First, the availability of trained staff (Dresden was the micro-electronic centre of the Eastern Bloc); second, the ability to build the necessary infrastructure over a short time period (Plastic Logic's manufacturing plant opened on 17 September 2008, sixteen months after the building's cornerstone was laid in May 2007); and third, the availability of subsidies.[150]

125. The potential for countries to act strategically to attract inward investment was raised by the Minister:

> We need to recognise that other countries, such as Germany, Singapore I know within biopharmaceuticals, Ireland in the past, have put really quite enormous sums of money into attracting these factories to their region.[151]

126. During our visit to Japan, the impact that strategic investment in the plastic electronics sector can have was apparent. The Japanese Government has acted to ensure strategic capability in the OLED industry of the future. For instance, the Ministry of Economy, Trade and Industry (METI), through the New Energy and Industrial Technology Development Organisation (NEDO), is providing ¥35 billion (£173 million) to fund a collaborative project between Sony, Toshiba, Panasonic, Sharp and other partners to develop 40-inch and larger OLED television panels to a pre-competitive stage.[152]

127. The establishment of industrial consortia to develop technologies at a pre-competitive stage is not unique to Japan. In Taiwan, the Industrial Technology Research Institute (ITRI) has worked for 35 years to accelerate industrial technology development. Its 6,000 employees work on advanced technology R&D, on intellectual property business and new ventures and on the provision of a variety of industrial services. ITRI also nurtures start-ups through its 'Open Lab' programme. Open Lab has assisted 150 start-ups (and 105 other companies) and ITRI has invested some £1 billion in this activity alone.[153] In relation to plastic electronics, ITRI opened a Flexible Electronics pilot laboratory in 2007 for "integrative tasks from material synthesis, development, product design, to trial production".[154] ITRI works with international companies and research organisations and has overseas offices but is focused primarily on generating and sustaining the industrial base in Taiwan.

128. The Electronics and Telecommunications Research Institute (ETRI)[155]—run by the Korea Ministry of Knowledge Economy—has a very similar mission to that of ITRI in Taiwan. We look to the Technology Strategy Board to take on this convening role in the UK. However, while the UK has world-leading strengths in basic research underpinning emerging industries such as plastic electronics, we recognise that it does not have the large companies necessary to build industrial consortia comparable to those established in, for example, Japan. **We encourage the Technology Strategy Board to engage with multinational companies across Europe to determine whether pan-European consortia could be established to progress the development of emerging industries with the potential for high economic returns.**

129. Despite widespread recognition that other countries are acting to create capability in plastic electronics, the UK Government has not articulated a clear vision with regard to its

150 Q 52 [Ev 516], Q53 [Ev 517]

151 Q 209 [Ev 543]

152 Myoken Y., *Overview of organic electroluminescence R&D in Japan*, British Embassy, Japan, 2008

153 www.itri.com/practices_5.php

154 www.itri.org.tw/eng

155 www.etri.re.kr/eng

strategic intent for plastic electronics. We are concerned that this may not only act to deter future investment in the UK, but also stymie current investment. In particular, we note that Polymer Vision's manufacture of rollable displays in Southampton—heralded as a sign that the UK could establish a manufacturing capability in this sector—is in jeopardy:

> With the current manufacturing technology used there, the Southampton facility will not be a cost competitive operation within just 2–3 years. To become cost competitive at larger volumes, PVL [Polymer Vision Limited] must establish greater production capacity based on a newly developed cost-effective manufacturing flow. The preference is to do this in the UK by expanding in Southampton. If investment to do so cannot be secured then PVL will be forced to look abroad to investment in the required cost-effective manufacturing. The future of the Southampton facility will then be in danger.[156]

130. **The manufacture of plastic electronics devices is not destined to occur outside of the UK. However, we are extremely concerned that without urgent action by the Government this will be the reality. As in our previous recommendation (Paragraph 72), we urge the Government to engage with the plastic electronics community, and to articulate a strategic vision for the development of this innovative industry.**

131. The UK's tax regime is not considered to be as favourable to manufacturers as that of other countries.[157] However, we believe that the UK's research base makes it an attractive prospect for industry in this sector, and are optimistic that a number of SMEs will establish manufacturing capability in the UK.[158] Asked where Nano e-Print anticipates manufacturing its products, Dr Richard Price told the Committee he "very strongly" hoped to do so in the UK,[159] and UK OLED lighting start-up Polyphotonex intends to manufacture lighting panels on a production line at PETeC.[160]

132. The decision for Polyphotonex to engage in product development and production at PETeC raises an interesting issue in terms of the UK's provision of open access R&D and manufacturing facilities. The Research Centres supporting the plastic electronics community provide access to facilities that are sufficient to scale-up technologies to the level of a demonstrator product. UKDL KTN and OLED-T suggested that as the costs of accessing capital equipment is often prohibitive for start-up companies, the Government should support an open access[161] production facility that would function as a volume fabrication facility for UK companies.[162] UKDL KTN believes that allowing companies to manufacture products, without having to invest in the infrastructure, will increase the exploitation of innovative research:

> De-risking this early stage exploitation will greatly increase the rate at which plastic electronics concepts and designs are created and delivered to a wider market place.[163]

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156 Ev 601

157 Ev 557, 577, 583, 591

158 Several multinational companies already manufacture products in the UK. For example, G24i has a manufacturing plant in Wales.

159 Q 171 [Ev 535]

160 www.electronicsweekly.com/Articles/2008/11/18/44941/first-oled-panels-to-be-manufactured-in-uk.htm

161 Open access facilities allow any user to access equipment whilst maintaining complete integrity over the intellectual property generated by the project being undertaken.

162 Ev 583, 592

163 Ev 583

133. **Support for innovative businesses as they transition from being primarily R&D focused to launching pilot manufacturing lines is imperative. We recommend that the Government consider whether there is merit in establishing an open access fabrication facility for the manufacture of Plastics Electronic devices by UK SMEs.**

Enabling industries

134. The plastic electronics industry is not only comprised of companies developing devices, but also those developing enabling technologies and processes. The history of the LCD industry tells us that these 'enabling' companies have the potential to be extremely profitable. As reported by Dupont Teijin Films:

> It is well understood in the LCD industry that the most profitable parts of the supply chain are at the "front end" (e.g. materials, glass, equipment) or at the end of the chain selling product to consumers.[164]

135. The most notable suppliers to the LCD industry are Merck and Chiso for liquid crystals and Corning for substrate glass (Corning sold $1.55 billion of glass for LC-TVs in the third quarter of 2007). Other key suppliers are 3M for light control films and DNP for colour filters. Dr Taylor also reported that Hitachi "make more money now supplying materials and chemicals into the flat panel industry than making flat panels themselves".[165]

136. There are now a number of companies in the UK engaged in developing materials for plastic electronic applications, rather than the devices themselves. For example, Merck Chemicals Ltd, based in Southampton, is attempting to commercialise ready-to-use semi-conducting inks, and Sumation is developing polymer and dendrimer materials for OLED displays.[166]

137. High Force Research Limited believed that the skills and expertise exist within the UK to "make major advances in this [materials] sector as has already been demonstrated with liquid crystal technology",[167] a view supported by Dr Keith Rollins (Dupont Teijin Films) who told us that the UK's history in terms of materials development meant that it would be "astonishing" if a range of companies did not participate in the area of plastic electronics research and development.[168]

138. **The economic opportunities provided by this growing industry do not only lie in the manufacture of devices, but also in the development of enabling technologies. It is imperative that any national strategy for this industry must embrace the materials supply chain, particularly as this sector holds huge potential for UK industry participation.**

Public procurement

139. The public sector is an important consumer of the products and systems that may be disrupted by plastic electronics (paper, printing, energy and lighting, for example). The 2007 Sainsbury Review of the Government's science and innovation policies, *The Race to the Top*, and the Government's 2008 innovation White Paper, *Innovation Nation*, both

164 Ev 589

165 Q 130 [Ev 528]

166 www.sumation.co.uk/about_us

167 Ev 602

168 Q 172 [Ev 535]

recognised that, used effectively, Government procurement has the potential to pull innovative goods and services through from business and drive innovation in the economy.[169] The Council for Science and Technology called on the Government to use procurement to "encourage marketable products and services" in the plastic electronics industry.[170]

140. In 2008–09, the Government will spend £175 billion on third party goods and services.[171] We asked Professor King whether he felt the Government was able to deliver on its commitment to foster innovation through procurement. He told us that this was a drum he had "been banging on for quite some time",[172] but that the need for Permanent Secretaries to demonstrate value for money was likely to deter them from procuring innovative solutions:

> [I]f you […] simply encourage each permanent secretary to use a proportion of their budget for procurement […] those permanent secretaries will be pulled hard in the other direction to demonstrate value for money on their purchases, and we are talking about risk procurement here. You are buying an object which is as yet unproven and you are asking for the product to be delivered in five years' time. That in itself means, in my view, you have to ringfence a proportion of the procurement budget and take it from each department, and then that money must be spent in the interests of that department, but it must be seen to be risk procurement.[173]

141. We put the same question to the Minister and were struck by the similarity of his answer. Like Professor King, he told us that Government spending represents "an enormous opportunity to make a positive difference", but that:

> The challenge here from my experience in the Ministry of Defence is that using government procurement to strategically develop the science base and innovation will require the civil servants responsible for that procurement to take risk and so there will always be a balance between the amount of risk you are prepared to take by trying a new innovation and the criticism which you may be subjected to if that risk-taking in a proportion of times leads to greater costs and more delays.[174]

142. The Minister went on to explain that DIUS was reforming the process by which departments "use their procurement budgets so support SMEs and support innovation". He highlighted the Ministry of Defence's (MoD) 'Grand Challenge' competition as a recent initiative that successfully enabled civil servants to more accurately assess technological risk, while providing an opening into the UK defence market for new suppliers and investors.[175]

143. We applaud initiatives to develop the use of procurement to drive innovation. However, the success of the MoD's Grand Challenge competition appears to lie in the fact that it: (a) acted to fulfil a specific need identified by its sponsor, the MoD; and (b) provided a forum to test product capabilities, and allow potential investors to assess technological suitability and risk. These factors, however, make it inappropriate as a means to inform decisions regarding the procurement of plastic electronics R&D. The relative

169 HM Treasury, *The Race to the Top*, October 2007, p 126

170 Council for Science and Technology, *Strategic decision making for technology policy*, November 2007, p 30

171 www.ogc.gov.uk/About_OGC_news_8748.asp

172 Q 124 [Ev 527]

173 As above.

174 Q 195 [Ev 540]

175 As above.

immaturity of the plastic electronics sector means that rather than being at the level of product readiness, emerging technologies may not yet be incorporated into functioning devices. Further, as the Minister was aware, the applications of these technologies are still being identified:

> It is not clear at the moment what product areas, what market areas, plastic electronics is likely to have the biggest impact on, so it is not possible for the Government to say today "This is the area we think the technology could have an impact on" and therefore I think it is right the way in which the Technology Strategy Board has supported this area […] because it is not yet clear what those key markets are going to be.[176]

144. As indicated by the Minister, support for technological R&D to address challenges that cut across Government departments is the responsibility of the Technology Strategy Board. Specifically, the Board's 'Innovation Platforms' function to "pull together policy, business, Government procurement and research perspectives and resources to generate innovative solutions" to such challenges.[177] Current Platforms include: Low Carbon Vehicles, Assisted Living, and Network Security. Lord Carter of Barnes, Minister for Communications, Technology and Broadcasting (BERR & the Department for Culture, Media and Sport (DCMS)), told us that:

> It is somewhere between interesting and conspicuous. If you look at the five platforms they [Technology Strategy Board] have chosen, most of those are ones where you have got government as a specific customer or potential procurer, and there is a question about how much more commercial they can be in their interest areas.[178]

145. We are concerned that the Technology Strategy Board is limiting support for technological development to areas where the Government is commissioning or procuring specific products. The early stage of technological development in the plastic electronics sector means that no single Government department can be identified as the industry's natural customer. Without a department to champion investment in what are inevitably high-risk technologies, we are concerned that plastic electronics will fail to be supported through Government procurement initiatives.

146. In order to support innovation in emerging industries, we believe the Government has to take the brave decision to procure future technologies and products, even if their 'killer' application is as yet unclear. The procurement of future technologies can result in highly successful outcomes. The decision by the scientific community at CERN to commission the Large Hadron Collider (LHC) is a case in point. Critical to the LHC's procurement was a decision to source state of the art technologies for 15 years hence. In September 2008, this instrumental apparatus was switched on for the first time. It is expected that outcomes of LHC experiments "will revolutionise our understanding, from the minuscule world deep within atoms to the vastness of the Universe".[179]

147. The Government has recognised the potential for Forward Commitment Procurement (FCP) to stimulate innovation, and DIUS is taking steps to raise awareness of FCP through the establishment of a number of flagship projects.[180] Each Government department is also

176 Q 202 [Ev 541]

177 www.innovateuk.org/ourstrategy/innovationplatforms.ashx

178 Q 210 [Ev 544]

179 http://public.web.cern.ch/public/en/LHC/LHC-en.html

180 www.dius.gov.uk/policy/public_procurement.html

committed to publishing an Innovation Procurement Plan, setting out how it will "embed innovation in its procurement practices and seek to use innovative procurement mechanisms".[181] Throughout this inquiry, organisations such as UKDL KTN, Plastic Logic and Dupont Teijin Films have proposed that Government might stimulate innovation in the application of plastic electronics research by sponsoring pilot projects. Suggested projects include: trialling e-readers in educational institutions; disposable, printed medical sensors for general medical use in the healthcare environment; and trialling Organic PV devices in Government construction projects.[182]

148. **Public procurement has the potential to be a valuable tool in driving innovation. We welcome the Government's efforts to develop innovative procurement mechanisms, and recommend it supports pilot projects in the area of plastic electronics in order to stimulate product development and manufacture.**

The Small Business Research Initiative

149. The Small Business Research Initiative (SBRI) was established in 2001 with the aim of boosting innovative Government procurement from SMEs. The scheme aimed to reproduce, as far as possible, the success of the USA's Small Business Innovation Research (SBIR) programme. Since its creation in 1982, the US SBIR has awarded over $12 billion to various small businesses and "has played an important part in sustaining the demand for new—and often radically new—products and services that are vital to support innovative activity".[183]

150. The 2007 Sainsbury Review identified little change in Government procurement practice as a result of the UK SBRI, reporting that it had "done little more than reproduce existing practice—with an additional bureaucratic burden".[184] The failure of the UK SBRI to replicate the success of the US scheme was made only too clear when we asked Mike Biddle (Technology Strategy Board) whether SBRI had ever benefited a UK plastic electronics company. We were disappointed, but not surprised, to hear that it had not.[185] This disappointment was compounded by Plastic Logic's assessment of the value of grants awarded under the US SBIR to a US start-up company engaged in plastic electronics R&D:

> Universal Display Corporation (one of the key US start-ups in plastic electronics) has won approximately 10 Phase II awards in flexible displays and solid state lighting, and reports SBIR has been very useful in enabling the company to launch new initiatives as well as providing a good external validation that is appreciated by the investment community.[186]

151. Dr Richard Price (Nano e-Print) not only identified the support provided to Universal Display Corporation, but compared it with the support, or relative lack of it, provided to the UK spin-out Cambridge Display Technologies (CDT):

181 As above.

182 Ev 575, 583, 591

183 HM Treasury, *The Race to the Top*, October 2007, p 130

184 As above.

185 We note that Molecular Vision did receive a £147,000 grant from the BBSRC under its Small Business Research scheme.

186 Ev 574. Note that since the evidence sessions for this inquiry, UDC has received two $750,000 US SBIR contracts to further advance white OLED technology. These grants are part of a package of measures aimed at meeting the US Department of Energy's targets for solid-state lighting.

> [T]he number of projects that UDC got was phenomenal from the US Government. Despite the success of CDT, I think they could have done much better by having additional support.[187]

152. As a direct result of recommendations made in the Sainsbury Review, the Technology Strategy Board, working with DIUS, has been asked to launch a reformed SBRI. In its new incarnation, the SBRI will emulate the US scheme to a greater degree, and Government departments participating in the scheme will buy at least 2.5% of their R&D requirements from SMEs. Suppliers for each project will be selected by an open competition process—administrated by the Technology Strategy Board—and will retain the intellectual property rights generated from the project.[188] Projects will be 100% funded.

153. Speaking of the reformed SBRI, Stuart Evans (Plastic Logic) said:

> I think they [SBRI grants] play a really important role in enabling pilot projects and because they provide 100 per cent funding, which is completely different to any other regime, they permit little companies like ours and Nano e-Print to do some different kinds of stuff, so it is a very welcome initiative and I do hope it progresses.[189]

154. Following evaluation of the pilot schemes now running in the Ministry of Defence and Department of Health, it is expected that the reformed SBRI will be rolled out across Government from April 2009.

155. **The Small Business Research Initiative (SBRI) is potentially a valuable source of funding for innovative companies in the UK. Our concern is that unless this support mechanism is re-launched in a format accessible to SMEs developing future technologies, UK companies will refocus their business models to engage with the lucrative procurement opportunities offered by the US under its Small Business Innovation Research programme. We ask that DIUS keep us updated on progress made in rolling-out the revised SBRI.**

Case study conclusion: innovation and commercialisation

156. While the UK's research base is world-class, this case study highlighted that:

— without a serious revision of the structures used to support the growth of fledgling industries the UK will miss out on the opportunity to exploit the economic potential offered by the commercialisation of innovative technologies;

— the UK has a strong track record in spinning out companies from the research base, but this has not translated into established companies; and

— countries such as Germany, Japan and the US are taking steps to create strategic capability in emerging industries. We note that the Government has embarked on a debate to determine whether the UK should identify, and concentrate support on, areas of research in which: (a) it could be world leading; and (b) have the potential to provide significant economic returns on any investment. The form of this debate is the focus of our forthcoming inquiry, 'Putting science and engineering at the heart of Government policy'.

187 Q 168 [Ev 534]

188 Certain rights of use are to be retained by the contracting department.

189 Q 168 [Ev 534]

157. In Chapter 6, we draw upon the evidence received during this case study to discuss how the UK's graduate population might be better equipped with the skills needed to progress emerging industries.

158. The provision of well targeted financial support and government policy is critical if the products of innovative research are to transition into the marketplace. In the next chapter we consider what steps might be taken in formulating policies relevant to one emerging sector of engineering in particular: geo-engineering.

4 Geo-engineering—a new policy area

> If you really want to change the world—choose a career in engineering. And I mean real engineering, not financial engineering.[190]
>
> Lord Mandelson, Secretary of State, BERR

Background

159. To date, climate change research has tended to concentrate on: (a) understanding the climate and how human behaviour impacts upon it; (b) the reduction of carbon emissions (mitigation); and (c) adapting to the effects of climate change (adaptation). As pointed out by the Royal Academy of Engineering, however, increased concentrations of greenhouse gases (GHGs) in the atmosphere have "led some to propose a fourth strand in our fight against catastrophic climate change, namely geo-engineering".[191] Unlike mitigation and adaptation, the UK has not developed any policies relating to geo-engineering research or its potential role in mitigating against climate change. This case study therefore provides us with an opportunity to consider the implications of a new engineering discipline for UK policy-making.

160. Geo-engineering can be loosely defined as relating to any engineering activity that is concerned with large-scale alterations to the Earth or its atmosphere.[192] Throughout the latter half of the 20th century a number of geo-engineering schemes were proposed to fulfil various climatic functions. For example, in the 1950s, Russian scientists proposed constructing "Saturn rings" in the earth's orbit. Composed of metallic aerosols, the rings would supposedly have supplied heat and light to northern Russia, and shadowed equatorial regions to provide their inhabitants with the supposed benefits of a temperate climate.[193]

161. In 1965, the US Presidential Science Advisory Committee (PSAC) produced the first high-level Government policy document to draw attention to the threat of CO_2-driven climate change. Presented to then President Lyndon B. Johnson, the report, *Restoring the Quality of Our Environment,* discussed climate science in a manner consistent with similar reports today.[194] However, PSAC identified geo-engineering as the only response to the CO_2 climate problem, reporting that "The possibilities of deliberately bringing about countervailing climatic changes therefore need to be thoroughly explored"; the possibility of reducing fossil fuel use was not discussed.

162. In this report, we use the term 'geo-engineering' to describe activities specifically and deliberately designed to effect a change in the global climate with the aim of minimising or reversing anthropogenic climate change. Rather than a 'fourth strand' in the fight against climate change, we consider these activities to be akin to mitigation efforts, albeit at a global level. Our definition does not encompass Carbon Capture and Storage (CCS) technologies as applied to power stations, because these technologies modify emissions content as opposed to the atmosphere.

190 www.berr.gov.uk/aboutus/ministerialteam/Speeches/page50022.html

191 Ev 646

192 As above.

193 David W Keith, *Engineering the Planet*, Climate Change Science and Policy, in press

194 President's Science Advisory Committee, *Restoring the quality of our environment*, Washington DC, Executive office of the president, 1965

Technologies

163. Two approaches have been suggested as means to reduce or reverse the impact of anthropogenic climate change: carbon sequestration and reducing the effect of solar insolation.[195] We describe some of the mechanisms proposed for geo-engineering the climate below. Our aim is not to undertake a comprehensive analysis of technologies or to assess their feasibility or relative merit, but to provide a context in which to consider the potential policy implications of this research area.

Reducing the effect of solar insolation

164. Schemes to modify the Earth's radiation balance aim to offset the effects of increasing GHG concentrations on the climate by reducing the amount of solar radiation that reaches the edge of the Earth's atmosphere, or by reducing the fraction of incoming solar radiation that is absorbed by the atmosphere and/or surface (that is increase the Earth's albedo[196]).

165. Some of the proposed mechanisms for altering the Earth's radiation balance are outlined below. None of these options will directly affect atmospheric CO_2 concentrations.[197]

Sun shades

166. Dr Roger Angel, University of Arizona, has proposed the launch of trillions of near transparent discs, each approximately 50 cm in diameter, into space to shade the Earth. He believes the discs would be sufficient to reduce the amount of solar radiation reaching the earth by approximately 1.8%.[198] The discs would last 50 years before needing to be replaced with fresh lenses. It is estimated that the deployment of sun shades on this scale might cost as much as $350 trillion.[199] Professor Angel has recently secured NASA funding for a pilot project.

Space mirrors

167. Positioning a superfine reflective mesh of aluminium threads in space between the Earth and the Sun was proposed by Dr Lowell Wood and Professor Edward Teller as a means to reduce the amount of sunlight that reaches the Earth."[200] It has been estimated that a 1% reduction in solar radiation would require approximately 1.5 million km^2 of mirrors made of a reflective mesh.[201]

195 The solar radiation striking Earth.

196 The ratio of the outgoing solar radiation reflected by an object to the incoming solar radiation incident upon it.

197 Ev 649

198 Angel, R., "Feasibility of cooling the Earth with a cloud of small spacecraft near the inner Lagrange point (L1)", *Proceedings of the National Academy of Sciences*, vol 203 (2006), pp 17184–17189

199 *The Telegraph*, 27 February 2009, www.telegraph.co.uk/earth/environment/globalwarming/4839985/Scientists-to-stop-global-warming-with-100000-square-mile-sun-shade.html

200 news.bbc.co.uk/1/hi/sci/tech/4762720.stm

201 Note from Defra [not printed]

Aerosol injection

168. Large volcano eruptions result in the mass injection of sulphate particles—formed from the emitted SO_2—into the stratosphere.[202] As these aerosols reflect solar radiation back to space, or themselves absorb heat, mass eruptions result in a cooling of the lower atmosphere. The eruption of Mount Tambora in present day Indonesia, for example, was thought to have produced the 'year without a summer' in 1816. Likewise, the 1991 eruption of Mount Pinatubo in the Philippines caused a readily detectable change in global temperatures. In the 1970s, Professor Mikhail Budyko proposed that 'artificial volcanoes' be geo-engineered. That is, that sulphate aerosols be injected into the stratosphere to mimic the cooling effect caused by these 'super-eruptions'. This idea has recently been revived by chemistry Nobel Laureate Professor Paul Crutzen.[203]

169. Rather than stratospheric aerosol injection, scientists such as Professor John Latham, National Center for Atmospheric Research, Boulder Colorado (USA), and engineers such as Professor Stephen Salter, University of Edinburgh, have suggested spraying seawater into the troposphere.[204] Professor Salter believes that tropospheric seawater injection would increase the size, longevity and whiteness of maritime stratocumulus clouds, thereby increasing cloud reflectivity and inducing a cooling effect.[205]

170. Irrespective of whether aerosols are injected into the stratosphere or troposphere, the impact of such injection on atmospheric temperatures is ephemeral. This was highlighted by Dr Vicky Pope, Met Office, when she told us: "you have got to keep doing it for hundreds of years because as soon as you stop doing it the warming goes up again".[206] Specifically, aerosols injected into the troposphere have a residence time of days to weeks, and aerosols injected into the stratosphere of two to five years.[207] The climatic impacts of tropospheric aerosol injection are currently being modelled by the Met Office Hadley Centre.[208] We discuss funding for, and the role of, climate-based models of geo-engineering technologies later in the report.

Changes in the land/ocean surface

171. The type of vegetation cover could be changed to modify the albedo of natural or artificial surfaces. For example, deserts could be covered with a white material to increase reflectivity or plants could be genetically modified to increase their albedo.[209]

Carbon sequestration

172. Geo-engineering schemes proposed as a means of carbon sequestration require the capture and removal of atmospheric CO_2. By removing and storing atmospheric CO_2, it may be possible to mitigate directly the impact of rising GHG concentrations on the

202 The region of the atmosphere above the troposphere and below the mesosphere—between 15 and 50km above the Earth.

203 Crutzen, P.J., "Albedo enhancement by stratospheric sulphur injections: A contribution to resolve a policy dilemma", *Climatic Change*, vol 77 (2006), pp 211-219

204 The lower atmosphere: a height of 8–15km above the Earth.

205 Ev 634, 646, 652, 675

206 Q 103 [Ev 618]

207 Ev 619; Q 72 [Ev 719] [Professor Watson]

208 Co-funded by Defra, the MOD and DECC, the Met Office Hadley Centre provides in-depth information to, and advise, the Government on climate change issues.

209 *Geo-engineering Research*, POSTnote 327, Parliamentary Office of Science and Technology, March 2009

climate. These schemes may also function to combat the effects of increasing global CO_2 levels such as ocean acidification.

173. Several mechanisms for the removal and storage of atmospheric CO_2 have been proposed for research and development. Some of these technologies are outlined below.

Ocean fertilisation

174. Phytoplankton take up CO_2 and fix it as biomass. When the organisms die, a small fraction of this 'captured' carbon sinks into the deep ocean. Proponents of ocean fertilisation schemes have argued that by fertilising the ocean it may be possible to increase phytoplankton growth and associated carbon 'removal'. Ocean fertilisation schemes involve the addition of nutrients to the ocean (soluble iron, for example), or the redistribution of nutrients extant in the deeper ocean to increase productivity (such as through ocean pipes).[210]

175. Unlike ocean pipe technologies, iron fertilisation schemes have been tested in small (less than 100 m^2) patches of seawater as research exercises. Of 11 studies conducted prior to 2007, two reported some sinking of additional biomass.[211] On 20 May 2008, 191 nations present at a meeting of the United Nations Convention on Biological Diversity in Bonn agreed to a moratorium on large-scale ocean fertilisation schemes, but allowed for small-scale research experiments in coastal waters. This moratorium was established to prevent private companies carrying out large-scale commercially-driven experiments, while making allowance for legitimate scientific research. However, because iron is abundant in coastal waters—and therefore iron fertilisation would not increase algal growth—subsequent meetings of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (the London Convention) agreed that small-scale ocean experiments should be permitted under regulation. Dr Santillo, Greenpeace, highlighted the London Convention's decision to permit regulated, small-scale experiments, as an exemplar for the development and implementation of future regulatory research protocols:

> [T]he elegance of it is that it does not say no to new scientific studies, it simply says that there should be a consistent and precautionary set of rules that need to be applied by all countries in order to determine what is legitimate scientific research into these [geo-engineering] techniques and what is not.[212]

176. On 26 January 2009, after conducting independent reviews to ensure compliance with the London Convention's guidelines, the German Government authorised one of the largest ocean fertilisation experiments to date. Researchers on the Lohafex expedition have started seeding six tonnes of iron sulphate over 300 km^2 of the Scotia Sea, east of Argentina. Numerous biological, chemical and physical parameters will be continuously measured inside and outside the fertilised area, and ecological changes in all layers of the water column—from the surface to the seafloor in 3,800 metres depth—will be monitored for tens of days. The plankton community biomass is expected to increase substantially about two weeks following fertilisation, and the fate of the organic matter produced will be investigated in detail.

177. The governance of geo-engineering research is an issue we will return to later.

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210 Lovelock, J.E. & Rapley, C.G., "Ocean pipes could help Earth cure itself", *Nature*, vol 449 (2007), p 403

211 www.ipcc.ch/ipccreports/ar4-wg3.htm

212 Q 41 [Ev 609]

Air capture

178. Air capture technologies attempt to directly remove CO_2 from the atmosphere and allow for its subsequent storage. The most well-known air capture option involves so-called ‘synthetic trees’. In a synthetic tree, air passes over a structure coated with an alkaline chemical that removes CO_2 for storage elsewhere. Professor Klaus Lackner, Columbia University (USA), has designed a 30 metre tall synthetic tree, or ‘scrubber’, that he claims has the potential to remove 90,000 tonnes of CO_2 from the air each year (equivalent to 1,000 real trees):

> I have been involved for the last nine years in an effort to develop the means of capturing carbon dioxide directly from the air. Some refer to this effort as the creation of synthetic trees. Just like a tractor is more powerful than a horse when it comes to plowing a field, these synthetic trees are about a thousand times faster in collecting carbon dioxide from the wind passing over them than their natural counterparts. […] Air capture would become the carbon dioxide collector of last resort, in that it would collect all carbon dioxide which is not amenable to capture at the point of emission. This includes but is not limited to the carbon dioxide from air plane engines, from the tail pipes of cars, and potentially the carbon dioxide from old power plants unsuitable for cost effective retrofits. We believe that air capture could compete with power plant retrofits and could collect the carbon dioxide from a liter of gasoline at a price that is dwarfed by gasoline taxes. We expect to move rapidly from an initial price of 20 pence a liter to ultimately less than three pence a liter.[213]

179. Synthetic trees could be located either on land or at sea, and in those environments not otherwise suitable for human exploitation (for example deserts). Further, the deployment of this technology could be scaled up, or down, with relative ease meaning that, like aerosol injection schemes, its impacts would be reversible.

180. Rather than deploy synthetic trees, increasing the land area under cultivation may result in greater CO_2 absorption (as plants act as carbon sinks). The Research Institute of Innovative Technology for the Earth, Japan, is undertaking research to develop large-scale plant-based CO_2 fixation technologies through selective breeding and genetic modification.

181. Over the course of this inquiry, we have heard different views as to whether carbon removal technologies are distinct from geo-engineering technologies. Intriguingly, views on this subject appear to depend on the country in which a researcher/organisation is based. Common to UK-based academics, Learned Societies and Government departments is the view that geo-engineering technologies encompass those that aim to reduce solar insolation *or* increase carbon sequestration.[214] By contrast, US-based academics Professor Lackner and Professor Ken Caldeira (Carnegie Institute, USA) drew a distinction between the two technological approaches, arguing that carbon sequestration technologies (synthetic trees and iron fertilisation schemes, for example) manipulate the carbon cycle and should therefore be viewed as a distinct research area: carbon-cycle management.[215] Specifically, Professor Lackner said:

> In the press, this approach has also been called geo-engineering because it actively manages the global anthropogenic carbon cycle. However, it should also be seen as the logical extension of capture at the point of combustion. Here we want to contrast

213 Ev 703

214 Ev 619, 646, 649, 660, 665, 695, 697

215 Ev 702; Q 73 [Ev 613]

> such carbon cycle management with albedo engineering efforts that try to counter greenhouse warming with active efforts of cooling the planet.[216]

182. **At this stage, we do not consider a narrow definition of geo-engineering technologies to be helpful. Technologies to reduce solar insolation and to increase carbon sequestration should both be considered as geo-engineering options.**

Policy considerations

183. We heard concern that current efforts to reduce GHG emissions may be insufficient, both in terms of scale and speed of implementation, to enable effective climate change management.[217] A similar view was expressed by Professor Launder, University of Manchester:

> There is increasingly the sense that governments are failing to come to grips with the urgency of setting measures in place that will assuredly lead to our planet reaching a safe equilibrium. Today, the developed world is struggling to meet its (arguably inadequate) carbon-reduction targets while emissions by China and India have soared. Meanwhile, signs suggest the climate is even more sensitive to atmospheric CO_2 levels than had hitherto been thought.[218]

184. The potential for the Earth to undergo greater adverse climate change impacts than expected, or for carbon reduction measures to be less effective than anticipated, has led to the suggestion that geo-engineering technologies may need to be considered as an emergency option akin to an insurance policy.[219] That is, in the words of Professor Launder, geo-engineering schemes may "offer a means of gaining two or three decades of breathing space while the world must find routes for moving to a genuinely carbon-neutral society".[220] Lord Drayson also invoked the concept of an 'insurance policy' when explaining why he thought geo-engineering merited policy consideration:

> I do not subscribe to the view that you should on purpose put all your eggs in one basket to make sure that you look after that one basket really carefully. […] I think it is right for us to have a watching brief […] on these areas of geo-engineering. I think they could rightly be described as an emergency plan B. That does not mean we should not absolutely put full effort into focusing our investments in plan A. But one never knows. That is the value of pure research and that is why it is right for us to be putting a moderate amount of money into this area, to be focusing on aspects such as modelling where we can learn an awful lot without having to invest too much.[221]

185. **Like the Minister of State for Science and Innovation, we believe that Government should give the full range of policy options for managing climate change due consideration, and we share the view of the Tyndall Centre that geo-engineering technologies should be evaluated as part of a portfolio of responses to climate change, alongside mainstream mitigation and adaptation efforts**.[222]

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216 Ev 702

217 Tyndall Centre for Climate Change Research & Cambridge-MIT Institute Symposium, *Macro-engineering options for climate change management and mitigation*, January 2004

218 Launder, B. & Thompson, M., "Preface", *Philosophical Transactions of the Royal Society Series A*, vol 366 (2009), p 3841

219 Ev 649

220 Ev 639

221 Q 67 [Ev 718]

222 Ev 649

186. However, this view does not appear to be held across Government, as according to Joan Ruddock, Parliamentary Under-Secretary of State at the Department for Energy and Climate Change (DECC), DECC has decided not to countenance such a strategy:

> Scientists should probably not be looking at what I regard as being somewhere down the list of priorities and potentially the plan B [geo-engineering], because we need all our energies directed at the plan A [mitigation and adaptation].[223]

187. **Given the need for urgent action in addressing the challenge of climate change, we can see no reason for not considering geo-engineering technologies as a 'plan B'. Quite the opposite, the decision not to consider any initiative other than 'plan A' could be considered negligent particularly, for example, if 'plan A' fails to act as planned or climate sensitivity is greater than expected.** Asked why DECC was averse to exploring the potential of geo-engineering technologies, the Minister gave two reasons. The first appeared to be based on a presumption of failure: "If plan A has failed […] then there is very little reason to imagine plan B could succeed",[224] and the second predicated on a belief that supporting geo-engineering research might be perceived as signalling a waning commitment to more conventional mitigation efforts:

> Our concern is that although we do not want to dismiss this work […], it could be used politically in that way, which would be extremely unfortunate because what we know about engineering is that [… it] can provide us with well-tried and trusted solutions to reduce CO_2 emissions from a huge range of activities and it is those existing engineering solutions that we seek to promote in the international arena […]. So it could be a means of deflecting engineering from the very best work which can be done to help the world community to get such a deal.[225]

188. This argument is a rehearsal of that originally used against examining climate change adaptation measures. The argument went as follows: "if we actually start to take adaptation seriously and look at it and analyse it seriously, then we are encouraging people to believe that it is okay to carry on emitting greenhouse gases".[226] Thankfully, this argument was dismissed, and adaptation research is now firmly on the international agenda. Given that this argument has been discredited, we are disappointed that the Government has sought to bring it back to the fore, and do not consider it to be helpful in progressing debate.

189. None of the evidence we received suggested that the science and engineering community consider geo-engineering technologies as having the potential to act as a 'silver bullet' in mitigating global climate change, not least, as the Royal Academy of Engineering points out, because: "even if it [geo-engineering] could help to alleviate the effects of climate change it has nothing to add in terms of security or sustainability of energy supplies".[227] Instead, the overriding view of individuals we spoke to was that geo-engineering efforts might, in the future, have the potential to complement the conventional mitigation and adaptation agenda.

190. **We find the divergent views of DECC and DIUS, as outlined by Lord Drayson and Joan Ruddock, as to the future potential of geo-engineering research to be confusing, and urge the Government to establish a clear view on the matter.**

223 Q 68 [Ev 718–719]

224 Q 67 [Ev 718]

225 Q 60 [Ev 717]

226 Q 43 [Ev 713–714] [Professor Steve Rayner]

227 Ev 648

191. **Further, we conclude that it would not be appropriate or sensible for opinion-leaders or the public to see any policy on the potential use of geo-engineering schemes as implying a lack of ongoing commitment to the development of conventional emission mitigation strategies or adaptation responses. We urge the Government to be proactive in communication efforts to dispel any incorrect perceptions.**

Assessing potential

192. Throughout this inquiry, we received repeated requests for an independent assessment to be undertaken to determine which, if any, of the proposed geo-engineering options would be technologically viable.[228] Dr Tim Fox, Institution of Mechanical Engineers (IMechE), told us that:

> What really needs to be done is to create a listing […] of the risks associated with the projects and to look at those which have a real practical potential to be applied' […] and to assess the feasibility of these, the practicality of these, the costs and risks associated with deployment to enable us to make those initial assessments and recommendations as to which solutions might offer potential should geo-engineering be regarded as a route which we need to go down. There has been little, if none, engineering assessment of these solutions.[229]

193. On the financial commitment required for technological research, development, demonstration and deployment (RDD&D)—initial expenditure and on-going costs—the Royal Academy of Engineering expressed the view that, compared to the global costs of co-ordinating and implementing conventional mitigation and adaptation efforts, geo-engineering technologies may not only have a more rapid impact, but may also be less expensive.[230]

194. A number of witnesses called for a technological assessment of proposed geo-engineering options. It is not surprising that such an assessment has not been conducted to date if considered in the context of the Intergovernmental Panel for Climate Change's (IPCC) view of geo-engineering technologies:

> Geo-engineering options, such as ocean fertilization to remove CO_2 directly from the atmosphere, or blocking sunlight by bringing material into the upper atmosphere, remain largely speculative and unproven, and with the risk of unknown side-effects. Reliable cost estimates for these options have not been published.[231]

195. As pointed out by Professor Watson, Defra Chief Scientific Adviser: "with that sort of statement by the IPCC it is not likely it [geo-engineering] would have been a major discussion point by politicians of the world".[232] Professor Watson went on, however, to highlight recent developments to begin assessing geo-engineering schemes:

> As we know, the Royal Society is looking at this particular issue and it would not be surprising to me if the National Academy of Sciences in the US also looked at it, but what would be, in my opinion, quite worthwhile would indeed be a more in depth

228 Q 4 [Ev 610] [Professor Brian Launder], Q 11 [Ev 708] [Dr Tim Fox and Professor Steve Rayner], Q 49 [Ev 610] [Dr Dan Lunt]

229 Q 10 [Ev 708]

230 Ev 648

231 www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-spm.pdf

232 Q 68 [Ev 719]

> analysis by the IPCC or a combination of all the major academies of the world, the US with, I would say, the UK, also with China, India and Brazil. [233]

196. The Royal Society has previously collaborated with the Science Academies of other nations to issue joint policy statements. For example, in June 2008 the Royal Society and the Science Academies of the G8 nations, Brazil, China, India, Mexico and South Africa signed a statement on global health.[234] This makes the Royal Society well-placed to bring an international perspective to bear on any assessment of the geo-engineering sector. Further, as much of the work in this area is not sufficiently developed to have resulted in the publication of research outputs, we believe the Royal Society is better suited to reviewing future technological potential than the IPCC. In its assessment of the sector, we would urge the Royal Society not simply to describe suggested technologies but to highlight those which, if any, hold the most potential in terms of safely engendering climatic change and might therefore be considered worthy of research support.

197. **In order 'to sort the wheat from the chaff' and identify those geo-engineering options it may be feasible to deploy safely in the future, it is essential that a detailed assessment of individual technologies be conducted. This assessment must consider the costs and benefits of geo-engineering options including their full life-cycle environmental impact and whether they are reversible. We welcome the efforts of the Royal Society to review the geo-engineering sector, and urge it to engage with the Royal Academy of Engineering and the Science and Engineering Academies of other nations in this regard.**

Geo-engineering research: finance and infrastructure

Current research activity

198. Geo-engineering is very much an emerging research discipline. The focus of work conducted to date has been the application of climate models to quantify the potential impact of technological deployment. We briefly outline this area of research, before discussing current and potential sources of research funding.

Modelling the future

199. Detailed modelling is critical as geo-engineering projects have the potential to trigger undesirable side-effects (making the oceans more acidic, adversely affecting air quality, or accidentally instigating an unexpected ecosystem response, for example).[235] The need for ongoing research in this area was highlighted by Professor Lackner:

> I would argue that we are not ready to do serious climate engineering in this day. I do hear people who say we should not even study it for that reason. I am opposed to that […] there are all sorts of side-effects and I think it is therefore very important that we do basic research and most of this will, by its nature, be virtual. It is important to do that because if there is a crisis we will not have time to do it and we might go down a road which might be potentially far more dangerous because we refused to look it at earlier.[236]

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233 Q 57 [Ev 716]

234 http://royalsociety.org/document.asp?tip=1&id=7820

235 Ev 647

236 Q 84 [Ev 615]

200. In addition to identifying possible side effects, modelling has the potential to determine the effectiveness of proposed geo-engineering technologies. In 2008, Dr Lunt and colleagues used a state-of-the-art climate model to assess the climatic impact of a space-based sunshade. The study found that although the deployment of a sunshade would reduce the climatic impact of CO_2 emissions, it would not return the climate to its pre-industrial state and changes sufficient to precipitate the loss of Arctic sea ice would still occur.[237] The fact that climate simulations have shown that climate engineering is unlikely to reproduce "the status quo ante" was also raised by Professor Caldeira who made clear that "nearly every simulation has shown that there is the potential to reduce overall amounts of climate change".[238]

201. To reduce the likelihood or extent of negative outcomes, modelling studies should be informed by real-world observations, monitoring and process experiments wherever possible.[239] We are aware, however, that the output of climate models may not be wholly representative of the 'real world' impacts of technological deployment, a point made by Dr Pope of the Met Office: "No prediction of the future can give you an absolute prediction of any sort. What we are really doing is assessing risk".[240]

202. Key to maximising alignment between the outcomes of virtual studies with real-world impacts is the continued development of the model used. The climate model used by Dr Lunt to model the impact of a sunshade was the same as used by the Hadley Centre to model tropospheric aerosol injection, and by the IPCC.[241] We asked Dr Lunt to what extent he felt this model was imperfect:

> Yes, it is certainly imperfect. The question is how good is good? How good do you need your model to be before you start interpreting the results? All I can say is that it does a good job compared to the observational record that we have had so far.[242]

203. **Support for detailed modelling studies will be essential for the development of future geo-engineering options, and to the construction of a credible cost-benefit analysis of technological feasibility. We urge the Research Councils to support research in this area.**

Funding research

Public funding

204. Professor Caldeira told us that public sector research funding was essential to ensure that policy makers received unbiased and accurate information with regard to potential geo-engineering technologies.[243] We were disappointed to find that none of the academics that we spoke to had received public funding to support their geo-engineering research (see Table 9).

237 Ev 639

238 Q 84 [Ev 615]

239 Ev 662

240 Q 85 [Ev 615]

241 Q 44 [Ev 609]

242 Q 46 [Ev 609]

243 Q 72 [Ev 613]

Table 9. Information as provided to the Committee during the first evidence session (10 November 2008) from academics engaged in research relevant to geo-engineering

Witness	Research activity	Funder
Professor Stephen Salter	Research and development of a technology to increase the albedo of marine stratocumulus clouds.	Professor Salter stated he received "no money at all". Previous EPSRC grant applications were unsuccessful.[244]
Professor Ken Caldeira	Research to examine the unintended consequences of geo-engineering proposals.	Professor Caldeira is supported by the Carnegie Institute (USA), which is privately endowed. He receives no federal or state funding, but has received funding from philanthropists.[245]
Professor Klaus Lackner	Research and development of a synthetic tree to 'capture', and make available for storage, carbon dioxide from the air.	Professor Lackner is supported by private endowments made to Columbia University.[246]
Dr Dan Lunt	Modelled the impact of sun-shade deployment.	Dr Lunt's research was conducted in his spare time.[247]

Government departments

205. Prior to 3 October 2008, the Department for the Environment, Food and Rural Affairs (Defra) was responsible for UK climate change policy. Professor Watson, Defra's Chief Scientific Adviser, explained that although Defra had not funded the development of any geo-engineering technology, it had compiled a discussion document on the subject "to see what the current thinking is of the academic community, what the potential implications are, positive and negative, of different approaches".[248] Further, Defra expressed a willingness to support the efforts of other nations in any future technological assessment.[249]

206. Like Defra, DIUS has identified a potential role for geo-engineering technologies: "some of those geo-engineering approaches currently proposed, or others that may yet be put forward, may offer bridging solutions to mitigate, probably to a limited extent, global warming impacts over the period until stabilisation at a "safe" level can be achieved".[250] Given the views of DIUS and Defra, we asked the Minister whether the Government department now responsible for UK climate change policy, DECC, intended to support geo-engineering research. In line with her comments regarding the department's single-minded commitment to developing and implementing 'plan A', her reply made very clear

244 Q 68 [Ev 613]

245 Q 67 [Ev 612]

246 Q 68 [Ev 612]

247 Q 13 [Ev 606]

248 Q 46 [Ev 714]

249 Ev 700

250 Ev 619

it did not: "as for the Department, let us make it absolutely clear there are no plans for us to fund research in this field".[251]

The UK Research Councils

207. Presently, two Research Councils support research relevant to geo-engineering: EPSRC and the Natural Environment Research Council (NERC). Research projects focus on modelling the Earth's climate and systems, information that, as we described earlier, is critical to any study examining the impact of geo-engineering technologies on the Earth's climate. However, Dr Phil Williamson, NERC, told us that:

> [I]n terms of absolutely directly saying, "This is money to support geo-engineering research," up until now I do not think we have actually funded any research grants or studentships.[252]

208. The Research Councils have now signalled that support for geo-engineering research may be forthcoming. EPSRC has allocated £3 million for a geo-engineering IDEAS factory to be held in autumn 2009, and NERC has allocated £2 million to support a consortium-led study of cloud seeding and cloud formation (via sulphate aerosol) and related albedo effects.[253]

The Carbon Trust

209. In 2001, the Government established the Carbon Trust as an independent company. Its mission is to accelerate the move to a low carbon economy by working with organisations to reduce carbon emissions and develop commercial low carbon technologies. Professor Launder suggested that the Carbon Trust be required to earmark a proportion of its budget to support so-called 'air capture' geo-engineering technologies.[254] As described previously, air capture technologies are designed to directly absorb CO_2 from the atmosphere.

The Virgin Earth Challenge

210. Sir Richard Branson launched the Virgin Earth Challenge on 9 February 2007. The Challenge offers a prize of $25 million to the individual or group able to demonstrate a commercially viable design that will result in the net removal of anthropogenic, atmospheric greenhouse gases each year for at least ten years. The technology must not trigger countervailing harmful effects, but contribute materially to the stability of the Earth's climate.[255] A panel of experts will assess entries submitted for the prize.[256]

211. The Virgin Earth Challenge prize is not relevant to technologies designed to modify the Earth's albedo. Further, as highlighted by Professor Rayner, Said Business School

251 Q 56 [Ev 716]

252 Q 6 [Ev 708]

253 Ev 670; Q 7 [Ev 708]. An IDEAS factory is a sandpit activity (a 5-day residential interactive workshop). Sandpits are led by a director with a group of stakeholders and international experts in support. This group is not eligible to receive research funding so act as impartial referees in the sandpit process. In addition to the group leading the sandpit, 20–30 people are selected to take part through a call for participants. Outcomes of sandpits range from a single large research project to several smaller projects, feasibility studies, networking activities, overseas visits and so on. The outcomes are not pre-determined but are defined during the sandpit.

254 Ev 639

255 www.virginearth.com

256 Sir Richard Branson, Al Gore, James Lovelock, Tim Flannery, James Hansen, Sir Crispin Tickell

(University of Oxford), it does not offer support for technological development: "The problem is, that does not fund research. That is the prize at the end, so you have got to have sufficient capital to invest up front before you are even in the running for the prize."[257] Consequently, while it may have stimulated interest in geo-engineering, it has not provided a means to further technological development.

The Met Office Hadley Centre

212. The Met Office Hadley Centre is the UK's official centre for climate change research. Partly funded by Defra and DECC, the Centre provides in-depth information to the Government on climate change issues.

213. Models developed by the Hadley Centre are already being used in research pertinent to geo-engineering. For example, a study by Dr Lunt and his colleagues on the impact of deploying a sunshade (discussed previously) used a climate model developed at the Met Office.[258]

214. Climate models will play a vital role in both testing whether proposed geo-engineering ideas will work and in identifying any unintended harmful or secondary effects. However, as Dr Vicky Pope (Met Office) explained, there are some discrepancies in the predictions of different models used:

> There are obviously uncertainties in the science […]. All of the models show that [the] climate is warming. They all share very many characteristics. What they differ in is the degree of the change and the details of the regional change. By using a number of different models that make different assumptions about the science, you can actually look at the range of possible outcomes and we are now able to start looking at the probabilities of different outcomes so that we can assess risk.[259]

The Tyndall Centre for Climate Change

215. The Tyndall Centre brings together scientists, economists, engineers and social scientists to develop sustainable responses to climate change through multidisciplinary research. Further, it acts to engage the research community, business leaders, policy advisors, the media and the public in dialogue.[260]

216. The Tyndall Centre's research programmes are selected and designed according to the criteria and strategic priorities of NERC, EPSRC and the Economics and Social Research Council (ESRC). Current programmes include: *Informing international climate policy*; *Constructing energy futures*; and *Building resilience to climate change*.[261] Dr Tim Fox, IMechE, suggested that the Tyndall Centre's ability to undertake large multidisciplinary research programmes would make it an ideal 'hub' through which to co-ordinate and deliver a geo-engineering research programme:

> I wonder […] whether there is potentially a model there for bringing together the multidisciplinary nature of the geo-engineering project through such an organisation similar to the Tyndall Centre, which has a number of strands of activity going on

257 Q 28 [Ev 711]

258 Ev 639

259 Q 85 [Ev 615]

260 www.tyndall.ac.uk/general/about.shtml

261 www.tyndall.ac.uk/research/index.shtml

> which are both social science oriented and hard science […] and technical and engineering issues.[262]

217. **The Tyndall Centre for Climate Change is well-placed to co-ordinate geo-engineering research, and we would welcome the conduct of geo-engineering-related work as an additional work-stream. Further, we recommend that the Government engage with organisations including the Tyndall Centre, Hadley Centre, Research Councils UK and the Carbon Trust to develop a publicly-funded programme of geo-engineering research. Research grants should be awarded on the basis of excellence after a process of competitive peer review.**

Industry involvement

218. A number of commercial start-up companies have been established and are actively engaged in geo-engineering research (Box 1). Established outside of the UK, principally in the US and Australia, these companies hope to develop technologies to sequester carbon, with a view to selling carbon offsets in return for their services.

Box 1. US and Australian companies engaged in geo-engineering research.

1. **Climos** (www.climos.com) is a California-based start-up company engaged in research on ocean iron fertilisation. The company intends to carry out a demonstration programme in order to understand the potential of ocean iron fertilisation as carbon mitigation tool. The company's ultimate aim is to sell carbon offsets in exchange for performing ocean iron fertilisation.
2. **Planktos** was a California-based start-up company with a similar business model to Climos. The company ceased trading in Spring 2008 as it could not raise the funds necessary to conduct demonstration trials.
3. **Atmocean Inc** (www.atmocean.com), based in Sante Fe, USA, is developing a 200 metre deep wave-powered ocean pump to bring cold, nutrient-rich, water to the ocean's surface. The company believes that this will stimulate the biota which will sequester extra carbon, a proportion of which will sink to the deep ocean.
4. **Ocean Nourishment Corporation** (www.oceannourishment.com), based in Sydney, Australia, aims to increase oceanic photosynthesis and associated carbon sequestration. Unlike Climos, the company uses nitrogen-rich urea, not soluble iron, as a fertiliser.

219. Dr Santillo argued there was a need for a mechanism to assess the legitimacy of commercial geo-engineering research, and its outputs:

> A very key part of that has to be a consideration of the commercial involvement because if there is an element of commercial interest in those experiments having a particular outcome, I think that would counter that legitimacy in terms of research.[263]

220. Lord Drayson did not rule out supporting such enterprises in the UK:

> [A]lthough we would not see at the moment that the commercial opportunity for geo-engineering projects is well-established, we do see that there would be a sound commercial business plan based around a general research area, which would include geo-engineering as part of a number of different areas within marine science. Providing that was done in an area where you had the benefits of the cluster effect, good intellectual property and a sound infrastructure to support it, then we would be supportive of such a development.[264]

262 Q 20 [Ev 710]

263 Q 41 [Ev 609]

264 Q 69 [Ev 719]

Socio-political and economic issues

221. In furthering discussion of geo-engineering options, it is critical that debate does not focus solely on technological feasibility. As this inquiry has progressed, we have become keenly aware of the need to invest in research to examine the socio-political and economic impacts of geo-engineering research and the potential deployment of future technologies.

An ethical debate

222. A recurring theme in the written and oral evidence we received was the moral legitimacy of geo-engineering the planet. Dr Santillo described the speculative promise of geo-engineering technologies as a 'moral hazard', with the potential to reinforce societal behaviours that impact negatively on the present climate:

> In the public's mind there is a danger perhaps that people will favour what they see to be a solution which does not involve them changing their way of life, does not involve them having to make difficult choices, if they can simply contribute to a scheme which somehow very distant from them will engineer the climate back to its normal state.[265]

223. While concerns over societal response to future technologies are valid, we believe that they are insufficient as a reason for not engaging in geo-engineering research. Instead, they highlight the need to develop a public dialogue on the issue, and to implement a programme of public education and engagement. If after such an initiative the overwhelming view of the public was that technologies were morally remiss, then at this point the authority of engaging in research could be questioned. At the present time, however, the assertion by Greenpeace that "tinkering with our entire planetary system is not a dynamic new technological and scientific frontier, but an expression of political despair"[266] appears to be a minority view. For example, the Royal Academy of Engineering, told us "if time really is running out and geo-engineering was able to provide some breathing space it would be morally remiss of us not to at least consider this option",[267] a view echoed by Professor Caldeira:

> If we did find that the sea ice is melting and threatening polar bears and arctic ecosystems with extinction and Greenland is sliding into the sea, is it better to say let's have that ecosystem go extinct, let's lose Greenland and that will be a good motivator for people to reduce emissions, or do you say no, we actually care about these ecosystems, we care about Greenland and maybe we should put some dust in the atmosphere to prevent this from happening while we are working on reducing emissions. I do not think the ethical and moral high ground is necessarily to say let's allow environmental destruction to proceed unimpeded while we are trying to reduce emissions.[268]

224. It is crucial that any geo-engineering research should be undertaken with one eye on societal understanding and public debate. We were therefore disappointed that Professor Launder, who is a leading advocate of geo-engineering research, was not familiar with the views of organisations commenting on this research area:

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265 Q 39 [Ev 608]

266 Ev 701

267 Ev 648

268 Q 101 [Ev 617]

> **Dr Gibson:** […] how do you see the criticisms that Greenpeace have levelled at the issue in terms of morality, ethics and so on? You must have had this levelled at you many times, I am sure.
>
> ***Professor Launder:*** I do not think I can answer that simply because I have not acquainted myself sufficiently. I just keep my head down like any eager-beaver scientist.[269]

225. We encourage scientists to familiarise themselves with arguments surrounding the validity of their research area, and to engage in debate relevant to that research, especially in areas as controversial as this one.

226. **Before deploying any technology with the capacity to geo-engineer the climate, it is essential that a rational debate on the ethics of geo-engineering be conducted. We urge the Department for Energy and Climate Change to lead this debate, and to consult on the full-range of geo-engineering options with representatives of the science, social science, and engineering communities and implementing agencies e.g. national Governments, international bodies or private sector organisations.**

Governance

227. Global planning permission was highlighted as fundamental to the future deployment of geo-engineering technologies by a number of organisations.[270] While international consensus might be the optimal context in which to deploy technologies, the Royal Academy of Engineering recognised the potential for a country to take unilateral action:

> Individual governments could see geo-engineering as an excuse to continue with a business-as-usual approach and would be able to act independently, thus bypassing the sometimes tortuous path to international agreement. A number of international treaties covering the oceans, atmosphere and space would, in theory, prevent such action. However, these are not always adhered to hence the risk, albeit small, of a state acting unilaterally cannot be ignored.[271]

228. Just as the effects of climate change will impact on different countries in different ways, the deployment of geo-engineering technologies is unlikely to impact on the climate of different countries with uniformity. The Tyndall Centre believes that there will effectively be "winners and losers associated with geo-engineering" (as there will be with climate change itself). As in any context where losses are incurred, 'losers' (in this case individual nation states) may appeal to beneficiaries for compensation. The need to develop an international framework to identify and manage these liabilities was raised by Professor Rayner, Said Business School:

> [O]ne has to be developing the institutional apparatus for managing and governing these technologies alongside developing the technologies themselves, and I think it has to be done […] in a way that engenders public trust, which demonstrates there are appropriate mechanisms for dealing with liability […] and finally for ensuring that there is actually some notion of consent on the part of populations for the implementations of technologies.[272]

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269 Q 9 [Ev 606]

270 Ev 662, 671, 699

271 Ev 648

272 Q 40 [Ev 713]

229. **It is essential that the Government support socio-economic research with regard to geo-engineering technologies in order that the UK can engage in informed, international discussions to develop a framework for any future legislation relating to technological deployment by nation states or industry.**

Case study conclusion: an emerging policy area

230. If the Government is to be an informed actor in the development of any future international policy relating to geo-engineering, it is essential that it draw on the expertise of the science and social science communities as well as that of the engineering base. The Government's capacity to act as an intelligent customer of engineering advice is a theme we explored in our final case study, Engineering in Government, and is the focus of the following chapter. In undertaking this inquiry, we became conscious of the potential of this sector to enthuse young people. We consider this possibility further, together with activities undertaken to inspire young people more generally, in Chapter 6.

5 Engineering in Government

> We cannot afford a public service culture where all you do is tell the Government what you think the Government wants to hear. […] The Government must receive the best advice, based on the best available information and evidence.
>
> Kevin Rudd, Prime Minister of Australia, 30 April 2008

> There is nothing a government hates more than to be well-informed; for it makes the process of arriving at decisions much more complicated and difficult.
>
> John Maynard Keynes

> It is a capital mistake to theorise before you have all the evidence. It biases the judgment.
>
> Sherlock Holmes in *A Study in Scarlet*, Sir Arthur Conan Doyle

Introduction

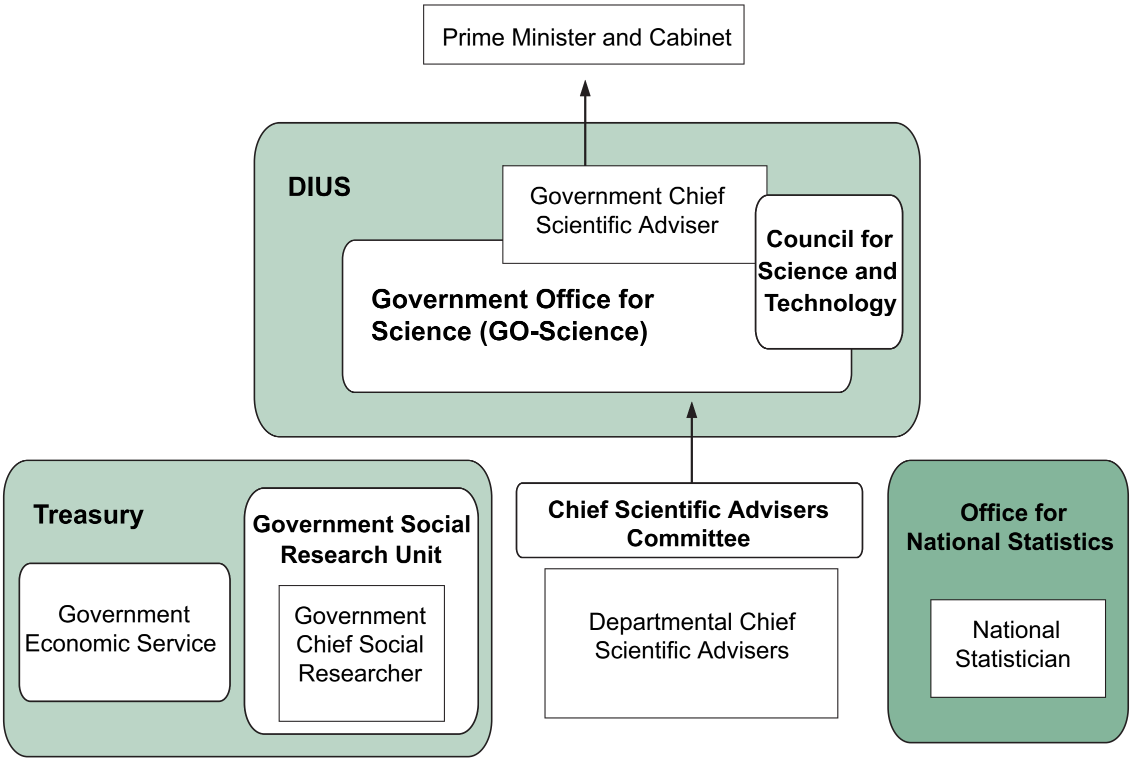
231. The impetus for this case study was to explore whether there is scope to improve Government policy making and delivery through changing the way in which engineers are involved with the process. Judging from comments made by the Secretary of State for Innovation, Universities and Skills, the Government will welcome our efforts in this regard. The Rt Hon John Denham MP told us that "The real challenge is getting the best policy advice, whether that is social science, science or engineering, into Government in a systematic way",[273] and that "this is a process we need to strengthen rather than say we have it absolutely all right at the moment".[274]

232. Before proceeding to explain how we think the policy-making process could be strengthened, it is necessary to outline the landscape of science and engineering advice structures in Government. It is a minefield of acronyms and initialisms, and we hope that the following paragraphs and Figure 2 help the reader make some sense of it.

273 Q 543 [Ev 80]

274 Q 532 [Ev 78]

Figure 2. Organogram of science advisory structures in Government



233. The **Government Chief Scientific Adviser** (GCSA), currently Professor John Beddington, oversees science advice—which the Government argues includes engineering advice[275]—across Government and is also head of profession for scientists and engineers in the civil service. The GCSA is supported by the **Government Office for Science** (GO-Science, once part of the Office for Science and Innovation). Although the GCSA and GO-Science have cross-departmental responsibility for science advice, they are situated within the Department for Innovation, Universities and Skills (DIUS), rather than the Cabinet Office as was suggested by the former Science and Technology Committee.[276]

234. Supporting the work of the GCSA are **Departmental Chief Scientific Advisers** (DCSAs), who are responsible for science advice in each of their departments. Not all DCSAs are necessarily scientists. For example, the DCSA for the Ministry of Defence is an engineer (Professor Mark Welland) and the DCSA for the Department for Culture, Media and Sport is an economist (Anita Charlesworth). Neither does every Department have a DCSA, which was an ambition of Professor Sir David King, the former GCSA, and remains a commitment for the present incumbent of that post.

235. DCSAs sit on the **Chief Scientific Advisers Committee** (CSAC), which is tasked with advising the GCSA (who chairs CSAC) on science, engineering and technology matters relevant to Government. The highest level Committee, which advises the Prime Minister on science and technology issues, is the **Council for Science and Technology**, which is co-chaired by the GCSA.[277]

275 Q 523 [Ev 76]; *Guidelines on Scientific Analysis in Policy Making*, HM Government, October 2005

276 Science and Technology Committee, Seventh Report of Session 2005-06, *Scientific Advice, Risk and Evidence Based Policy Making*, HC 900-I, para 25

277 www2.cst.gov.uk

236. Also working under the broad heading of 'specialist advice' to Government are the **National Statistician** (currently Karen Dunnell), the **Chief Government Social Scientist** (currently Professor Paul Wiles, who is also DCSA for the Home Office), and the joint heads of the **Government Economic Service** (currently Vicky Price, BERR, and Dave Ramsden, HM Treasury)—presently there is not a Government Chief Economist.

237. The most significant change since our predecessor Committee considered the science-policy structure in Government is that of the role of the **Minister for Science and Innovation**, currently Lord Drayson, who acts to promote the importance of science advice across Government. He attends Cabinet and chairs the newly formed **Cabinet Sub-Committee on Science and Innovation**.[278] This Committee is made up of Ministers from key Departments with a science remit, such as the Department for Health (DH), Defra, Transport and DECC. Lord Drayson told us that "I have been given the task of setting up this brand new committee for science and innovation to make sure that science is put at the heart of government policy".[279]

238. Working alongside the Minister for Science and Innovation at DIUS is the **Director General for Science and Research**, Professor Adrian Smith, who is responsible for science and research policy, including the science budget allocations and public engagement on key scientific issues. He is also DIUS's DCSA.

Science = science + engineering?

239. The Government is adamant that when it talks about science, it means science and engineering,[280] and acknowledges that "We tend perhaps not to see them as quite separate activities".[281] The Secretary of State appealed to us not to take the Government's shorthand as "a judgment of the department's interest in engineering".[282] We take him at his word, and accept that the Government does not *intentionally* seek to downgrade engineering. (Although his Department's new campaign, *Science: So what? So everything*, surely cannot help.) However, it may be that the persistent use of the solitary word 'science' as code for science, technology, engineering and maths, not to mention social science, economics and statistics, is a *symptom* of the status of engineering advice in Government.

240. Before we consider this point, however, it is useful to explore the way in which the Government and others perceive the relationship between science and engineering (and scientific advice and engineering advice). We have heard two interpretations of the relationship between science and engineering in a policy context. These interpretations are not mutually exclusive, but as a matter of emphasis they are interesting.

241. **The 'essential continuum' interpretation** is that pure science and pure engineering sit at two ends of a continuum with heavy science—or light engineering, depending on your professional persuasion—sitting between the two. This is the position taken by the GCSA[283] and Secretary of State for Innovation, Universities and Skills,[284] who use it as a line of argument to support a system in which a GCSA oversees DCSAs without a need for

278 www.cabinetoffice.gov.uk/secretariats/committees/edsi.aspx

279 Uncorrected transcript of oral evidence taken before the Innovation, Universities, Science and Skills Committee on Monday 26 January 2009, HC (2008–09) 168-i, Q 2

280 Q 523 [Ev 76]

281 Q 522 [Ev 76]

282 Q 523 [Ev 76]

283 Q 539 [Ev 80]

284 Q 522 [Ev 76]

an additional Government Chief Engineering Adviser or his/her departmental concomitants. As Professor Beddington put it:

> [T]hese strands of advice form an essential continuum and to put them into silos would be unhelpful. I have scientific and engineering advice, and what is pure science and what is engineering does not seem to me a fruitful debate as they link across lots of different areas.[285]

242. The alternative to focusing on the similarities is to place more emphasis on the differences. **The 'essential difference' interpretation** is the notion that notwithstanding niche research areas, science and engineering are disciplines that differ fundamentally, particularly in their goals: scientists set out to find out how things work whereas engineers typically are more interested in whether they can turn ideas into reality. In a policy situation the distinction is obvious. For example, in setting carbon emissions targets one might turn to scientists to gain an understanding of what impact carbon emissions have on the climate and to engineers to identify what is possible in terms of practical actions. Only with both strands of advice is it possible to set meaningful targets and develop a strategy for meeting them. To give an historic example:

> When Michael Faraday explored the problem of exploding dust in coal mines, he cracked the science and then, in his final report on these tragic events, gave his view of how much fresh air needed to be supplied in order to stop this happening, and then very bluntly says he does not have an idea how on earth how he would get that amount of fresh air down into the mine. "This has to be left", he said, "to men who are practical".[286]

The 'essential difference' interpretation inexorably leads to the conclusion that there should, at least in some cases, be both scientific advisers and engineering advisers.

243. These arguments are not mutually exclusive but differ in emphasis. It is obviously true both that science and engineering are different disciplines and that there is an overlap between the two. It is matter of determining the relative weight of the differences and the similarities. We take the view that the majority of professional activity that can be classified as science and/or engineering falls very clearly into one of the categories—science or engineering—but not both. Even in cases where people move between engineering and science, they know the difference between the two:

> I think there is a strong overlap and that people move from being engineers to being scientists and back again. Of course I spent my working career in industry in the United States and there we did that all the time. We would even be both scientists and engineers almost simultaneously. I managed large projects during the day and in the evening I looked at viruses in the scanning electron microscope that I had built.[287]

What engineers bring to policy making

244. Irrespective of whether one chooses to focus on the similarities or the differences between engineering and science, the fact that there *are* differences strongly suggests that there will be instances in which engineering advice is more useful than scientific advice. Professor Beddington despite his position that "there is a clear continuum" between

285 Q 539 [Ev 80]

286 Ev 722 [Professor Fisk]

287 Q 49 [Ev 729] [Lord Broers]

science and engineering,[288] clearly distinguishes between the two. When the Department for Energy and Climate Change (DECC) was formed, he stepped in "to ensure that they had engineering advice"[289]; and he has advised the Department for Communities and Local Government (CLG) that it needs both engineering and social science advice.[290] His conclusion is that "we need to have, as chief scientific advisers, where appropriate, engineers".[291] The Government is clearly in support of Professor Beddington's position, since the MoD, BERR, DfT and CLG have engineers in the DCSA role. In other words, the differences between engineering advice and science advice are already recognised by Government.

245. So what, specifically, is it that engineers bring to the policy environment? The Royal Academy of Engineering put this clearly on behalf of a large section of the engineering community, including most of the professional engineering institutions:

> [E]ngineering is a quite different discipline [from science], pursued in a different manner towards different ends. Engineering is concerned with solving practical problems and in changing the physical world, using scientific, technical and business skills. Science, on the other hand, is principally about understanding the nature of the world. The practical nature of engineering means that engineering advice and expertise is of great value in developing policy and delivering projects. For example, the need for engineering advice is particularly pertinent in the area of climate change. The big challenge is no longer the search for evidence for climate change but rather the search for means of avoiding its advance and mitigating its effects, many of which will be matters of engineering and technology.[292]

246. Professor Chris Snowden expanded on the expertise that engineers can provide:

> [T]o be an engineer […] you have to have a clear understanding of the science behind the issues you are addressing. At the same time, you also have to understand (a) how it is applied, (b) how it would be implemented, so that has cost implications, reliability implications and it also has […] socio-economic implications.[293]

247. And Professor Michael Kelly went further:

> It comes back to the distinction between a scientist and an engineer. Any engineer worth his/her salt has managed a complicated programme somewhere along the way. It is one of the preconditions for even consideration to be a Fellow of the Academy: what is the big project you have seen through? When it comes to management, there are short courses for civil servants on how to manage but even the management that goes on inside a department of something going on outside tends to be at arm's length and comes back to the point that David made earlier, that as long as the finances are right and there is a good line to put against each bullet point in the milestones to the project, that is it. For somebody to get up there and say, "This is going awry", or "this is going off the tracks or this will not work at some point", engineers are past masters at that.[294]

288 Q 538 [Ev 80]

289 Q 528 [Ev 77]

290 Q 529 [Ev 77]

291 Q 540 [Ev 80]

292 Ev 758

293 Q 54 [Ev 730]

294 Q 47 [Ev 729]

> [M]aking professional judgements about the feasibility of aspects of projects [… is] integral to an engineering training and […] may not necessarily come through the regular scientific route.[295]

248. **We conclude that engineering advice and scientific advice offer different things to the policy formulation process and that the benefits of both should be recognised. Further, it should not be assumed that a scientific adviser can offer competent engineering advice or even know when it is needed.**

Engineering advice in policy

249. Engineering advice is crucial to many policy areas. The Government has consulted closely with engineers on how to keep Vehicle Borne Improvised Explosive Devices at safe distances from critical national infrastructure, on the implementation of a new Incident Recording System for the Fire Service and on dealing with cable corrosion on the Severn Bridge.[296] Adaptation and mitigation of climate change is a major policy area: the flood and coastal erosion risk management is run by engineers from Defra, the Environment Agency, local authorities and internal drainage boards; "practitioners [i.e., engineers] are at the forefront of policy development and the consideration of strategic solutions".[297] The Energy Research Partnership and the Energy Technologies Institute, which are both joint public-private ventures to promote energy research and innovation in the UK, are other examples where engineering is at the heart of the Government's strategy for moving towards a carbon neutral economy.

250. One regular voice for engineering in Government is the Council for Science and Technology. CST advises the Prime Minister and the First Ministers of Scotland and Wales on "strategic issues that cut across the responsibilities of individual government departments".[298] According to CST, it organises its work around five broad themes: research, science and society, education, science and Government, and technology innovation. No mention of engineering, which is strange since seven of its members are engineers and many of its reports are engineering-related. We aim to revisit the role of CST in our inquiry on 'Putting science and engineering at the heart of Government policy'.

251. Unfortunately, the policy-making machine does not always operate effectively. During the course of this inquiry we came across several examples of bad practice. In each case the common factor is an absolute or relative absence of engineering advice:

- on carbon efficiency:

> We have been told privately by reliable sources that unrealistic estimates have been made about the contribution of non-fossil fuel sources to energy supply and CO_2 emissions reduction as well as the potential carbon emissions savings of various energy efficiency measures. A sound engineering insight would have given a clearer picture of the contributions of the different energy technologies, the timescales in which they could feasibly come on-stream and the measures necessary to mitigate risk—whether technical, political, commercial or otherwise.[299]

295 Q 2 [Ev 721]

296 Ev 738–741

297 Ev 740

298 www.cst.gov.uk

299 Ev 759 [Royal Academy of Engineering and the engineering institutions]

> If you look at all the 30 odd policy measures out there for reduction of carbon emissions in buildings, I have been asking for two years what exactly is the expectation in terms of actual carbon savings by 2015. That is a hard engineering question so that we will know in 2012 if we are on the trajectory. I am afraid I cannot get that answer.[300]

- on microgeneration:

> Engineers' views are […] essential to identify barriers to certain policy solutions […] For example, while the use of microgeneration of electricity through wind power might be recommended, this recommendation is undermined by the fact that the electricity grid is not currently designed to deal with the feeding back of large amounts of power into the grid—the distribution system is designed to be one-way.[301]

- on renewables:

> [T]he new commitment to 25 gigawatts of offshore wind by 2020 is, to say the least, going to be a massive, if not impossible, challenge. It is going to mean installing ten large turbines a day every day that you can practise in the North Sea, which is about 60 days a year, until 2020, ten a day every day until 2020, and there is one barge at the moment that is capable of carrying, and erecting, one of those towers, so you do not gain engineers' confidence by having a strategy that just states that there is going to be 25 gigawatts of offshore wind in the North Sea.[302]

- on eco-towns:

> Recent plans for developing Eco-towns were drawn up with the help of a steering committee (the Eco Towns Challenge Panel) which had no engineering input. The contribution of an engineer in this case would have been to look at the intended outcome—reducing domestic carbon emissions within the UK—and assessing whether this was the best means to meet that outcome.[303]

> I am well aware of one eco-town site that, for example, does not have the transport infrastructure to connect it to the economy it would have to serve, so I would suggest that that is a fairly serious problem in terms of the rationale for the eco-town.[304]

- on building new houses:

> [V]ast housing proposals have been made […] only to find that all of these housing proposals had been made without any consideration of water supply. Engineers would have stopped that immediately.[305]

- on large IT projects:

> Large IT systems are an area of Government procurement that has and continues to experience both bad press and implementation problems. Some would assert that specifications have been driven by political imperatives rather than being derived

300 Q 18 [Ev 723] [Professor Kelly]

301 Ev 759 [Royal Academy of Engineering and the engineering institutions]

302 Q 59 [Ev 731] [Lord Broers]

303 Ev 759 [Royal Academy of Engineering and the engineering institutions]

304 Q 62 [Ev 731] [Professor Snowden]

305 Q 62 [Ev 731] [Lord Broers]

> from operational requirements; a situation which would apply to both the ID Card project and the National IT Programme (Connecting for Health). It is possible that this approach has led to decisions about the architecture of systems being taken or assumed before detailed expert advice was taken. Here, a distinction needs to be made between the advice received by Government in the procurement of systems, which is often good and realistic, and the advice received in the development of policies which are delivered through the procurement of IT, which is often lacking.[306]

252. One particularly alarming example was the review of the Severn Tidal Power Feasibility Study to assess options for harnessing the tidal power of the Severn Estuary. Professor Beddington told us that he "wrote to the Secretary of State […] indicating that it was absolutely essential […] that there was significant engineering input",[307] which suggests that at the time Professor Beddington wrote the letter that the level of 'engineering input' was not 'significant' enough. It is alarming not only because it is plainly obvious that engineering input on a project like this is crucial at all stages of consideration, from initial discussion to implementation, but also because the Government uses this feasibility study as a example of best practice in its written submission.[308]

253. These examples raise a number of points: the absence of strategic planning and roadmaps, the importance of acting as an intelligent customer, a lack of clear guidance on policy making and the dangers of not seeking engineering advice early in policy formulation. We shall deal with these points in turn.

Strategic planning and roadmaps

254. We discussed strategic planning and roadmaps in the chapters on nuclear engineering and on plastic electronics. It is clear from the above examples that detailed roadmaps are not used in several areas of Government.

Intelligent engagement with stakeholders

255. The Royal Academy of Engineering and the engineering institutions have called for the Government to be an 'intelligent customer':

> Government needs to be an intelligent customer for the engineering advice it receives. This means having civil service staff who are able to understand and evaluate engineering advice. With the focus strongly on evidence-based policy, the civil service should have amongst its staff engineers who are able to source and assess technical evidence. Evidence-based policy in key areas such as climate change, energy supply and low-carbon transport is only achievable with the input of policy advisers with an understanding of the required evidence—and that will include engineering evidence.[309]

The examples of bad practice given above suggest that the Government does not have sufficient engineering capacity in several major policy areas. One of the problems with a capacity shortage is that the Government has to rely more on bought-in expertise.

306 Ev 759 [Royal Academy of Engineering and the engineering institutions]

307 Q 530 [Ev 78]

308 Ev 740

309 Ev 757

Professor David Fisk, a former Chief Scientific Adviser, outlined three situations in which consultants might be used:

- when in-house staff out-source engineering analysis that they could have completed themselves so they have more time to focus on the most difficult issues—the staff can then check that the out-sourced work is correct
- when in-house staff are able to formulate the problem but are not able to devise the solution, so it out-sources the analysis—in this situation staff can still check the quality of the work
- when in-house staff are unable to formulate the problem coherently but still out-sources some analysis—in this situation staff are unable to assess the quality of the answers that come back.[310]

He therefore commented that:

> *Innovation Nation* rightly proposes obtaining private sector advice in formulating tenders to provoke more innovative proposals but it is silent as to how in the proposals received the innovative are to be distinguished from the disasters.[311]

256. We asked Professor Snowden why he thought this problem existed:

> **Chairman: [**U]nless the Government is an intelligent customer and it actually has at board level or certainly at the very highest level that sort of advice, that critical advice, then, no matter how many consultants you have thereafter, if you have made an initial policy decision which is flawed, you are living with it thereafter, are you not?
>
> ***Professor Snowden:*** You may be.
>
> **Chairman:** Well, if that is obvious to me and it is obvious to you, why is it not obvious to the Government?
>
> ***Professor Snowden:*** Because they have not got the advice in the first place or the training. It is a serious point, and I will give an example. You may wonder why these things arise, but, if you look at the makeup in other countries of governments, you will find that engineers and scientists populate a large number of these places. The President of China himself is actually an engineer, so is his Vice President. They are not practising engineers today obviously, but they do have an appreciation of the skill-set. Now, I am not suggesting everybody needs to be engineers, but it is useful to have some content of that from the point of view of having input at that early stage.[312]

257. How the Government should go about improving its engineering capability is something we discuss later. In the meantime, **we conclude that the Government, in several policy areas of several departments, does not have sufficient in-house engineering expertise to act as an intelligent customer.**

310 Ev 752–753

311 Ev 753

312 Qq 66–67 [Ev 732]

Policy guidelines

258. One way in which the policy process could be improved is effective implementation of sensible guidelines on policy making. Such guidelines already exist for science, but not for engineering. The Government claims that 'science' as a broad heading includes engineering, but the GCSA's *Guidelines on Scientific Analysis in Policy Making*[313] only refers to engineering in a footnote. It is the only time that engineering is mentioned in the whole document. In the footnote, 'science' is broken down into, for example, forestry science, veterinary science, mathematical sciences and so on, while engineering is lumped as an entirety into 'engineering and technology'.

259. We asked Professor Beddington whether these guidelines should be updated. He agreed that they should,[314] and told us that "it is one of the things that I am going to be discussing with my team of chief scientific advisers".[315]

260. **The *Guidelines on Scientific Analysis in Policy Making* should explicitly include engineering advice. We are pleased that Professor Beddington has already agreed to review these guidelines, and suggest that the research and engineering community be consulted on the content of the guidelines.**

Timely engineering advice

261. Our final observation on the examples given above is that even in cases where engineering advice has been sought, it often comes too late. This can have profound implications. For example, with regard to eco-towns, the Royal Academy of Engineering argues that had consultation with engineers taken place before the policy decision was taken: "Engineers would have been highly likely to conclude that the outcome would be better served by retro-fitting existing housing to reduce its carbon emissions, a view that seems to be emerging through the consultation process".[316]

262. In another example from the Royal Academy of Engineering and the engineering institutions:

> Although the MoD continues to struggle to deliver projects to time, cost and performance, it appears more likely to take engineering advice than other Departments. The recent review of the Royal Navy procurement of two large aircraft carriers by Sir John Parker FREng was instigated at a late stage to give the Government comfort that the contract could be managed and delivered by industry. It is welcome that the Government should seek such advice, but it could be an integral part of the procurement process for difficult projects rather than a late stage add-on.[317]

263. This theme of early consultation was something that was raised time and again in submissions:

313 *Guidelines on Scientific Analysis in Policy Making*, HM Government, October 2005

314 Q 531 [Ev 78]

315 Q 540 [Ev 80]

316 Ev 759

317 As above.

> I do not think Government engages engineers early enough in the procurement processes. I think they should be there from day one on these large-scale projects and identified as such.[318]

> [T]he Royal Academy and the institutions […] are quite often consulted very far down the process. In one particular case this year, we had 48 hours' notice to provide a consultation on a paper on energy, which, as you can probably appreciate, provides a very limited ability to usefully input to that process and it is far too far down the process. The key point I would make is that engineering input needs to be in the developmental and formulation phase of the policies and strategies, not as an afterthought or in the implementation phase.[319]

> Even in our own department [CLG] where it was a matter of setting up a climate change group, we have two economists and a statistician; that was the starting point of a problem which is essentially about climate change in buildings. If they had said, "Let us get a buildings engineer and a couple of people to support that", I would have said that was the appropriate way to start.[320]

264. And the Government Chief Scientific Adviser honestly observed:

> [E]co-towns is one where it seems to me engineering advice should have been sought at an earlier time and I have concerns with that.[321]

265. **Engineering advice should be sought early in policy formulation and before policy is agreed, not just in project delivery. We recommend that the Secretary of State for Innovation, Universities and Skills and the Minister for Science and Innovation act as champions in cabinet for the early engagement of engineers in policy making. Further, this issue should also be central to discussions in the Science and Innovation Cabinet Sub-Committee.**

Sourcing engineering advice

266. So how should the civil service go about sourcing engineering advice? We were struck by the ease of communication between the engineering communities and Governments in China and Japan and observed that the close ties between the two are largely cultural. China is still a developing country that is rapidly building itself, literally, and engineers are highly valued as a result. Japan traditionally has a very strong engineering base—it built itself out of the post-war economic doldrums and through its high-tech engineering industries it has a strong economy. Although both nations are noticing that the younger generation is increasingly attracted to financial services, it is noteworthy that engineers still occupy high places in both Governments.

267. In addition, the Chinese and Japanese engineering academies—the Chinese Academy of Engineering (CAE) and the Engineering Academy of Japan (EAJ)—carry enormous authority. The President of the CAE bears the same rank as a Government minister. There are stark differences between the Chinese political system and the UK's, which perhaps makes it easier for policy to be influenced by engineers at the highest level of the Chinese Government. However, the Japanese and UK political systems are quite similar, yet in Japan, the engagement between the EAJ and the Government is—or at least appeared to

318 Q 4 [Ev 721] [Professor Hall]

319 Q 65 [Ev 732] [Professor Snowden]

320 Q 14 [Ev 722–723] [Professor Kelly]

321 Q 530 [Ev 78]

us—to be more policy-oriented than the relationship between the Royal Academy of Engineering and the UK Government.

268. One of our predecessor Committees, the Science and Technology Committee, was equally impressed by the system in the United States:

> We saw during our visit to the US the more formalised role fulfilled by the National Academies—the National Academy of Science, National Academy of Engineering, Institute of Medicine and National Research Council—in the provision of scientific advice to Government. The National Academies have a mandate to "investigate, examine, experiment, and report upon any subject of science or art" whenever called upon to do so by any Department of the Government. Most of the science policy and technical work is conducted by the National Academies' operating arm, the National Research Council, which was created expressly for this purpose. Collectively, the National Academies "provide a public service by working outside the framework of government to ensure independent advice on matters of science, technology, and medicine". We recognise that the UK's learned societies were established within a different institutional framework. Nonetheless, the Government has on occasion commissioned work from the learned societies, including a well-received Royal Society/Royal Academy of Engineering study on nanotechnology. **We find the institutional structure of the scientific advisory system in the US attractive and encourage the Government to discuss with the learned societies the extent to which similar arrangements could be adopted in the UK and the changes that this would necessitate.**
>
> In the meantime, **there is ample room for greater involvement of the learned societies and professional bodies in the UK scientific advisory system**.[322]

269. We were surprised that when we asked Professor Beddington whether or not the Government should be required to consult the UK National Academies over policy decisions he replied: "It is not a question I have thought about".[323] Consequently, we find ourselves in a situation where we could repeat these 2006 recommendations without alteration in 2009, which suggests a certain amount of inattention on the Government's part. As we have stated, the Government could source engineering advice better, which means that the Civil Service Steering Board—on which the Government had pinned its evidence-based-policy hopes—has not yet contributed a sufficiently stringent "check on the quality of evidence-based policy making".[324]

270. In particular, the Science and Technology Committee's assertion that "there is ample room for greater involvement of the learned societies" remains true. In relation to this point, Lord Broers posed and answered a question to the Committee:

> Well, would you choose, in order to get a transport policy, the ex-CEO of British Airways? Is that the way to get a transport policy for the country? Surely, one should have gone to the Royal Academy of Engineering.[325]

271. It is a fair comment, but why the Royal Academy of Engineering rather than, for example, one or more of the professional institutions? As Lord Broers warned, the Royal Academy of Engineering has "to tread very carefully because the institutions are very

322 Science and Technology Committee, *Scientific Advice, Risk and Evidence Based Policy Making*, para 81

323 Q 550 [Ev 82]

324 Science and Technology Committee, First Special Report of Session 2006–07, *Scientific Advice, Risk and Evidence Based Policy Making: Government Response to the Committee's Seventh Report of Session 2005–06*, HC 307, p 16

325 Q 79 [Ev 735]

jealous" of its closeness to Government.[326] The Government has itself pointed out that it has "many organisations" to which it can turn for specialist advice.[327] This represents a further problem in our view: many officials do not have sufficient knowledge of the sector to be able to decide who to turn to for advice. We are not even convinced that all DCSAs, the majority of whom do not have an engineering background, and some of whom do not even have a scientific background, would know all the players in this complex landscape.

272. The danger of such a situation, where policy makers know that they need engineering advice—let us assume that this step has been taken—but do not know who to turn to are two-fold. First, most obviously, they may go to the wrong people for advice and receive inadequate advice. Second, and more likely, they will go to lots of people and receive a plurality of advice. As Professor Snowden warned us, currently "different departments in government are very happy to go to different institutions" and as a result they end up with an unnecessary "diversity of input".[328] He argued that it would be better for the Government "to go to the Royal Academy of Engineering who could also then quite easily liaise with the relevant institutions for the expertise that the Government would need. It would be a very straightforward thing to do."[329] This suggestion has also been put forward by a large section of the engineering profession[330] in a joint statement: "The Royal Academy of Engineering could act as a broker in the preparation, collation and submission of profession-wide advice where and when it is required".[331] We agree. **For engineering advice, the Government should consider the Royal Academy of Engineering as its first port of call. The Academy can then bring together the relevant experts, including representation from the relevant professional institutions, to provide impartial, expert and timely input to policy formulation.**

273. **The Government should set up a Working Group with the Royal Society, the Royal Academy of Engineering, the British Academy and the Academy of Medical Sciences to explore how and whether the relationship between Government and the Academies could be formalised so as to improve policy making. We reiterate the 2006 Science and Technology Committee recommendation that strong consideration should be given to the US model.**

Engineering in the civil service

274. No-one knows how many civil servants were trained as scientists or engineers. When asked if he knew how many there were, Professor John Beddington told us:

326 Q 78 [Ev 735]

327 Science and Technology Committee, *Scientific Advice, Risk and Evidence Based Policy Making: Government Response to the Committee's Seventh Report of Session 2005–06*, p 16

328 Q 80 [Ev 735]

329 Q 70 [Ev 733]

330 Signatories for this proposal were: the British Computer Society; the British Nuclear Engineering Society ; the Chartered Institution of Building Services Engineers ; the Engineering and Technology Board; the Energy Institute; Engineering Council UK; the Institute of Acoustics; the Institute of Healthcare Engineering and Estate Management; the Institute of Highway Incorporated Engineers; the Institute of Marine Engineering Science and Technology; the Institute of Materials, Minerals and Mining; the Institute of Measurement and Control; the Institution of Civil Engineers; the Institution of Chemical Engineers; the Institution of Engineering and Technology; the Institution of Engineering Designers; the Institution of Lighting Engineers; the Institution of Mechanical Engineers; the Institution of Nuclear Engineers; the Institution of Railway Signal Engineers; the Institution of Royal Engineers; the Institution of Structural Engineers; the Institution of Water Officers; the Royal Academy of Engineering; the Royal Aeronautical Society; the Royal Institution of Naval Architects; the Society of Environmental Engineers; and the Welding Institute.

331 Ev 757

> No, I do not. I posed that question when I walked in the door, Chairman. The answer is: it is difficult to tell. The information is not available in any detail to be able to do it. Some departments have it well; other departments do not.[332]

And when asked when he would have that information, he replied: "I do not know […] I make no promises on this, Chairman."[333]

275. Unlike the economist and statistician classes, Government has kept no central record of engineers in Government since the mid-1980s.[334] Professor David Fisk, whose long tenure as a Chief Scientific Adviser in Government places him in a good position to comment, explained:

> In central government the numbers of professionally qualified engineers are to say the least modest. DTI in its last year did not know the precise number of Chartered Engineers through it 'could recall ten'. If this is really true it is a smaller number than the number of members of the Chinese Politburo with engineering qualifications! DfT's Rail Group which undertakes much of the role of the old Strategic Rail Authority has just twelve chartered engineers in a staff of almost 300.
>
> These figures are in stark contrast to those of the 1960s when a great deal of engineering was undertaken in, or close to, Central Government. […] At this time the Civil Service had a well defined class called 'Professional and Technical Officer' that paralleled 'Scientific Officer' class. Between 1939 and 1959 the numbers in both classes rose from 11,000 to 70,000. The dramatic reduction since then reflects a change in Government structure rather than the amount of engineering undertaken in the name of the public sector. If anything, engineering issues have increased both in scale and complexity.[335]
>
> My broad conclusion is that the strength of engineering knowledge in government is largely the result of accident; that, despite the Professional Skills Agenda, there is not much evidence of nurturing professional skills; that neither sponsor departments nor supervisory boards seem to take much interest in human capital in engineering as part of a statutory function's 'balanced scorecard'; that, while there may be no magic percentage of engineers in public service, other pressures mean the UK is likely to have ended up with too few not too many.[336]

276. The Government has provided us with the most up-to-date data on the number of civil servants with a scientific or engineering background.[337] Engineers play a key role in several departments and agencies. For example:

— in the Health and Safety Executive there are 594 civil servants with a degree in engineering, and 135 chartered engineers (out of approximately 3,500 staff); and

— in the Ministry of Defence there are approximately 650 chartered engineers (out of approximately 76,000 full-time equivalents).[338]

332 Oral evidence taken before the Innovation, Universities, Science and Skills Committee on Wednesday 5 November 2008, HC (2007–08) 999-iii, Q 245

333 Oral evidence taken before the Innovation, Universities, Science and Skills Committee on Wednesday 5 November 2008, HC (2007–08) 999-iii, Qq 247–248

334 Ev 751

335 Ev 751

336 Ev 752

337 Ev 788–790

338 Ev 788–790. 650 people may be an underestimate.

277. In most departments, however, the Government does not know how many engineers it has. This is true of the Department for Business, Enterprise & Regulatory Reform (BERR), the Department for Communities and Local Government (CLG), the Department for Culture, Media and Sport (DCMS), the Department for Energy and Climate Change (DECC), the Department for Environment, Food and Rural Affairs (Defra), the Department of Health (DH), the Department for Work and Pensions (DWP), and the Foreign and Commonwealth Office (FCO). In the Department for Children, Schools and Families (DCSF) there appear to be none.[339]

278. The lack of records is problematic because without a clear understanding of what expertise exists in the civil service, it is impossible to say one way or the other whether the right expertise exists in each policy area. It is worrying because it flies in the face of repeated calls for such data to be kept. It is worth reproducing what one of our predecessor Committees had to say on the matter:

> There are no accurate figures regarding the total numbers of scientists and engineers in the workforce, despite the recommendation in the 2002 Cross-Cutting Review of Science and Research that "Departments should maintain records on specialist staff in order to be able to identify their scientific qualifications and experience". Nevertheless, Sir David King said there had been a "continuing reduction of scientists and engineers in the civil service", which he described as "a concern". […] **We recommend that the Government implement the 2002 recommendation of the Cross-Cutting Review of Science and Research to maintain records on specialist staff in order to identify their qualities and experience […].**[340]

279. The Government responded that:

> From 2007, the Common Employee Record (CER) is likely to provide data on professional categories and PSG [Professional Skills for Government] career grouping. At present plans for rollout of the CER does not include collecting data on qualifications but this might be added once the CER has been successfully implemented.[341]

280. It appears that the Government has made little progress.

281. **We reiterate the 2006 Science and Technology Committee's previous recommendation that: "the Government implement the 2002 recommendation of the Cross-Cutting Review of Science and Research to maintain records on specialist staff in order to identify their qualities and experience".**

Professionalism in the civil service

282. We also heard that the civil service frequently does not keep track of professional qualifications or accreditation of its specialist staff. Professor David Fisk told us, with typical frankness:

> I think the human resources in the Civil Service at the moment have rather lost the plot on professionalism in general. […] One or two of the human resources departments I received information from clearly did not really understand what a Chartered Engineer was. One rather extreme case, Ofcom, that works in a very

339 Ev 788–791

340 Science and Technology Committee, *Scientific Advice, Risk and Evidence Based Policy Making*, para 45

341 Science and Technology Committee, *Scientific Advice, Risk and Evidence Based Policy Making: Government Response to the Committee's Seventh Report of Session 2005–06*, p 11

> technical area, did not know how many Chartered Engineers they had but they did notice that they paid the fees for three. It seemed to me when I looked at the board of a number of them—the Environment Agency was one I looked at yesterday—very often the scorecards given to the board do not measure the internal competence of the organisation. They will measure how well the outside world is performing as it is being regulated but there is not a track. As you will see from my evidence, at the time I asked the question the Financial Services Agency did not know how many Chartered Accountants it had.[342]

283. Failure to promote and monitor engineering professionalism in the Civil Service is problematic. Not only does it mean that managers do not have a firm grasp on what professional expertise exists across the Service, but it also misses an opportunity to promote professionalism in engineering and promote the role of engineers to the public.

284. **The Government could promote the importance of professional accreditation in engineering by insisting that staff and consultants in technical roles are chartered. Additionally, the Government should keep proper records of the professional qualifications of its staff so as to improve its human resources information and continuing professional development.**

Specialism in the civil service

The senior civil service

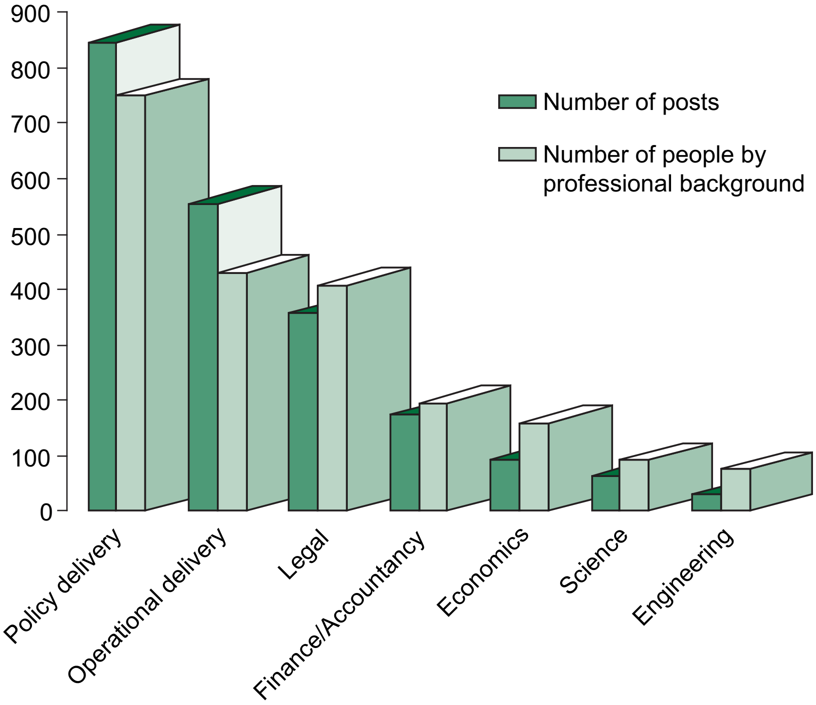
285. At the top of the civil service, Professor Beddington was satisfied that there is a good number of scientists and engineers. "There are 180 scientists and engineers in the senior civil service and that is a greater number than economists and a greater number than a number of the other professions."[343] In fact, according to the Government's own data,[344] there are 168 engineers and scientists in the senior civil service. But as we discussed above, engineers and scientists usually bring different skills sets to policy advice—as do, for example, economists and accountants, the former being more theoretical and the latter being more practical; for our purposes they could be taken as analogous to scientists and engineers—so we should take these figures separately: 76 engineers and 92 scientists. These figures compare to 160 economists, 194 accountants, 408 lawyers, 431 'operational delivery' specialists, and 749 'policy delivery' specialists; the grand total of senior civil servants is 4,212 (see Figure 3). But it gets worse. Of those 76 engineers and 92 scientists, 30 engineers and 65 scientists are doing jobs that require specialist knowledge of engineering and science. In other words, 95 of this group *have* to be engineers and scientists. Therefore, of the 1,399 jobs in policy delivery (845) and operational delivery (554) there are, probably at most, 46 engineers and 27 scientists. That compares to 94 economist jobs and 174 accountant jobs in the senior civil service, which leaves 66 economists and 20 accountants doing other jobs in the senior civil service. So in the generalist senior civil service, scientists and engineers are almost certainly outnumbered by economists and accountants, which is the opposite of what Professor Beddington's rehearsal of the data implied.

342 Q 27 [Ev 725]

343 Q 562 [Ev 85]

344 SCS Database 2008, Cabinet Office

Figure 3. Senior Civil Service by profession of post and by profession of person, April 2008. This is a selected list of professions. See Ev 364-365 for full tables.



Non-SCS grades

286. The Science and Engineering Fast Stream (SEFS) was set up to ensure that there are generalist civil servants who have a background in science and engineering: it is run to recruit individuals with science or engineering degrees who go on to be trained as generalists. According to the Government, "engineers are valued for their generic problem-solving skills and their ability to produce practical solutions to problems and drive delivery through project management skills".[345] It is therefore surprising that only four departments recruit from the SEFS: MoD, DIUS, BERR and DECC. Further, the number available to departments is low: last year only 9 out of 249 successful candidates for the general fast stream, which includes the Science and Engineering Fast Stream, had engineering degrees.[346] This is an issue on which the Government Chief Scientific Adviser agrees that more needs to be done: "This is one of the areas where I really have to engage with the departments".[347]

287. **The Government claims that the Science and Engineering Fast Stream is highly valued, yet only four departments recruit from it. We ask the Government to explain why this situation has arisen and what steps it plans to take to ensure that all Departments recruit from the Science and Engineering Fast Stream.**

288. A separate, but related issue, is what happens to SEFS recruits after they enter the civil service: they immediately begin training as a generalist and within their first few years will usually work in areas that are not related to science or engineering. While it is clearly important that there is a residual engineering expertise across the generalist service, the Royal Academy of Engineering, among others, has additionally called for science and engineering fast streamers to be given opportunities for progression while retaining their

345 Ev 744

346 Ev 779 [CaSE]

347 Q 564 [Ev 85]

specialisms.[348] This would not only ensure that there was a good supply of specialists in those policy areas in which engineers are most useful—for example energy, building, transport and so on—but also improve the standing of specialists in the civil service and make the prospect of pursuing a career in policy attractive to people with an engineering training, who do not necessarily want to be a generalist.

289. We note that Professor Beddington has taken steps to improve the recognition and community of scientists and engineers in the civil service:

> When I came into government, […] I said who are the professions that I am heading, where are they and how do I find them because I want to engage with them as that is part of my job. As you know, that proved to be much more difficult than I had expected. What I did was I said let us have a community who genuinely recognises that they are scientists and engineers. That was done by circulating an email, and so on, which said "We are doing this. Would you like to be part of that community?" A little under 1,600 people elected that they would like to be considered as scientists and engineers and that was in the first flush of this. Yesterday we had a conference with about 310 of them and one of the things we said was "Is this helpful and how do you want to take it forward?" 97 per cent of the responses said this was helpful and they did want to take it forward. I made a commitment at that conference to say we will engage you but you have to go away and tell us what you need as a community of civil servants who are scientists and engineers […] We went through a number of key issues: career development, whether you should be moving into policy or can you be rewarded if you remain dealing with your expertise, all very important questions.[349]

290. This effort by the GCSA to make the title 'Head of Profession for Science and Engineering' a more tangible role is encouraging. It is noteworthy that the emphasis of the work thus far is to look at career development and whether scientists and engineers can work as policy specialists. This indicates the Government recognises the lack of scientific and engineering expertise in the generalist civil service as a weakness.

291. **There should be more trained and experienced engineers in the civil service at all levels. One way of helping to achieve this would be to expand and adapt the Science and Engineering Fast Stream (SEFS) so that more scientists and engineers are recruited, more departments recruit from this cohort and SEFS recruits have the option to pursue careers as policy specialists. We also recommend that the Government prioritise training in the civil service to improve the ability of generalist civil servants to identify issues where engineering advice will be critical to the viability of a policy.**

Career flexibility between the public and private sectors

292. Another way of getting more engineers into the civil service is to improve the flexibility between the public and private sectors. Both Professor Fisk and the Royal Academy of the Engineering looked to the USA as a model that the UK could potentially follow. Professor Fisk noted that:

> The US has a much more flexible career relationship between private and public sectors at Federal and State level. The US National Academy of Engineering (NAE) records that 7% of its members as in the 'government and not-for-profit' sector, in

348 Ev 757

349 Q 559 [Ev 84]

> contrast to around 3% (my estimate of the NAE equivalent) in the Royal Academy of Engineering.[350]

293. Such flexibility already exists in the UK between industry and universities:

> Universities [engineering departments] are not a bad example […]. We as academics spend only a small amount of time in industry, so we have visiting professors who spend most of their time in industry and who come and teach our students and help the design classes. We have developed a personal HR policy that works with them in a very flexible way.[351]

There is no reason to presume that a similar culture of exchange could not be developed between industry and the civil service. First, secondments between the two already happen.[352] Secondly, there is much to gain for both parties:

> I can see the advantage to both sides if major firms like Arups or WS Atkins were to second one of their engineers for a period of two or three years at a pretty senior level. The reason is that they will bring the outside experience in, but also they can go back to their parent organisation as the person with the experience of working within government.[353]

294. Third, the current economic climate makes engagement between the Government and engineers in the private sector more advantageous and pressing.

295. **The Government should seek ways to improve the career flexibility between industry and the public sector. Both sides would benefit: engineers from the private sector would improve their understanding of Government, and civil servants would improve their understanding of industry; additionally, the public sector would benefit from using the skills of engineers who have managed major projects in the private sector.**

The Treasury

296. The Treasury is a stand-out Government department. It has a trans-departmental role, controlling the money that goes to each department, and through its budgetary leverage it can play a formative role in shaping policy. But it is the only department that does not have a Chief Scientific Adviser. Professor David Fisk raised specific concerns:

> While acknowledging the undoubted skill set of public sector economists, there is no reason to expect that they have much experience in either the risk management issues or the modality of operation of real world engineering enterprises. The Treasury Green Book used as the basis for policy appraisal does not distinguish engineering innovation issues at all.[354]

297. He recalled:

> I had an opportunity to interview the [Treasury] team that designed rail privatisation. It turned out it had never occurred to them that the track and the wheels that rest on it are a coupled spring system. They were not all mechanical engineers. They had in

350 Ev 753

351 Q 44 [Ev 728] [Professor Fisk]

352 Q 28 [Ev 725] [Professor Kelly]

353 As above.

354 Ev 753

> their mind the sort of model you would get owning a train set when you are a boy. So they thought them quite independent and very easy to divide the market in that way. They may still have been right to stratify the market for rail privatisation as they did but what they did not realise was that there would be an engineering cost for making the break where they did.[355]

And Bob Dover, the former Chairman and Chief Executive of Jaguar Land Rover, had a similar concern:

> ***Mr Dover:*** Personally I have had meetings with the Treasury which have been a complete waste of time. […] I obviously presented my case very badly, but it was just ignored, it was a waste of both our time.
>
> **Chairman:** Is this because they did not understand the engineering case?
>
> ***Mr Dover:*** You have got to have an intelligent [… q]uestioner and you have to ask the right questions […] Often an adviser can help in understanding what is important and what questions to ask. If you do not ask the right questions, you can just go completely wrong. One example of that would be generation one biofuels where because no-one asked whether the numbers stood up we went down completely the wrong path.[356]

298. The former Science and Technology Committee recognised the problem of science advice in the Treasury, and suggested that the GCSA should have a seat on the board of the Treasury, and that the Treasury should have a Chief Scientific Adviser.[357]

299. **We share our predecessor Committee's concern that the Treasury does not have scientific or engineering advice at the highest level. The Treasury should appoint both a Chief Scientific Adviser and a Chief Engineering Adviser.**

Case study conclusion: the need for Chief Engineering Advisers

300. When the Government talks about evidence-based policy or the STEM agenda, we have observed that 'science' always comes before 'engineering' and usually to the exclusion of it. This is not a banal pecking-order dispute. It is an observation about the Government's attitude towards science and engineering. Or is it engineering and science? According to a new Government campaign, it is neither: the name of the campaign is 'Science: So What? So Everything'! As Professor Wendy Hall put it:

> David King and John Beddington both use science to mean science and engineering but to me—and you will understand this—it is very like when people say, "Well, 'he' means he and she" but when people say "he" then mean he, particularly "he's" [men] when they say "he". When scientists say "science" they mean science.[358]

301. And Professor the Lord Broers, who plainly told us that he considers himself both an engineer and a scientist, had the following exchange with the Chairman:

> **Chairman**: You have just heard, Lord Broers […] an impassioned plea for engineers to be recognised as, if you like, a chief engineer within departments alongside Chief Scientific Advisers, but you seem to be saying that these are

355 Q 20 [Ev 724]

356 Qq 461–464 [Ev 65]

357 Science and Technology Committee, *Scientific Advice, Risk and Evidence Based Policy Making*, para 25

358 Q 4 [Ev 721]

opposite sides of the same coin and that therefore we do not need to make that distinction.

> ***Lord Broers***: I think that is the case but I would have approached this problem from a different point of view. I would have asked the question: is it necessary to have a Chief Scientist alongside the Chief Engineer?
>
> **Chairman**: What is your answer?
>
> ***Lord Broers***: Probably not in many instances.
>
> **Chairman**: So you would have a Chief Engineer?
>
> ***Lord Broers***: Yes.
>
> **Chairman**: Would you settle for a Chief Scientific and Engineering Adviser?
>
> ***Lord Broers***: I would settle for a Chief Engineering and Scientific Adviser.[359]

302. We have already discussed at length the fact that engineers have a different set of skills to scientists and that Government could benefit from more engineering advice. This leads to a natural question, raised in the discussion between the Chairman and Lord Broers: should there be a Government Chief Engineering Adviser?

303. The engineering community certainly thinks that there should be. The strength of feeling was at times palpable. Bob Dover, former Chairman and CEO of Jaguar Land Rover, when asked if the Government would benefit from having a Chief Engineer, replied: "Yes, much more important than a Chief Scientist".[360] We heard several reasons:

- Because engineering advice is distinct from other kinds of advice: We have argued this above (Paragraph 248). Additionally, the Royal Academy of Engineering pointed out that:

  > There is growing support for the appointment of a Chief Engineer, distinct from the Government Chief Scientist. Engineers have particular skill in the deployment of resources to meet national goals and measures; the management of risk and the assessment of technological solutions to problems like climate change and security of energy supply—all of which are essential to good policy making. Such an appointment would also go a substantial way to ensure that engineering is appropriately represented in Government and that the needs and contributions of engineering are dealt with by Government in a strategic manner.[361]

- Because engineers are best qualified to set best practice in engineering advice: Professor Wendy Hall noted in her impassioned call for a Chief Engineering Adviser that "just as Chief Scientific Advisers set best practice for science policy in a department, you need the engineering expertise to set best practice for engineering policy".[362]
- Because the Government should recognise the importance of engineers: The professional engineering community submitted in a joint statement that "As currently happens with Science (through the Chief Scientist [i.e., Government Chief Scientific

359 Qq 50–53 [Ev 730]

360 Q 469 [Ev 66]

361 Ev 246

362 Q 13 [Ev 722]

Adviser]), appropriate recognition should also be given to Engineering and Technology in the policy making process".[363]

- Because it has proved successful elsewhere: Professor Snowden told us that having a Chief Scientific Adviser and a Chief Engineering Adviser could "work very well", at the same time putting pay to the fear over putting the two disciplines in 'silos':

> I would like to add that I have been in a company in the United States, I was a chief scientist there, and I actually worked in parallel with their chief engineer and, I have to say, we did not see the differences there. Similarly, in my own companies, I have had similar roles, so I do not see them as competitive, I see them as complementary.[364]

304. We would add to this list:

- Because Departmental Chief Engineering Advisers (DCEAs) would be able to take an overview of a Department's engineering advice needs and ensure that sufficient capacity existed to meet those needs. We have already demonstrated that engineering capacity in the civil service is currently insufficient (see Paragraph 257).
- Because Chief Engineering Advisers would provide useful points of contact between departments trying to co-ordinate overlapping engineering programmes.
- Because Chief Engineering Advisers would provide useful points of contact to the outside world—particularly the engineering community. We were alerted about the need for this when Lord Broers, who has more experience than most in engineering-related policy, through his work as the former President of the Royal Academy of Engineering and the former Chairman of the House of Lords Science and Technology Committee, admitted:

> Yes, well, I am afraid, Chairman, even I am ignorant of quite where these [Government policy] decisions are made. My experience, having chaired the Science and Technology Committee, is that we are always trying to bring back decisions that were made somewhere, but I was never quite sure where, to bring sanity back to the case. In fact, as you know in your Committee, my Committee, when I chaired it, was quite effective in many instances in bringing things back by taking the right evidence from the right people and establishing what is the sensible strategy, but I am not sure where these strategies originate. They are made somewhere deep inside departments, I suppose.[365]

- Because the Government already recognises other specialist expertise that it also puts under the broad heading of 'science'.

305. **The Government could easily support its claim to recognise the importance of engineering and engineers by appointing Chief Engineering Advisers, at a minimum in positions where existing Chief Scientific Advisers act as Chief Engineering Advisers.**

306. **The Government has argued on several occasions that 'science' includes engineering, and therefore there is no need for a Chief Engineer. But it also argues that 'science' includes social science and statistics, yet there is a Chief Social Scientist and a National Statistician. The Government's position is illogical.**

307. **Some departments should have Departmental Chief Engineering Advisers (DCEAs), some Departmental Chief Scientific Advisers (DCSAs), and some should**

363 Ev 186

364 Q 56 [Ev 730]

365 Q 60 [Ev 731]

have both. The Government Chief Scientific Adviser should liaise with Departments to determine which arrangement is most appropriate.

308. One further issue that was raised regarding the role of DCEAs and DCSAs is the role that they play in the senior management of a department and whether they should sit on the boards of departments.[366] We note that some departments do have their DCSA on the board, for example Defra and DIUS, but most do not. We shall return to this issue during our inquiry on 'Putting science and engineering at the heart of Government policy'.

309. We agree with Professor Beddington that there should be one person to head up the research and engineering strand of advice across Government.[367] Currently, that person is the GCSA, Professor Beddington. For reasons that follow, we are proposing an enhanced role as head of scientific, social science and engineering advice across Government. A job title that would be more befitting this role—and in line with the GCSA's current role as Head of the Science and Engineering Professions—would be Government Chief Scientific and Engineering Adviser (GCSEA).

310. The civil service currently has a Chief Social Scientist and a National Statistician, and in the past there has been a Chief Economic Adviser. We take the view that there should also be a cross-departmental head of engineering, whose job it would be to ensure that engineering advice across Government was adequate and engineering programmes across Government were co-ordinated. Since the departmental engineering heads will be called Departmental Chief Engineering Advisers, and not to confuse with the GCSEA, this individual could simply be called the Government Chief Engineer. Additionally there should be a Government Chief Scientist, Government Chief Social Scientist and a Government Chief Statistician. These would make up a cross-departmental advice and co-ordination team, and would be responsible for keeping the GCSEA briefed. The GCSEA would take on a more prominent role, with more regular meetings with the Prime Minster and Cabinet Office Officials and Advisers.

311. In order to maximise the benefits of this new arrangement, there needs to be a location change. Currently, the GCSA is based in DIUS but answers to the Prime Minister. We agree with the former Science and Technology Committee, which recommended in 2006 that the GCSA and the office of the GCSA should be relocated to the Cabinet Office to reflect and better enable its cross-departmental remit.[368]

312. These proposals would be easy for the Government to implement, would put down a marker of the Government's commitment to evidence-based policy, and would lay the structural and cultural foundations for a more evidence-focused civil service. To summarise (also see Figure 4):

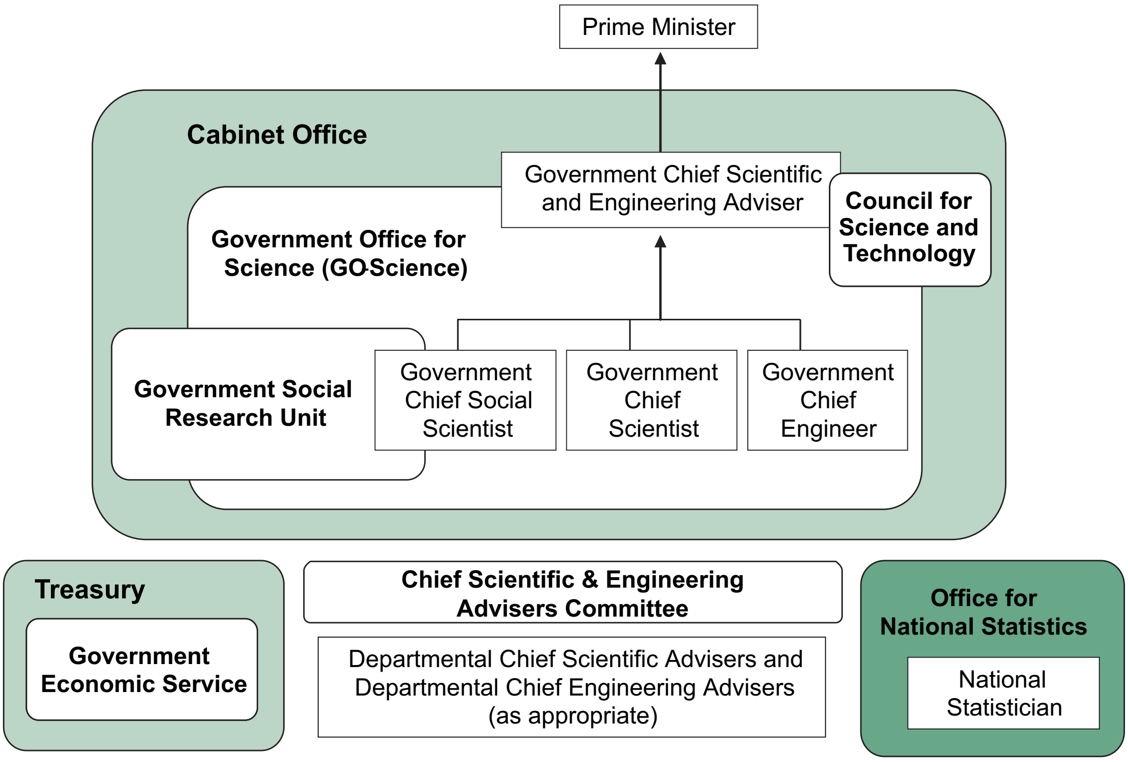
313. **The role of the GCSA should be altered. We suggest that the GCSA should be renamed the Government Chief Scientific and Engineering Adviser (GCSEA). This person would be the head of profession for science, engineering, social science and statistics and should have a more senior role in the Government with direct access to the Prime Minister. The GCSEA would head up the Government Office for Science and Engineering, which should be placed in the Cabinet Office. Beneath the GCSEA should be a Government Chief Engineer, a Government Chief Scientist and a Government Chief Social Scientist. We recommend that the Government implement these changes as a priority.**

Figure 4. Organogram of our recommendations for the organisation of science advisory structures in Government

366 Qq 30–32 [Ev 726]

367 Qq 538–541 [Ev 80–81]

368 Science and Technology Committee, *Scientific Advice, Risk and Evidence Based Policy Making*, para 25


Prime Minister
Cabinet Office
Government Chief Scientific and Engineering Adviser
Council for Science and Technology
Government Office for Science (GO-Science)
Government Social Research Unit
Government Chief Social Scientist
Government Chief Scientist
Government Chief Engineer
Treasury
Government Economic Service
Chief Scientific & Engineering Advisers Committee
Departmental Chief Scientific Advisers and Departmental Chief Engineering Advisers (as appropriate)
Office for National Statistics
National Statistician

6 Overview and general conclusions

> We need to rediscover the power of engineering, its impact and contribution. It can stimulate young minds and it can stimulate the economy.
>
> James Dyson, founder of Dyson plc

Introduction

314. During the course of this inquiry, we have become increasingly conscious of the critical contribution that engineering makes to the economy and societal well-being, and the decisive role it must play in tackling global challenges such as climate change, water and food supply, and energy security. Nuclear engineering, plastic electronics engineering and geo-engineering will play their part, but they make up only a tiny segment of the engineering sector. In this chapter, we broaden out the discussion and outline a number of recommendations that are applicable across the whole engineering sector.

Engineering skills and the formation of engineers

315. In January 2009, the Government published the results of its consultation on STEM skills, *The Demand for Science, Technology, Engineering and Mathematics (STEM) Skills*. The evidence the Government received was very similar to the evidence we received during the course of our inquiry (see Chapter 2). 11% of employers were experiencing some hard-to-fill vacancies, with the greatest difficulties in marine engineering (20%) and aerospace engineering (16%). Of those organisations with problems recruiting graduates, the biggest shortage was amongst mechanical engineers (43%), with electronics and electrical engineers also in short supply (27% and 22% respectively).[369]

316. Training the next generation of engineers is always a national priority, but it takes on an element of urgency when there is a shortage. The economic downturn provides both a challenge—in terms of persuading people to train for a career that is clouded by media stories of severe job losses—and an opportunity—as a level of economic restructuring is inevitable as the country (and world) comes out of recession. Additionally, because the timescales involved in large engineering projects are so extensive, projects being planned now will be staffed by people who are currently in school. Therefore, to answer a simple question such as ‘how can the UK solve engineering skills shortages?’, one must consider the complex path by which a child becomes a professional engineer. The engineering profession call this process ‘formation’.

Formation of engineers

317. The first step in the formation of engineers is in schooling. We have avoided detailed consideration of this stage, since it lies outside the Committee’s core remit. However, much has been said on this subject—not least in our e-consultation for employers and young engineers—and the Government has been very supportive of STEM teaching in schools, which we applaud.

318. The engineering community undertakes a range of activities to highlight the range of opportunities afforded by a career in engineering. We participated in one such event—The

369 *The Demand for Science, Technology, Engineering and Mathematics (STEM) Skills*, DIUS, January 2009, p 14–15; 2006 Labour Market Survey of the GB Engineering Sectors, SEMTA

Big Bang[370]—and congratulate all the organisations that were involved in delivering this, and many other, engineering events, after schools clubs and activities. These include:

- engineering clubs for young people (90% of which are in state schools);[371]
- engineering challenges, for example: the Young Engineer for Britain Competition; the Royal Navy Challenge; the BAA Challenge; the Airbus Challenge; and the K'Nex Challenge (which in 2006/07 involved 93,000 students);[372]
- programmes delivered by the Engineering Development Trust: Year in Industry (a year out before or during degree course); Headstart Courses (summer courses assisting informed choice regarding technology based degrees and careers); Engineering Education Scheme (links year 12 student teams with local companies to work on real problems over a 6 month period); and Go4SET (linking teams of year 9 pupils with companies and universities on a 10 week SET experience);[373]
- the NOISE campaign: targets 11–19 year olds, and uses a range of early career researcher role models to promote STEM skills and careers;[374] and
- Greenpower, which runs electric car races for schools, colleges, apprentices and youth groups to promote engineering and technology as careers.[375]

319. Several of the young engineers we spoke to told us they were inspired to study engineering as they wanted to work on projects that addressed global challenges. They share this inspiration with Norman Haste, Chief Operating Officer of Laing O'Rourke, who told us:

> It is really about creativity, it is about making a difference, it is about contributing to the future well-being […] of the Earth in general, because we have some really big problems worldwide.[376]

320. One of the biggest global challenges we face today is climate change. In the future, geo-engineering technologies may play a role in climate change mitigation, and IMechE, among others,[377] has identified the potential for this sector to inspire young engineers: it recently ran an international competition in which teams of young engineers made technical assessments of the feasibility and sustainability of potential geo-engineering solutions. [378] A team from the Science and Technology Facilities Council at the Rutherford Appleton Laboratory in Oxfordshire won for the design for an artificial tree.

321. To get a feel for the impact of engineering competitions and activities on the aspirations of young people, we spoke to members of 'Young Engineers', an organisation that develops and manages a national network of extra-curricular engineering clubs in both the primary and secondary sectors. We greatly enjoyed meeting these promising young engineers, and were impressed with their enthusiasm. We were told by Oyenuga Abioye

370 The first UK young scientists and engineers fair for schools and colleges

371 Ev 124

372 Same as above.

373 Ev 159

374 Ev 260

375 Ev 121

376 Q 82 [Ev 9]

377 Ev 678 [Professor Caldeira], Ev 666 [RCUK], Ev 690 [IMechE], Ev 663 [NOCS]

378 Q 33 [Ev 690]

that "Engineers are creative people; they do imagine things and bring it to normal life",[379] a sound definition! We heard why engineering is important:

> You get to achieve things in building, design and creation. Not just write your design on paper but to actually build it and say "Yes, I have achieved something; everybody enjoys my creation and anyone can use it". So, engineering is really for everyone.[380]

And we heard inspiring optimism:

> **Dr Gibson:** When you are young, people often ask you that daft question, "What do you want to do when you grow up?" […] what do you say?
>
> ***Josh Simpson:*** My answer is that I want to be an engineer; I want to create something; I want to change the world.[381]

322. What set these young engineers apart from their peers, is that they had the opportunity to experience engineering at a young age, coupled with good career advice. The young engineers we interviewed felt that the latter is particularly important:

> ***David Lakin:*** Careers advisers and teachers do not necessarily push kids into engineering, mainly because they do not have the right perception of engineering themselves. Those who have an interest in engineering, science and maths, it then gets wasted because they get pushed into other areas.[382]
>
> ***Chris Martin:*** … sciences are taught by science teachers who have done science degrees, there is no one who has actually done engineering because they are all working in practice. So students are not made aware that this whole career is out there.[383]
>
> ***Le'val Haughton-James:*** At GSCE level, I did double science and IT, but I dropped technology because I was not interested in it in school, but it gives you that introduction to the skill which you can take on and then expand further. In school, they do not relate it to engineering so you do not realise you are doing engineering until you hear about it from somewhere else.[384]

323. **We were greatly impressed by the high quality and wide-ranging work to give young people experience of engineering. We are supportive of all efforts to make young people aware of the rewarding and challenging nature of a career in engineering. While we would not advocate that geo-engineering be championed as a research field above any other, we believe that it might have the 'X-factor' when it comes to alerting young people to global engineering challenges and we welcome its inclusion in engineering events. We are concerned, however, that engineering is not always promoted as a worthwhile, challenging and exciting career option, and advocate that it feature more prominently in the provision of careers advice at schools.**

324. Following school, students can pursue professionalism through two main routes: further education and higher education. Further education is particularly important, and in

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379 Q 6 [Ev 1]

380 Q 8 [Ev 1] [Mr Haughton-James]

381 Q 59 [Ev 6]

382 Q 10 [Ev 2]

383 Q 32 [Ev 4]

384 Q 35 [Ev 4]

Chapter 2 we noted our support for the employer-led Skills Academies that are working in this area. The Government has also invested in revitalising apprenticeships in the UK, an issue we dealt with in detail in our reports *Pre-legislative Scrutiny of the draft Apprenticeships Bill*[385] and *Re-skilling for recovery: After Leitch, Implementing skills and training policies.*[386] We do not expand on those reports here.

Higher skills

325. During the Chairman's visits to Imperial College London and UKAEA Culham in September 2008, concern was expressed at the shortage of high calibre UK applicants for post-graduate research positions, and at the overall shortage of suitably qualified applicants for PhD studentships in physics and materials disciplines.

326. A facet of research common to plastic electronics, geo-engineering and the nuclear industry is its multidisciplinary nature. For example, geo-engineering research requires knowledge of atmospheric chemistry and physics, climate systems and marine sciences to name but a few of the disciplines involved,[387] and plastic electronics research teams comprise a whole range of experts from "narrow specialists that typically work on materials, to generalists, to systems people".[388] The message we received throughout these case studies was that general engineering expertise was important to employers—who expect to put new recruits through further training—rather than the formation of specialised workers. For example, in respect to food manufacturing, Richard Midgley told us:

> I think we are looking, clearly, for people of high academic calibre but, also, with that […] "native curiosity and energy" and so on. When we put people into technical jobs in Unilever, we cannot expect that there will be some University College London department of margarine making.[389]

327. The importance of 'native curiosity' in prospective employees was also underlined by Richard Archer, who told us that when he was recruiting medical engineers:

> What I wanted were guys who were immensely curious about what was going on, with a fire in their belly and a twinkle in their eye, and whether they were called a chemical engineer or a mechanical engineer did not really matter because you could turn them loose on things and they had big brains and off they went.[390]

328. Despite the undoubted importance of general engineering skills, it is unquestionable that some industrial sectors require highly specialised engineers. Plastic electronics is an example of one such industry. Rather than the development of a plastic electronics degree programme, submissions to this case study called for increased investment in post-graduate training to better support the industry,[391] and organisations such as Plastic Logic called for the development of a plastic electronics conversion course:

385 Innovation, Universities, Science and Skills Committee, Seventh Report of Session 2007–08, *Pre-legislative Scrutiny of the Draft Apprenticeships Bill* , HC 1062-I

386 Innovation, Universities, Science and Skills Committee, *Re-skilling for recovery: After Leitch, implementing skills and training policies*

387 Ev 647

388 Q11 [Ev 509] [Dr French]

389 Q 491 [Ev 70]

390 Q 489 [Ev 70]

391 Ev 593 [CEESI], Ev 564 [Cambridge Integrated Knowledge Centre], Ev 581 [UKDL KTN]

> I think it would be very interesting to see an emergence of a plastic electronics conversion course at some kind of UK institution that could take guys who were basically electronics engineers in yesterday's technology and make them electronic engineers in tomorrow's technology. There is a very nice precedent in the UK DisplayMasters programme[392] which does something like that and I think that would be very, very helpful.[393]

329. In identifying those areas of engineering that would most benefit from the introduction of specialised training courses, it is important that the Government take into account the engineering needs of the future in addition to those of the present, including competition between sectors. For example, a commitment by Government to invest in renewing/upgrading the nation's infrastructure as part of a fiscal stimulus package would have implications for the number and 'cadre' of engineers required. Without any horizon-scanning, a significant time-lag would undoubtedly arise between the point at which the Government commits to embarking on a project and the point at which the UK can provide a workforce with the requisite skills to deliver it.

330. In assessing the UK's engineering skills needs, it is important that the Government should not 'navel gaze' but keep one eye on the competition. Monitoring the extent to which the activities of other nation states are likely to compete for the indigenous skills base is particularly important in the current economic climate. For example, the $787 billion US economic stimulus package will create opportunities for engineers to work on projects including upgrading the electric grid ($11 billion), kick-starting the Advanced Research Projects Agency-Energy ($400 million), battery research ($2 billion) and proposes $1 billion be given to NASA ($400 million of which could be spent on rocket development).[394] These opportunities are unlikely to appeal only to the US's domestic engineering population.

331. **The key to solving sector-specific shortages of engineers will ultimately lie in the UK's ability to train the next generation of generalist engineers, who will then specialise after university. Plastics electronics is one example of an industry that would benefit from the introduction of post-graduate programmes that offered generalist engineers specialised training. We recommend that EPSRC engage with industry to assess the potential for establishing a range of conversion courses according to need across the engineering sector to upskill generalist engineers.**

Management training

332. The technical and theoretical knowledge of an engineer is only part of his or her arsenal. Another is management skills, which we heard from several sources are often lacking in recruits from university. For example, in evidence to the plastic electronics case study, Stuart Evans from Plastic Logic made a plea for the inclusion of management training in post-graduate education:

> I want young scientists to know how to supervise people, how to write project reports, and how to do some of the basic blocking and tackling that represents the move from being a fantastic professional to being a young manager and then to be a

392 The DisplayMasters programme was designed by industry and academia with the aim of creating a new generation of Display Technologists, Engineers, Scientists and Managers. DisplayMasters is sponsored by the EPSRC and run by Dundee University in collaboration with the Universities of Abertay Dundee, Cambridge, Edinburgh Napier, Oxford and Nottingham Trent.

393 Q 178 [Ev 536]

394 Hand, E & Wadman, M (2009) *Nature*, 457, 942-945

> great leader. So whether you do it in under-graduate degrees, I am not certain that is relevant; it is definitely relevant in post-graduate qualifications.[395]

333. Lord Drayson also highlighted the value of management experience to early career academics with a desire to set-up a spin-out company.

> We have seen very effective models for spin-out companies where it has been a professor and a post-doc. The professor has worked with the post-doc to create new intellectual property [… and] the post-doc has then transferred to be the first managing director of the spin-out company […]. You have to have that central focus for the science first and then train the management experience on top of it.[396]

334. We do not consider it is necessary to wait until individuals are engaged in post-doctoral research before introducing them to management skills. Indeed, giving evidence as part of our Engineering in Government case study, Professor David Fisk, Imperial College London, highlighted the advantages of French engineering degrees in terms of management education:

> I would score France up very high in the sense that its basic engineering education is far superior to the UK. People leave French engineering schools able to run companies the day they leave, not absolutely packed with five years learning of technology.[397]

335. Although concern was expressed over the availability of management skills in the graduate population, we recognise that steps are being taken to rectify this through, for example, EPSRC's Engineering Doctorate (EngD) programme. This PhD-level programme operates at academic centres that recruit a group of research engineers to work within a research area and industrial sector. Open to graduates in any branch of engineering (or other relevant discipline), EngD students are expected to spend around 75% of their time working directly with their collaborating company. Packages of training courses are tailored to their needs in order to develop management skills, as well as specialist technical subjects. Projects are designed jointly by the academics and the co-operating company.[398]

336. **We believe there to be value in incorporating management skills in post-graduate masters and doctoral programmes. We recommend that HEFCE, EPSRC, the Royal Academy of Engineering and the professional institutions co-ordinate to advise on best-practice in the delivery of this training by higher and further education institutes.**

Diversity

337. Diversity is a major problem in engineering. Only 2% of engineering apprentices are female and only 4% are black or an ethnic minority (BME).[399] And in universities, the proportion of engineering graduates who are female is low: in 2006/07 it stood at 14.3%, compared with 60.5% for other subjects.[400] It is not a problem of differential ability: girls

395 Q 180 [Ev 537]

396 Q 213 [Ev 546]

397 Q 39 [Ev 727]

398 www.epsrc.ac.uk/PostgraduateTraining/Centres/EngD/Intro.htm

399 Ev 275

400 Ev 97

across all ethnic groups generally outperform boys at science GCSE and A Level.[401] Rather, it is more likely to do with cultural issues, such as peer pressure and career advice at school and work-life balances in the job.[402] The Women's Engineering Society has suggested that action should be taken to address the long hours and family unfriendly work cultures that contribute to the 'leaky pipeline' for women engineers, particularly those with children and caring responsibilities.[403] And the WISE Campaign (Women into Science, Engineering and Construction) has suggested that there should be more girls-only enhancement and enrichment activities, and those that are mixed gender should be 50:50 boys and girls—it cites the London Engineering Project as evidence that such aims are feasible.[404]

338. Work in this area is carried out by a range of organisations, including the WISE Campaign, the Smallpeice Trust, Science Technology Engineering and Mathematics Network (STEMNET) and the Learning Grid. The Engineering and Technology Board says that there are too many independent initiatives:

> Greater effective coordination is needed on the multiplicity of promotional and awareness-raising activities that are currently undertaken by a wide range of public, private and professional organisations. While many of these interventions and initiatives are excellent and have national coverage, better coordination would maximise impact and improve the consistency of messaging.[405]

339. However, the Learning Grid, which is an organisation that promotes engineering to students and teachers, has countered that:

> Our experience leads us to treat with caution the frequently-expressed view that there are too many initiatives, that this is unhelpful and confusing and that consolidation should be the first objective. The diversity and dynamism of engineering-related initiatives is an opportunity not a threat.[406]

340. Whoever is correct, three things are certain. First, an attempt to rationalise efforts is already underway: Shape the Future aims to bring coherence to the many SET schemes that focus on 10–14 year olds, increasing their impact and effectiveness. It was started by the Royal Academy of Engineering but is owned by the whole science and engineering community. This is a worthwhile project, and support for it should continue. Second, some improvements have been made. For example, the number of female students in engineering increased from 13.1% in 2002/03 to 13.7% in 2005/6;[407] the percentage of female professional engineers increased from 5.3% in 2005 to 6.2% in 2007;[408] and last year 40% of employers reported that they believed the number of female candidates was increasing.[409] Third, however, where improvements have been made, they have been small, and much more needs to be done. To begin with, if 40% of employers think the number of female candidates is increasing, the implication is that 60% do not see such a

401 Ev 234

402 Ev 232, 336, 206

403 Ev 204

404 Ev 287

405 Ev 169

406 Ev 268

407 Higher Education Statistics Agency (HESA) 2004 & HESA 2007

408 Ev 235

409 *Summary of 2008 survey findings: engineering and technology skills and demand in industry*, Institute of Engineering and Technology, p 4

pattern. Further, where improvements exist they have been small because the baseline is so low: only 5% of engineers, 5% of technicians and 7% of IT professionals are women.[410]

341. In order that initiatives to broaden the diversity profile of the engineering sector impact positively on recruitment and retention, it is essential that they are founded on an understanding of the factors that affect the career choices of under-represented groups and effectiveness of different interventions. This point was underlined by Philip Greenish, Chief Executive of the Royal Academy of Engineering: "we need to work really hard to understand how interventions at different stages of a young person's life actually make an effect in terms of their decisions and where they end up at the end".[411]

342. Efforts have been made by organisations such as the Smallpeice Trust to establish an evidence base on which to build widening participation initiatives. However, Pat Langford from STEMNET told us that these efforts have not been sufficiently co-ordinated and that while "there is this great plethora of stuff out there but nobody has actually ever produced any real workable, consistent evidence". A point also made by Terry Marsh, WISE:

> I have been told in the past there is plenty of research, we are drowning in research, but actually we are swimming in polluted waters, we do not have good solid evidence as to what it is that is affecting girls and their decisions in life. Is it their peers, is it the media, is it their parents, is it teachers? If we could actually do a really nice piece of snapshot research, followed by longitudinal research […] you [… would] start to see what is happening and […] how these decisions are made.[412]

343. We asked Francis Evans (Learning Grid) whether responsibility for conducting detailed research of this kind lay with industry or the Government. His clear view was that, as a central co-ordinating body, it was the role of government.[413] We agree with this view.

344. **We support the Government's efforts to promote diversity in engineering. Its financial support for STEMNET and the Science and Engineering Ambassadors programme, WISE, the Computer Club for Girls, and the work of the Royal Academy of Engineering and the Engineering Development Trust is welcome and should continue.**

345. **We are concerned that evidence is lacking on the factors that affect the career choices of women and other under-represented groups. We recommend that DIUS commission research to examine these factors. This evidence should then be used as a platform from which to develop and target widening participation initiatives.**

The perception of engineers

346. Whatever the historical reasons or causation, engineers in the UK have a lower status than their peers elsewhere in the world, for example in China, Japan, Germany or France. This was elegantly brought home to us when we were reminded that: "If you ask a group of teenagers to name the most famous engineer in Britain the majority of them will talk about Kevin Webster who is a car mechanic on Coronation Street".[414]

410 Same as above.

411 Q 190 [Ev 26]

412 Q 221 [Ev 30]

413 Q 222 [Ev 30]

414 Q 224 [Ev 31] [Ms Langford]

347. We agree with an unnamed member of the Engineering and Machinery Alliance who wrote:

> In Germany an engineer is a revered person. He can only be called an engineer providing he/she is suitably university qualified. In England we have many levels of engineer ranging from the university graduate to the Corgi gas fitter! We seem ashamed to refer to trades people and must disguise their trade with the term engineer. Sadly as a nation we have far too few qualified trades people whether it be in manufacturing or building trades. It seems unless you have been to university and have a degree you are deemed to be a failure, which of course is absolute nonsense.[415]

348. During our visit to China and Japan, we were struck by the respect held for British engineers and UK engineering. The perception of the UK engineering profession as portrayed by the British media is of systematic budgetary and timetable overruns. This is far from the truth in other parts of the world, where British engineers and engineering firms are considered to be amongst the best in the world. In particular, there are two key strengths associated with the UK. The first is an outstanding research base, fuelled by a competitive academia that is keen to engage with industry. The Japanese were particularly envious of the UK's university-based research. We were told on our visit that the reason that approximately 80% of R&D takes place in the private sector in Japan, is that the universities are not trusted as they are in the UK.

349. The second strength is the chartering system in the UK. Andrew Ramsey, the Chief Executive of Engineering Council UK explained to us what a chartered engineer is:

> "[C]hartered engineer" is a standard applied by the Engineering Council, it belongs to the Engineering Council, and that was something the Government established back in 1984, and we hold the register of all the people who are able to call themselves chartered engineers. There are something like 180,000 of them, many of them overseas, but the majority in the UK, of course. In order to be awarded chartered engineer designation people have to demonstrate they have the competence to practise as a chartered engineer, and that competence is assessed through a process which involves looking at their education, their training and, in particular, the evidence that they are practising at a level capable of being accepted as a chartered engineer. The way in which this is done (and this is where the profession works very well together) is that we, as a relatively small organisation, review and audit the processes of the 36 institutions that we recognise—in fact there are many more, but there are only 36 that are able to meet the standards required—and those people who pass through the process are registered by us as chartered engineers.[416]

350. The international respect for UK Chartered Engineers that we noticed was echoed in the evidence we received. Keith Read, who represented the G15 group of engineering institutions, confirmed that "the British chartered engineer has a far higher status internationally than he does at home".[417]

351. Norman Haste, who built the Severn Bridge and Terminal 5 at Heathrow, gave us one possible explanation, and solution, for the UK's low perception of its engineers:

> We are very bad in this country at celebrating success. When you say that we are not very good at delivering projects, I can name a few projects that […] have been

415 Ev 196

416 Q 138 [Ev 19]

417 Q 214 [Ev 29]

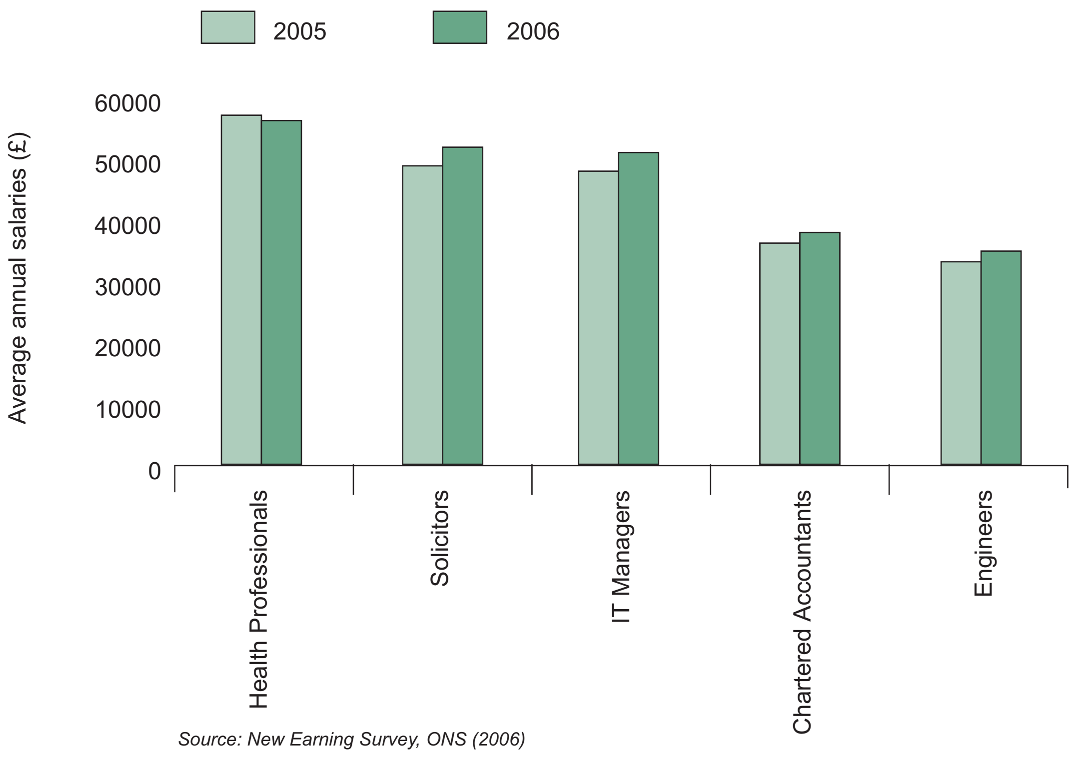
tremendous successes. […] I led a team of 600 people; engineers of all disciplines, planning and designing Terminal 5 for six and a half years, but unfortunately, instead of celebrating that as an engineering success, it has become notorious because of British Airways' troubles with their baggage handlers. That is putting the wrong bias completely. What I would like to see is a much greater celebration of success with engineering because we are very good at it.[418]

352. We received several other suggestions to resolve this issue of perception. The e-consultation for young engineers highlighted some concern about the salaries of engineers:

> The salary is really not equal to the work you put in during your degree […]. A pertinent example would be at my university (Bath). The 55 Civil Engineers in my year, can expect on average to start on something around £26–30K if they achieve a 2:1 or 1st […]. For a BBA (Bachelors of business and administration) the starting wage for that same 1st or 2:1 student could well be the same, despite having done a far easier degree both in time-wise and syllabus wise. In addition after 5 year their projected salary will be far greater than the equivalent civil engineer […]. The trend continues throughout the careers, with engineers earning less. Why should I do engineering if this is the case?[419]

353. The lower salaries of engineers in comparison with health professionals, lawyers, accountants and bankers is stark (see Figure 5).

Figure 5. New Earnings Survey—Comparison of Salaries of Main Professions[420]



418 Q 98 [Ev 11]

419 Ev 796

420 *Engineering UK 2007*, ETB, p 55

354. Another suggestion, apparently from a journalist covering science for 40 years, focussed on the engineers and their responsibility to communicate why their profession is so important:

> A better solution […] would be for engineers to stop whining and to celebrate their subject in public. Point out to young people the engineers are the ones who will solve the problems of climate change and energy shortages. Remind them that engineers created their iPods and the football stadiums they love to visit. Oh, and add that engineers are pretty well paid, despite the whingeing letters that occasional sneak into the newspapers.
>
> For that to happen, engineers have to become better communicators. Don't leave it to the […] physicists to claim the glory from the Large Hadron Collider. Learn how to talk to ordinary people, and not just fellow engineers.
>
> There has been a revolution in science communication over the past 20 years. Sadly, the engineers have missed the boat, perhaps because their institutions are too busy competing with one another when they should be collaborating on this important aspect of their profession.[421]

355. Another approach explored by a Mr Jennings in a 10 Downing Street petition, could be to tackle terminology. We outlined our definition of an engineer in the first chapter—an engineer turns ideas into reality—but we did not delve into terminology, which is far more complicated. In the UK, for example, the term 'engineer' is generically used to describe both chartered engineers and technicians. This is not the case in, say, Germany or France, where engineers and technicians are distinguished in everyday language.[422] Mr Jennings has suggested legal protection should be afforded to the title 'Engineer':

> As a recently qualified Astronautics Engineer and with 8 years experience as a Robotics Engineer I am at a point where due to the lack of respect by the Government, the media in particular the BBC, and society as a whole, I feel there is little point staying in the UK. Car mechanics, Plumbers and Electricians are now commonly referred to as Engineers and Banks now regard Engineers as non/semi skilled. With the UK falling behind most other countries in training Professional Engineers and the falling numbers of children undertaking science based subjects this can only result in a reduction in the UK's competitiveness. I believe for the long turn prosperity of the UK and to attract students back to science subjects the Government must act decisively and introduce laws to protect Engineers such that only "Chartered Engineers" ImechE, RAeS [Royal Aeronautical Society] can use the title Engineer. This will give Engineers the same professional status in our society as doctors, lawyers similar to Europe.[423]

356. The petition received 35,360 signatories, and great deal of support during our e-consultation exercise with employers. However, the Government rejected the petition:

> The Government looks to the Engineering Council UK to regulate the professional status of engineers, through its Royal Charter. It is true that there is nothing to stop anyone from describing themselves as an "engineer" but only those individuals who have a current registration on the ECUK Register of Qualified Engineers and Technicians may use the professional titles of Chartered Engineer, Incorporated

421 Ev 797

422 In German, 'ingenieur' means a chartered engineer, and 'techniker' means a technician; in French, 'ingénieur' means a chartered engineer and 'dépanneur' means a technician.

423 http://petitions.number10.gov.uk/Engineer-Status

Engineer and Engineering Technician. It would not be practical or appropriate for the Government to attempt to introduce new legislation on this matter.[424]

357. While dissatisfied with the current situation, we find ourselves in agreement with the Government. The catchall use of 'engineering' is regrettable, but legislating on language cannot be the answer to raising the status of engineers. Chartered Engineer, Incorporated Engineer and Engineering Technician are already protected terms and respected titles, especially internationally. **We suggest that the engineering institutions, Engineering Council UK and the Government (see Paragraph 284, Chapter 5) should do a better job of promoting Chartered Engineer status (CEng), Incorporated Engineer status (IEng) and Engineering Technician status (EngTech). In the same way the general public respects academic qualifications such as PhDs, Masters and Honours Degrees, or professional qualifications in law and medicine, so should it be possible to inform the public about the professional status of CEng, IEng and EngTech.**

Conclusion

358. When we decided to conduct this inquiry, the enormous scope and breadth of engineering and the problems that this might cause were at the forefront of our minds. We attempted to mitigate against this problem of breadth and scope by identifying themes and exploring them through case studies. The engineering profession and Government do not have this luxury: engineers must continue to be trained in all the necessary disciplines, in appropriate quantities, while keeping standards consistent and high across the whole; engineering advice must be sourced from Government and available from engineers as and when it is needed, no matter what the subject and sometimes on short timescales; long-term engineering projects that affect disparate parts of the UK, many engineering companies and several Government departments must retain focus while economic and political factors fluctuate around them. None of these tasks are easy; all are necessary.

359. In the preceding chapters, and to an extent in this chapter, we have discussed some of the broad issues and made some specific recommendations. In Chapter 2 we discussed the complicated interaction between skills training and capacity, overlapping engineering programmes and supply chain difficulties in relation to nuclear engineering. We concluded that the Government would benefit from taking a more strategic approach to its large-scale engineering programmes. In Chapter 3 we discussed the role Government plays in innovation and commercialisation and we concluded that the Government should be more strategic in its approach to supporting emerging industries. In Chapter 4 we explored the policy implications of a new engineering discipline, concluding that the views of the engineering, science and social science communities are all critical to shaping domestic and international policy and that Government should consult widely in developing relevant legislative frameworks. And in Chapter 5 we outlined deficiencies in the Government's capability to make engineering advice the foundation of many policy areas. We recommended that Government would benefit from having more engineers at all levels of the Civil Service and suggested some structural changes to enhance the cross-departmental organisation of specialist advice.

360. **There is a need for better trans-departmental management of engineering policy. The Government should adopt a practice of formulating and following roadmaps for each major engineering programme, including skills provision (see Chapter 2) with co-ordination between each of them. The Government should also be more strategic in its support for emerging industries and policy areas (see Chapters 3 and 4). Finally, Government would benefit from having senior officials tasked to**

424 www.number10.gov.uk/Page14749

oversee engineering roadmaps and strategic plans, and to manage engineering advice in a Civil Service with more residual and specialised engineering expertise. There should be two people responsible for this challenging body of work: a Government Chief Scientific and Engineering Adviser and a Government Chief Engineer (see Chapter 5).

361. While we have been critical about the Government's lack of detailed strategic planning and use of engineering advice, there are significant positives to take from this inquiry. We welcome the co-ordinated way in which the engineering community approached this inquiry (Chapter 1). We have been impressed by efforts to inspire and train the next generation of engineers, including the Government's commitment to the STEM agenda (Chapter 6) and to employer-led training (Chapter 2). We have discovered that our engineering research base is world-class (Chapter 3). And we welcome the Government Chief Scientific Adviser's ongoing efforts to improve the recognition of the engineering community in Government (Chapter 5). But most importantly, we have come to appreciate the critical contribution that engineering makes to society, the economy and to solving or mitigating against many of the world's most daunting challenges. **We are convinced that the considerable strength of the UK's engineering base makes it both this nation's responsibility and in its economic interest to play a major part, through our engineering base, in solving global problems such as climate change, food and water supply, energy security and economic instability. The recent economic crisis has presented the Government with a once-in-generation opportunity to restructure the economy by building on the existing substantial strengths of UK engineering.**

Conclusions and recommendations

The profession

1. The engineering community's approach to this inquiry has been coherent and co-ordinated, with the institutions working together to communicate a common message with and through the Royal Academy of Engineering. **The Academy must take forward and formalise its leadership role, so that the engineering community can communicate—and co-ordinate—more effectively.** (Paragraph 10)

Nuclear engineering: skills

2. The Generic Design Assessment (GDA) process is important and requires highly skilled inspectors. **The Government should make available sufficient resources to the Health and Safety Executive and the Environment Agency so that they can recruit enough staff to complete the GDA process in a timely fashion and to the high standards required. A clear timetable should be published by the end of 2009.** (Paragraph 33)

3. We note the Government's optimism that delivering new nuclear power stations within ten years is possible. However, we are not convinced that the skills shortage in nuclear engineering can be bridged quite as easily as some have suggested. In particular, the General Design Assessment, which kick-starts the whole process, is already running slower than expected, and the remaining workforce is ageing. **The Government must continue its investment in engineering and nuclear engineering skills and produce a clear skills plan by the end of 2009 (see Paragraph 33), to ensure its nuclear new build ambitions can be met.** (Paragraph 41)

4. We welcome the formation of the National Skills Academy for Nuclear: employer-led training is the best way to ensure that industry gets the skills it requires. **However, we also believe that there should be greater clarity from industry and Government about which institutions do what in terms of skills provision.** (Paragraph 47)

5. The design of fourth generation nuclear reactors will go ahead with or without UK participation, and it is likely that the UK will want to start building fourth generation power stations in the future. **The UK should avoid positioning itself so that it has little expertise in the very nuclear systems it needs in the future. In a post-oil economy, nuclear power will be a major player in the energy market and the UK should grasp enthusiastically the opportunity to take a lead role in the international nuclear industry.** (Paragraph 50)

6. **The Government should consider which research programmes—including the Generation IV programme, EURATOM, and IAEA and OECD research programmes—are required to support its nuclear activities. We strongly recommend that the Government commission the National Nuclear Laboratory to conduct a cost-benefit analysis on what international R&D offers the UK in relation to maintaining UK nuclear engineering capability and ensuring future UK energy policy is supported.** (Paragraph 52)

7. We support the formation of the Office for Nuclear Development, but remain concerned about the lack of a clear and detailed plan for delivering the next generation of nuclear power stations. **There should be a master roadmap for all major engineering projects, including nuclear new build. The Office for Nuclear**

Development should take ownership of the roadmap for nuclear. The roadmap should include consideration of: what skills are required over time and what will be needed to deliver the skills capacity ahead of time; other general engineering programmes and nuclear engineering programmes, both national and international; potential bottlenecks in the supply chain; and who is responsible for the delivery of each part of the roadmap. There should be six-monthly progress reports against the roadmap. The roadmap should be in place by the end of 2009. (Paragraph 57)

Plastic electronics engineering: innovation and commercialisation

8. The UK is well placed to capitalise on the economic potential of the growing plastic electronics industry. However, we are concerned that without a clear understanding of how best to build on and market the UK's strengths in this sector this opportunity might not be fully realised. We urge BERR to engage with the Technology Strategy Board, UK Trade and Investment, UK Displays and Lighting Knowledge Transfer Network and the plastic electronics community to develop a technology roadmap. In constructing this roadmap it is essential that stakeholders across the sector be consulted, from spin-out companies to multinationals. (Paragraph 72)

9. We welcome the support for plastic electronics research and development provided by EPSRC and the Technology Strategy Board, and believe sustained support by these organisations is vital to the growth of the industry. (Paragraph 80)

10. We do not believe that the Technology Strategy Board's grant schemes and the Managed Programme proposed by UKDL KTN and the former-DTI are mutually exclusive forms of support. UKDL KTN champions the needs of the plastic electronic community, and as such we urge BERR and the Technology Strategy Board to engage with it, and to reconsider the deployment of a Managed Programme in this area. (Paragraph 89)

11. The future success of the UK plastic electronics industry not only lies in its ability to lever public and private finance, but also in the co-ordination of funding sources. We recommend that BERR, the Technology Strategy Board and UKDL KTN take immediate steps to increase the understanding of technological risk in the private sector, and to review the funding landscape. (Paragraph 95)

12. PETeC's location is a function of the fact that it was established as a regional initiative. It is an open question whether PETeC would have been sited elsewhere had it been founded as a national resource, something that it undeniably is. However, we do not see further discussion on this issue as constructive or worthwhile, and wish to see a line drawn under the debate. (Paragraph 100)

13. We are sympathetic to PETeC's need to generate income in order both to assure its future survival and to allow it to participate in UK grant competitions. The Technology Strategy Board and OneNorthEast should review whether the requirement for self-sustainability within five years is realistic. (Paragraph 104)

14. We urge PETeC to continue developing its relationships with other Research Centres, and to liaise with these Centres to ensure national capability in facilitating R&D across the spectrum of plastic electronic technologies. (Paragraph 106)

15. The plastic electronics industry is likely to grow substantially over the next few years. Although the UK's research base puts it in a unique position to capitalise on this growth, we must not be complacent as countries such as Germany and the USA are becoming increasingly competitive. We recommend that the Research Centres supporting UK plastic electronics R&D engage with the academic research base to ensure state-of-the-art facilities are accessible to the academic community. (Paragraph 112)

16. The UK academic research base should be applauded for its strong record in 'spinning out' start-up companies. Focused support, however, is needed to ensure these businesses grow into world-class enterprises. We recommend that the Technology Strategy Board, BERR and UKTI consult with UK business, from start-ups to multinationals, to identify how best to support the growth of innovative businesses in emerging industries. (Paragraph 120)

17. We encourage the Technology Strategy Board to engage with multinational companies across Europe to determine whether pan-European consortia could be established to progress the development of emerging industries with the potential for high economic returns. (Paragraph 128)

18. The manufacture of plastic electronics devices is not destined to occur outside of the UK. However, we are extremely concerned that without urgent action by the Government this will be the reality. As in our previous recommendation (Paragraph 72), we urge the Government to engage with the plastic electronics community, and to articulate a strategic vision for the development of this innovative industry. (Paragraph 130)

19. Support for innovative businesses as they transition from being primarily R&D focused to launching pilot manufacturing lines is imperative. We recommend that the Government consider whether there is merit in establishing an open access fabrication facility for the manufacture of Plastics Electronic devices by UK SMEs. (Paragraph 133)

20. The economic opportunities provided by this growing industry do not only lie in the manufacture of devices, but also in the development of enabling technologies. It is imperative that any national strategy for this industry must embrace the materials supply chain, particularly as this sector holds huge potential for UK industry participation. (Paragraph 138)

21. Public procurement has the potential to be a valuable tool in driving innovation. We welcome the Government's efforts to develop innovative procurement mechanisms, and recommend it supports pilot projects in the area of plastic electronics in order to stimulate product development and manufacture. (Paragraph 148)

22. The Small Business Research Initiative (SBRI) is potentially a valuable source of funding for innovative companies in the UK. Our concern is that unless this support mechanism is re-launched in a format accessible to SMEs developing future technologies, UK companies will refocus their business models to engage with the lucrative procurement opportunities offered by the US under its Small Business Innovation Research programme. We ask that DIUS keep us updated on progress made in rolling-out the revised SBRI. (Paragraph 155)

Geo-engineering: a new policy area

23. At this stage, we do not consider a narrow definition of geo-engineering technologies to be helpful. Technologies to reduce solar insolation and to increase carbon sequestration should both be considered as geo-engineering options. (Paragraph 182)

24. Like the Minister of State for Science and Innovation, we believe that Government should give the full range of policy options for managing climate change due consideration, and we share the view of the Tyndall Centre that geo-engineering technologies should be evaluated as part of a portfolio of responses to climate change, alongside mainstream mitigation and adaptation efforts. (Paragraph 185)

25. Given the need for urgent action in addressing the challenge of climate change, we can see no reason for not considering geo-engineering technologies as a 'plan B'. Quite the opposite, the decision not to consider any initiative other than 'plan A' could be considered negligent particularly, for example, if 'plan A' fails to act as planned or climate sensitivity is greater than expected. (Paragraph 187)

26. We find the divergent views of DECC and DIUS, as outlined by Lord Drayson and Joan Ruddock, as to the future potential of geo-engineering research to be confusing, and urge the Government to establish a clear view on the matter. (Paragraph 190)

27. Further, we conclude that it would not be appropriate or sensible for opinion-leaders or the public to see any policy on the potential use of geo-engineering schemes as implying a lack of ongoing commitment to the development of conventional emission mitigation strategies or adaptation responses. We urge the Government to be proactive in communication efforts to dispel any incorrect perceptions. (Paragraph 191)

28. In order 'to sort the wheat from the chaff' and identify those geo-engineering options it may be feasible to deploy safely in the future, it is essential that a detailed assessment of individual technologies be conducted. This assessment must consider the costs and benefits of geo-engineering options including their full life-cycle environmental impact and whether they are reversible. We welcome the efforts of the Royal Society to review the geo-engineering sector, and urge it to engage with the Royal Academy of Engineering and the Science and Engineering Academies of other nations in this regard. (Paragraph 197)

29. Support for detailed modelling studies will be essential for the development of future geo-engineering options, and to the construction of a credible cost-benefit analysis of technological feasibility. We urge the Research Councils to support research in this area. (Paragraph 203)

30. The Tyndall Centre for Climate Change is well-placed to co-ordinate geo-engineering research, and we would welcome the conduct of geo-engineering-related work as an additional work-stream. Further, we recommend that the Government engage with organisations including the Tyndall Centre, Hadley Centre, Research Councils UK and the Carbon Trust to develop a publicly-funded programme of geo-engineering research. Research grants should be awarded on the basis of excellence after a process of competitive peer review. (Paragraph 217)

31. Before deploying any technology with the capacity to geo-engineer the climate, it is essential that a rational debate on the ethics of geo-engineering be conducted. We urge the Department for Energy and Climate Change to lead this debate, and to consult on the full-range of geo-engineering options with representatives of the science, social science, and engineering communities and implementing agencies e.g. national Governments, international bodies or private sector organisations. (Paragraph 226)

32. It is essential that the Government support socio-economic research with regard to geo-engineering technologies in order that the UK can engage in informed, international discussions to develop a framework for any future legislation relating to technological deployment by nation states or industry. (Paragraph 229)

Engineering in Government

33. We conclude that engineering advice and scientific advice offer different things to the policy formulation process and that the benefits of both should be recognised. Further, it should not be assumed that a scientific adviser can offer competent engineering advice or even know when it is needed. (Paragraph 248)

34. We conclude that the Government, in several policy areas of several departments, does not have sufficient in-house engineering expertise to act as an intelligent customer. (Paragraph 257)

35. The Guidelines on Scientific Analysis in Policy Making should explicitly include engineering advice. We are pleased that Professor Beddington has already agreed to review these guidelines, and suggest that the research and engineering community be consulted on the content of the guidelines. (Paragraph 260)

36. Engineering advice should be sought early in policy formulation and before policy is agreed, not just in project delivery. We recommend that the Secretary of State for Innovation, Universities and Skills and the Minister for Science and Innovation act as champions in cabinet for the early engagement of engineers in policy making. Further, this issue should also be central to discussions in the Science and Innovation Cabinet Sub-Committee. (Paragraph 265)

37. For engineering advice, the Government should consider the Royal Academy of Engineering as its first port of call. The Academy can then bring together the relevant experts, including representation from the relevant professional institutions, to provide impartial, expert and timely input to policy formulation. (Paragraph 272)

38. The Government should set up a Working Group with the Royal Society, the Royal Academy of Engineering, the British Academy and the Academy of Medical Sciences to explore how and whether the relationship between Government and the Academies could be formalised so as to improve policy making. We reiterate the 2006 Science and Technology Committee recommendation that strong consideration should be given to the US model. (Paragraph 273)

39. We reiterate the 2006 Science and Technology Committee's previous recommendation that: "the Government implement the 2002 recommendation of the Cross-Cutting Review of Science and Research to maintain records on specialist staff in order to identify their qualities and experience". (Paragraph 281)

40. The Government could promote the importance of professional accreditation in engineering by insisting that staff and consultants in technical roles are chartered. Additionally, the Government should keep proper records of the professional qualifications of its staff so as to improve its human resources information and continuing professional development. (Paragraph 284)

41. The Government claims that the Science and Engineering Fast Stream is highly valued, yet only four departments recruit from it. We ask the Government to explain why this situation has arisen and what steps it plans to take to ensure that all Departments recruit from the Science and Engineering Fast Stream. (Paragraph 287)

42. There should be more trained and experienced engineers in the civil service at all levels. One way of helping to achieve this would be to expand and adapt the Science and Engineering Fast Stream (SEFS) so that more scientists and engineers are recruited, more departments recruit from this cohort and SEFS recruits have the option to pursue careers as policy specialists. We also recommend that the

Government prioritise training in the civil service to improve the ability of generalist civil servants to identify issues where engineering advice will be critical to the viability of a policy. (Paragraph 291)

43. The Government should seek ways to improve the career flexibility between industry and the public sector. Both sides would benefit: engineers from the private sector would improve their understanding of Government, and civil servants would improve their understanding of industry; additionally, the public sector would benefit from using the skills of engineers who have managed major projects in the private sector. (Paragraph 295)

44. We share our predecessor Committee's concern that the Treasury does not have scientific or engineering advice at the highest level. The Treasury should appoint both a Chief Scientific Adviser and a Chief Engineering Adviser. (Paragraph 299)

45. The Government could easily support its claim to recognise the importance of engineering and engineers by appointing Chief Engineering Advisers, at a minimum in positions where existing Chief Scientific Advisers act as Chief Engineering Advisers. (Paragraph 305)

46. The Government has argued on several occasions that 'science' includes engineering, and therefore there is no need for a Chief Engineer. But it also argues that 'science' includes social science and statistics, yet there is a Chief Social Scientist and a National Statistician. The Government's position is illogical. (Paragraph 306)

47. Some departments should have Departmental Chief Engineering Advisers (DCEAs), some Departmental Chief Scientific Advisers (DCSAs), and some should have both. The Government Chief Scientific Adviser should liaise with Departments to determine which arrangement is most appropriate. (Paragraph 307)

48. The role of the GCSA should be altered. We suggest that the GCSA should be renamed the Government Chief Scientific and Engineering Adviser (GCSEA). This person would be the head of profession for science, engineering, social science and statistics and should have a more senior role in the Government with direct access to the Prime Minister. The GCSEA would head up the Government Office for Science and Engineering, which should be placed in the Cabinet Office. Beneath the GCSEA should be a Government Chief Engineer, a Government Chief Scientist and a Government Chief Social Scientist. We recommend that the Government implement these changes as a priority. (Paragraph 313)

Overview and general conclusions

49. We were greatly impressed by the high quality and wide-ranging work to give young people experience of engineering. We are supportive of all efforts to make young people aware of the rewarding and challenging nature of a career in engineering. While we would not advocate that geo-engineering be championed as a research field above any other, we believe that it might have the 'X-factor' when it comes to alerting young people to global engineering challenges and we welcome its inclusion in engineering events. We are concerned, however, that engineering is not always promoted as a worthwhile, challenging and exciting career option, and advocate that it feature more prominently in the provision of careers advice at schools. (Paragraph 323)

50. The key to solving sector-specific shortages of engineers will ultimately lie in the UK's ability to train the next generation of generalist engineers, who will then specialise after university. Plastics electronics is one example of an industry that would benefit from the introduction of post-graduate programmes that offered generalist engineers specialised training. We recommend that EPSRC engage with industry to assess the potential for establishing a range of conversion courses according to need across the engineering sector to upskill generalist engineers. (Paragraph 331)

51. We believe there to be value in incorporating management skills in post-graduate masters and doctoral programmes. We recommend that HEFCE, EPSRC, the Royal Academy of Engineering and the professional institutions co-ordinate to advise on best-practice in the delivery of this training by higher and further education institutes. (Paragraph 336)

52. We support the Government's efforts to promote diversity in engineering. Its financial support for STEMNET and the Science and Engineering Ambassadors programme, WISE, the Computer Club for Girls, and the work of the Royal Academy of Engineering and the Engineering Development Trust is welcome and should continue. (Paragraph 344)

53. We are concerned that evidence is lacking on the factors that affect the career choices of women and other under-represented groups. We recommend that DIUS commission research to examine these factors. This evidence should then be used as a platform from which to develop and target widening participation initiatives. (Paragraph 345)

54. We suggest that the engineering institutions, Engineering Council UK and the Government (see Paragraph 284, Chapter 5) should do a better job of promoting Chartered Engineer status (CEng), Incorporated Engineer status (IEng) and Engineering Technician status (EngTech). In the same way the general public respects academic qualifications such as PhDs, Masters and Honours Degrees, or professional qualifications in law and medicine, so should it be possible to inform the public about the professional status of CEng, IEng and EngTech. (Paragraph 357)

55. There is a need for better trans-departmental management of engineering policy. The Government should adopt a practice of formulating and following roadmaps for each major engineering programme, including skills provision (see Chapter 2) with co-ordination between each of them. The Government should also be more strategic in its support for emerging industries and policy areas (see Chapters 3 and 4). Finally, Government would benefit from having senior officials tasked to oversee engineering roadmaps and strategic plans, and to manage engineering advice in a Civil Service with more residual and specialised engineering expertise. There should be two people responsible for this challenging body of work: a Government Chief Scientific and Engineering Adviser and a Government Chief Engineer (see Chapter 5). (Paragraph 360)

56. We are convinced that the considerable strength of the UK's engineering base makes it both this nation's responsibility and in its economic interest to play a major part, through our engineering base, in solving global problems such as climate change, food and water supply, energy security and economic instability. The recent economic crisis has presented the Government with a once-in-generation opportunity to restructure the economy by building on the existing substantial strengths of UK engineering. (Paragraph 362)

Annex 1—Glossary

AFCI	Advanced Fuel Cycle Initiative
ACR	Advanced CANDU Reactor
BERR	Department for Business, Enterprise and Regulatory Reform
BMBF	Federal Ministry of Education and Research
BME	Black and Minority Ethnic
BNFL	British Nuclear Fuels plc
CAE	Chinese Academy of Engineering
CCS	Carbon Capture and Storage
CDT	Cambridge Display Technologies
Cenamops	Centre of Excellence for Nano, Micro, and Photonic Systems
CEng	Chartered Engineer
CIKC	Cambridge Integrated Knowledge Centre
CPI	Centre for Process Innovation
CSAC	Chief Scientific Advisers Committee
CST	Council for Science and Technology
DCEA	Departmental Chief Engineering Adviser
DCLG	Department of Communities and Local Government
DCMS	Department for Culture, Media and Sport
DCSA	Departmental Chief Scientific Adviser
DCSF	Department for Children, Schools and Families
DECC	Department of Energy and Climate Change
DEFRA	Department for the Environment, Food and Rural Affairs
DfT	Department for Transport
DH	Department of Health
DIUS	Department for Innovation, Universities, and Skills
DTI	Department of Trade and Industry
DWP	Department for Work and Pensions
EAJ	Engineering Academy of Japan

ECUK	Engineering Council UK
EngD	Engineering Doctorate
EngTech	Engineering Technician
EPSRC	Engineering and Physical Sciences Research Council
ESBWR	Economic Simplified Boiling Water Reactor
ESRC	Economic and Social Research Council
EURATOM	European Atomic Energy Community
FCO	Foreign and Commonwealth Office
FCP	Forward Commitment Procurement
GCSA	Government Chief Scientific Adviser
GCSEA	Government Chief Scientific and Engineering Adviser
GDA	Generic Design Assessment
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIF	Generation IV International Forum
GO-Science	Government Office for Science
HSE	Health and Safety Executive
IAEA	International Atomic Energy Agency
IEE	Institute of Electrical Engineers
IEng	Incorporated Engineer
IMechE	Institute of Mechanical Engineers
IPCC	Intergovernmental Panel for Climate Change
IPMS	Institute for Photonic Microsystems
IRIS	International Reactor Innovative and Secure
JET	Joint European Torus project
LCD	Liquid Crystal Display
LC-TV	Liquid Crystal Television
LHC	Large Hadron Collider
LWR	Light Water Reactors
METI	Ministry of Economy, Trade and Industry

MoD	Ministry of Defence
MRSEC	Materials Research Science and Engineering Centre
NAE	National Academy of Engineering
NEDO	New Energy and Industrial Technology Development Organisation
NERC	Natural Environment Research Council
NGNP	Next Generation Nuclear Plant
NNL	National Nuclear Laboratory
NSAN	National Skills Academy for Nuclear
NSF	National Science Foundation
N-TEC	Nuclear Technology Education Consortium
OECD	Organisation for Economic Cooperation and Development
OLED	Organic Light Emitting Diode
OMIC	Organic Materials Innovation Centre
OND	Office for Nuclear Development
OPV	Organic Photovoltaic
PBMR	Pebble Bed Modular Reactor
PETeC	Printable Electronic Technology Centre
P-OLED	Polymer Organic Light Emitting Diode
PSAC	Presidential Science Advisory Committee
PVL	Polymer Vision Limited
RAeS	Royal Aeronautical Society
S/NVQ	Scottish and National Vocational Qualifications
SBRI	Small Business Research Initiative
SEFS	Science and Engineering Fast Stream
SEMTA	Sector Skills Council for Science Engineering and Manufacturing Technologies
SET	Science, Engineering and Technology
SME	Small and Medium-sized Enterprises
STEM	Science, Technology, Engineering and Mathematics
STEMNET	Science, Technology, Engineering and Mathematics Network

UKAEA	United Kingdom Atomic Energy Authority
UKDL KTN	UK Displays and Lighting Knowledge Transfer Network
UKTI	UK Trade and Investment
VC	Venture Capital
WCPC	Welsh Centre for Printing and Coating
WISE	Women into Science, Engineering and Construction

Annex 2—Case study terms of reference

Nuclear engineering

The terms of reference for the Nuclear Engineering case study are as follows:

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

— the value in training a new generation of nuclear engineers versus bringing expertise in from elsewhere;

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

— the overlap between nuclear engineers in the power sector and the military.

Plastic electronics engineering

The terms of reference for the Plastic Electronics Engineering case study are as follows:

— the current and future roles of engineers in the field of plastic electronics;

— the potential for plastic electronics in the UK/global economy;

— how universities, industry, venture capital and Government are involved in the development of the UK plastic electronics sector; and

— whether the UK engineering and manufacturing sector are set up to handle growth in this area or other areas like it.

Geo-engineering

The terms of reference for the Geo-engineering case study are as follows:

— the current and potential roles of engineering and engineers in geo-engineering solutions to climate change;

— national and international research activity, and research funding, related to geo-engineering, and the relationship between, and interface with, this field and research conducted to reduce greenhouse gas emissions;

— the provision of university courses and other forms of training relevant to geo-engineering in the UK;

— the status of geo-engineering technologies in government, industry and academia;

— geo-engineering and engaging young people in the engineering profession; and

— the role of engineers in informing policy-makers and the public regarding the potential costs, benefits and research status of different geo-engineering schemes.

Engineering in Government

The terms of reference for the Engineering in Government case study are as follows:

— the role and effectiveness of the Government Office for Science and the Chief Scientific Advisers in providing engineering advice across Government and communicating issues relating to engineering in Government to the public;

— the use of engineering advice in Government policy making and project delivery, including examples of policy decisions or project delivery that have been or will be taken with or without engineering advice;

— how Government identifies the need for engineering advice and how Government sources engineering advice;

— the status of engineering and engineers within the civil service, including assessments of the effectiveness of the science and engineering fast streams, and the role and career prospects of specialist engineers in the civil service;

— the role and effectiveness of professional engineers and the engineering community in promoting engineering and providing engineering advice to Government and the civil service; and

— international examples of how engineers and engineering advice are imbedded in Government.

Formal Minutes

Wednesday 18 March 2009

Members present:

Mr Phil Willis, in the Chair

Mr Tim Boswell
Dr Evan Harris
Dr Brian Iddon
Mr Gordon Marsden
Graham Stringer

The Committee deliberated.

Draft Report (*Engineering: turning ideas into reality*), proposed by the Chairman, brought up and read.

Ordered, That the draft Report be read a second time, paragraph by paragraph.

Paragraphs 1 to 361 read and agreed to.

Annexes and Summary agreed to.

Resolved, That the Report be the Fourth Report of the Committee to the House.

Ordered, That the Chairman make the Report to the House.

Ordered, That embargoed copies of the Report be made available, in accordance with the provisions of Standing Order No. 134.

Written evidence was ordered to be reported to the House for printing with the Report, together with written evidence reported and ordered to be published on 30 April 2008, 18 June 2008, 7 July 2008 and 10 and 19 November 2008.

[Adjourned till Wednesday 25 March at 9.00am.

Witnesses [Engineering]

Department for Innovation, Universities and Skills, and **Professor John Beddington**, Government Chief Scientific Adviser

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

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List of Reports from the Committee during the current Parliament

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

Session 2007–08

First Report	Re-skilling for recovery: After Leitch, implementing skills and training policies	HC 48-I (HC365)
Second Report	The Work of the Committee 2007-08	HC 49
Third Report	DIUS's Departmental Report 2008	HC 51-I

Session 2007–08

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