COUNCIL FOR SCIENCE AND TECHNOLOGY

An Electricity Supply Strategy for the UK

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Council for Science and Technology

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Executive Summary

UK electricity supply largely depends upon a network and infrastructure laid down in the 1940s to the 1960s. The changing resource base and the challenge of climate change require a fundamental adaptation and renewal of both network and infrastructure. A new strategic approach is needed. The following are key issues for any emerging strategy:

- the collapse of energy RD&D[1] budgets over the past 15 years accompanied by a stagnation in workforce supply and training;
- the lack of attention to large-scale forms of electricity generation;
- the need for an improved institutional strategy.

We recommend that government consider incentives that will increase the level of RD&D investment and training by the industry. Investment by government in RD&D should be targeted towards the development of new and renewable fuel sources, energy management and intelligent networks.

We highlight the need for large-scale non-carbon electricity generators in order to meet the White Paper CO_2 targets in 2020. Wind power alone will not achieve this goal. Suitable technologies include nuclear and tidal generation and these options should be further assessed and progressed to the point they could be executable, if deemed appropriate, as soon as possible.

Current regulatory structures have an impact on energy options and the market. These structures and licensing regimes require periodic review to ensure that unintended distortion of the market does not occur. A review across the energy sector is timely to ensure that a level playing field exists.

Funding of renewable and low-carbon energy initiatives in the UK is too fragmented. We recommend that there be institutional changes aimed at coordinating research funding, achieving greater leverage from participation in international programmes and evaluating the outcomes of government investment in the energy sector.

We are concerned that the relative economic costs (including the cost of transmission) of low-carbon electricity generation technologies do not sufficiently influence strategy on RD&D investment. Investment in renewable-energy research for the UK, where the technology is both expensive and has a low market penetration potential, should be weighed against support for international action, aimed especially at emerging economies, which will achieve a reduction in global carbon emissions by the use of existing, low-cost, technologies

Structure of the report

Our conclusions on each of the three themes above are presented in sections A-C. Supporting evidence is presented in the Annex, arranged under the three themes.

[1] Research, Development and Demonstration

Background

The CST energy sub-group was convened in May 2004 and the group identified a number of priority energy issues over that summer. A subset of these issues was selected in October 2004 and these three themes form the basis of this report. Input from industry experts was requested to develop these themes. The DTI Energy Group and Ofgem have been consulted as the report has developed. The paper has been challenged to ensure the validity of its conclusions.

Introduction

The Energy White Paper of February 2003 identified four key objectives for the UK's energy supply which included support for renewable sources of energy. The White Paper also expresses a commitment to reduce greenhouse gases by implementing the Kyoto Protocol and this target has been met. The White Paper sets ambitious domestic goals for reducing carbon emissions by 20% by 2010 and by 60% by 2050 and these goals will be hard to achieve. If the UK misses these targets it will lose credibility, reducing its influence and ability to lead.

The objective of a 60% cut in carbon emissions by 2050 and at the same time, an increased security of supply, is the challenge. Over this period, the expected economic growth rate will be 2.5-3.0% so the White Paper goals must be met within the context of a growing, not static, UK economy. Since 1997, CO_2 emissions have not fallen at all; carbon emission levels will be under pressure from increasing air travel, car usage and the closure of most of the UK's nuclear generation facilities.

To increase the probability of meeting the goals in the White Paper, or of recovering performance if the early goals are missed, an increase in the development and integration of a range of credible options for energy supply – in particular for electricity generation – will be required.

Wind-powered generators and increasing energy efficiency will not meet the White Paper targets on their own. The projected decline in non-CO_2 generation capacity is greater than the feasible increase in existing renewable energy sources up to 2020.

Transport

Looking beyond the electricity sector, attention needs to be paid to the long-term future of all the major contributions to CO_2 emissions, such as transport, where developments may lead to dramatic increases in the demand for electricity through, for instance, greater commercialisation of fuel cell and advanced battery technology.

The contribution of CO_2 emissions from the transport sector to climate change is an major additional factor for a low-carbon energy strategy to overcome. Significant reduction is likely to involve a greater reliance on electricity generation, either via batteries, fuel cells or the emergence of hydrogen as an energy vector. The transport sector currently contributes around 25% to UK emissions, and this proportion is expected to increase significantly in future years given the relative difficulty and cost of reducing emissions in transport compared to other sectors.

In respect of transport, we highlight (i) that more action is needed to address the contribution to emissions reduction that can be made by the sector, (ii) that other sectors may, nonetheless, in practice be required to contribute disproportionately, and (iii) that developments in the transport sector (such as a move to electric vehicles) only contribute to CO_2 reduction if the overall energy route is low-carbon, i.e. if the electricity itself can be produced from a low-carbon source. Government's policy with respect to investment in Energy RD&D needs to reflect these strategic issues.

Key Recommendations

Keeping the Options Open

- Investment in large-scale, low-carbon, generation facilities is needed now in order to meet the CO_2 targets in the Energy White Paper.
- Government should keep the nuclear option open and to look at continued use of fossil fuel with carbon sequestration or the potential of tidal power as the need for low-carbon options is increasingly important. A timescale for decisions on technologies with long lead times is needed.
- Government should engage in dialogue with the public, framing the questions about future energy broadly, including the different options, their impacts and CO_2 targets, following good practice[2,3]. This should be seen as a measure to help to inform decisions and make them more quickly, not a means of delaying decisions.

More Investment in RD&D and Training

- Government should consider incentives that will increase the level of RD&D investment and training by the industry.
- Investment by Government in RD&D should be targeted towards the development of new and renewable fuel sources, energy management and intelligent networks, electricity storage, and to improve the supply and training of skilled workers in the UK .
- Government should encourage business investment in energy RD&D, for example by sharing the risks in nuclear generation, and by a commitment to promote hydrogen research and infrastructure.

Institutional and Regulatory Issues

- Government should intensify its efforts to promote international emissions trading.
- Government should carry out a review of current regulatory structures across the energy sector to ensure that a level playing field exists.
- Government should consider institutional changes to coordinate research funding, achieve greater leverage from participation in international programmes and evaluate the outcomes of government investment in the energy sector.

Network and Energy Management Issues

- Government should quantify the potential and benefits of intelligent networks, together with developing an energy management programme. Existing building management systems and future intelligent metering systems should be promoted and deployed.
- Government and the industry should develop the transmission network and its protection mechanisms to enable more diverse electricity generation and Distributed Generation to be accommodated in the UK.
- Government should recognise the contribution to CO_2 emissions from the transport sector as a major additional factor for a low-carbon energy strategy to overcome.

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[2] *Policy Through Dialogue*, CST Report, www.cst.gov.uk

[3] Government Response to the Royal Society and Royal Academy of Engineering 'Nanoscience and Nanotechnologies' Report, Annex B on Good Practice in Dialogue

Contents

The UK Electricity Industry

A. Collapse in RD&D and training

1. RD&D in the electricity generation sector has effectively collapsed[4] (Figure 1). Compounding the issue is that the remaining RD&D is unfocused and is spread across many players[5]. This applies to both those who fund and those who deliver. Recent initiatives, although welcome, are disparate and diffuse. This is of great concern when we are wanting to transform the UK from a carbon-based to a non-carbon-based economy.
2. Investment by government in RD&D should be targeted[6] towards the development of new and renewable fuel sources, energy management and intelligent networks.
3. A study into which forms of low-carbon generation will be most effective is essential, prior to setting funding priorities. Effectiveness in this context includes the potential generation capacity, cost of transmission and reliability of each source.[7]
4. Certain intermittent generation options could become economic if short-term[8] storage of electricity were available. Investment in research into electricity storage should be increased as large-scale (up to 40 MW) installations have been recently demonstrated in the US and Japan[9].
5. The potential and benefits of the intelligent network should be quantified[10]. An energy management programme to provide network control down to the sub-station level, for example, to adjust load profiles is recommended. Existing building management systems and future intelligent metering systems should be promoted and deployed.
6. Much of the UK's energy infrastructure needs to be updated over the next twenty years. The electricity distribution networks will need to adapt to more distributed generation. The UK faces a short-term challenge to make decisions in the next 4 –5 years, and has as an opportunity to lead in pioneering radically new energy infrastructures. Not enough work is currently going on in this area.
7. Changes to the structure of the Grid and its protection mechanisms must be developed[11] in parallel with new energy sources, in order that more diverse electricity generation can be accommodated in the UK. A more flexible transmission network will assist in the development of intermittent generation capacity, such as combined heat and power (CHP) systems. CHP plant could be part of a future energy management system where CHP installations provide energy on demand.
8. To encourage private investment in energy RD&D there needs to be certainty concerning international emissions trading. In addition, further regulatory certainty is required by the nuclear industry and a commitment for government to take some of the back-end risks. Other examples of government commitments which will encourage and increase in RD&D are a commitment to promote hydrogen research and a commitment to install photovoltaic panels in a proportion of new buildings.
9. The supply and training of skilled workers is of concern. The need for skilled workers has been recognised by the industry[12] but more needs to be done to train designers and research workers at postgraduate level.

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[4] Annex: A1-A4

[5] Annex: A7-A9

[6] Annex: A12-A14

[7] The same is true for large-scale generators (Section B 15)

[8] i.e. a timescale in the order of a few seconds; much shorter than existing pumped-storage installations.

[9] Annex: A17

[10] Annex: A18

[11] http://www.dti.gov.uk/renewables/publications_pdfs/tiwgreport.pdf

[12] Annex: A10

10. Investment in training is essential[13] and requires modest investment. For example in the nuclear industry, a £5m annual commitment would meet the staff costs required to keep skills and capabilities in the programmes.
11. A survey should be carried out of the research, development, technology and skills needs underpinning each of the technological options for energy generation. In particular to identify in each case where the UK's strengths are and where gaps exist. This survey will also include the innovation and skills needs for regulatory assessment of the industry's licence to operate, and the technology needed to maintain and create the necessary infrastructure. Items on the critical path to developing diverse options[14] should be identified.

B. Large-scale non-carbon electricity generation

12. The White Paper was ambitious in setting a target of a 60% reduction in CO_2 emissions. It took the first steps towards a more comprehensive energy policy by placing the initial emphasis on renewables and energy efficiency. But the existing policy to reduce CO_2 will not be sufficient in the light of the closure of the UK nuclear capacity[15], since nuclear stations are likely to be replaced by carbon-based technology (e.g. gas) in the short term. Attention should be given to reducing emissions from existing sources. The UK emissions target is particularly challenging when the limited improvements expected over the next 10-15 years in the transport sector are taken into account.
13. We are concerned that no timescale appears to have been drawn up for decisions which need to be taken now in respect of technologies with long lead times or which have a problem of public acceptance.
14. Many of the non-carbon or renewable energy sources are small-scale and are not currently achieving a high penetration rate[16]. Large-scale low-carbon energy sources need to be considered now[17], to help the UK meet its targets for carbon reduction by 2020, and to be well placed for further cuts in the following decades.
15. There is a need for a transparent assessment of the economic aspects of the technology options. In particular: are the market failures in RD&D being properly addressed; is carbon priced properly; and are subsidies for non-carbon generation equitable across technologies?
16. The long-term advantages of the widespread adoption of small generators will be that (a) diversity and increased security of supply and (b) fluctuations in individual generators (capacity factor) will become less significant when the numbers are large and spatially diverse. The UK is currently some way from achieving this position.
17. In addition, many renewable sources are currently not often located near to existing power stations or a suitable grid connection[18]. Connecting many small generators to the grid, possibly over long distances, is feasible but carries substantial added costs. High concentrations of such sources (e.g. a large wind farm) will require upgrading of the grid protection mechanisms to handle local reverse energy flows during periods of peak generation. There is limited funding available for investment in the transmission network in the short term.[19]
18. In addition to grid issues, it should be noted that most renewables are intermittent and thus require backup capacity if deployed on a significant scale. Such backup capacity will almost inevitably be fossil (gas-fired) because of the flexibility required. Furthermore,

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[13] Annex: A11

[14] e.g. the cost of fuel cells and storage

[15] Annex: A22

[16] Annex: A22, A23

[17] Annex: A20, A21

[18] Annex: A23

[19] Annex: A6

progress to date on delivering renewable generation has not lived up to aspiration, due to issues including planning delays and investor uncertainty.

19. For these reasons, it is not possible to meet the challenging CO_2 objectives in the medium term without large-scale technologies which do not add to the carbon burden. Some of the options are described below.
20. **Nuclear energy** is one form of large-scale technology which does not have the disadvantages of poor grid connection or low availability mentioned above.
21. The White Paper indicated a need to *keep the nuclear option open* (KNOO[20]) and to look at continued use of fossil fuel with carbon sequestration or the potential of tidal power, for example. As noted earlier, the need for these contingent low-carbon options is increasingly important.
22. There are key steps[21] which need to be taken now to realise the KNOO policy objective, and are associated with regulatory approvals, infrastructure (nuclear sites), skills and technology. The issue of nuclear skills is crucial. One cornerstone of the high-level skills required for a new build programme is the re-establishment of nuclear modules in higher education. The Cogent Sector Skills Council was licensed on 2 March 2004. It will take a strategic view of the nuclear sector to ensure that the education and training base can meet the nuclear employers current and future needs.
23. The issue of licensing[21] is a major concern where nuclear energy has a unique 3-year hurdle to overcome in terms of the regulatory assessment and licensing of available designs. Regulatory review of currently available reactor designs would help to revitalise knowledge in reactor technologies and processes, and additionally to rejuvenate nuclear skills in the regulatory body. This will have the added benefit of shortening the timescale for any potential nuclear build in the future.
24. There is an option cost of KNOO which is quite modest yet it will materially improve the effective availability of this option in the future, without any commitment to deploy at this stage. Funding would support the UK's contribution towards the international programmes, which are very heavily leveraged[22]. and specific KNOO related skills and capabilities. Investment in international collaborative nuclear R&D programmes, such as Generation IV, will serve to sustain the UK's position and influence on new reactor technologies, to contribute to intergenerational transfer of valuable expertise and know-how, and to maintain the UK's awareness of longer-term energy options.
25. We assume that any future new nuclear build will take place on existing nuclear sites, and it is therefore important that technical information on these sites is retained for potential future use.
26. We wish to note that, should the nuclear option be exercised, waste products from a series of around ten of the latest design of nuclear reactor (enough to replace the current 20-25% nuclear component of the generation mix) will add no more than around one tenth to the existing volume of radioactive waste over a 60 year period. The issue of nuclear waste from modern reactors might therefore be seen as a smaller barrier to positive decisions on new power stations than that currently perceived. Furthermore, we believe that any ultimate solution derived for the existing legacy should be suitable to accommodate the waste from new nuclear plants.
27. Looking to the longer term, advanced reactor technologies (e.g. HTRs) offer the potential to provide a carbon free energy source for the efficient production of hydrogen, underpinning the potential for a **hydrogen economy** in the future.
28. As the number of nuclear installations in a series of identical reactors increases, there is a reduction in the cost of each reactor and a reduction in the related costs of (a)

[20] Annex: A25-A28

[21] Annex: A29

[22] France's commitment is approximately 100 times higher and Japan's is 1,000 times higher.

supplying the base load, (b) reducing carbon emissions and (c) in assuring security of supply.

29. **Tidal** generation[23] is another large-scale option, which will add to the diversity of UK generation and reduce carbon dioxide (CO_2) emissions. It is recommended that new feasibility studies be carried out for tidal lagoons[24] or marine current turbines as we believe these have environmental advantages over barriers.

30. As robust civil structures, tidal energy enclosures would guarantee secure, predictable and sustainable energy supplies, free of atmospheric emissions, for at least 100 years. For instance a Severn barrage could provide 6% of the UK’s electricity requirement from an installed capacity of 8640 MW[25] and a Mersey barrage, 0.5% of the UK's needs. The potential for tidal power was recognised in the energy White Paper and the option left open. We recognise that any future decision to re-open this area of work would be socially and politically controversial. Therefore any future work should focus first on environmental issues and the financing of such schemes.

31. A recent study has been carried out by the Environment Agency into flood barriers. We recommend that future flood barrier studies look at the possibility of electricity generation or storage. Since flood barriers normally operate at very low activity factors, this will not be a major contribution to the UK's energy supply.

32. There are regulatory issues associated with storage, since the licensing framework does not recognise storage as an option for generating electricity. A DNO[26] wishing to add storage to the transmission network might not be licensed to generate energy by this means.

33. **Fossil generation with carbon capture[27]** is the third large-scale option which is being seriously considered in the medium term. Although a number of technologies for capture of CO_2 have been demonstrated, the storage side remains controversial and although there are some projects which are successfully storing CO_2 geologically (e.g. The Sleipner project in the Norwegian sector of the North Sea as well as in North America), it has yet to be established as a reliable means of disposal. Opportunities exist for CO_2 storage in disused oil and gas reservoirs under the North Sea as well as in some saline aquifers. Furthermore, CO_2 used for enhanced oil recovery (EOR) would offer opportunities not only for CO_2 storage but with a payback of recovering oil which might otherwise have been abandoned. The risks remain high for this option.

34. A systematic assessment would be required of the key scientific, engineering, legal and economic issues around both the use of CO_2 for enhanced oil recovery (EOR) and around geological storage of CO_2. Aspects such as risk analysis of the infrastructure and reservoirs, site selection criteria, evaluation of data on gas leakage, seismic behaviour, options for ultimate reservoir closure, and long-term monitoring techniques will need to be considered.

35. It is clear that the prospects for international collaboration in RD&D projects in this area should be assessed – both with other national programmes and in international efforts.

C. Institutional issues

36. The government should facilitate diverse energy options to give it, and future administrations, executable options several years ahead. Furthermore, government should factor in the impact of regulation on RD&D, licensing regimes and market design, as regulation affects different technologies in different ways.

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[23] Annex: A31-A33

[24] Annex: A32

[25] i.e. a barrage would be able to supply 41% of its installed (peak) capacity.

[26] Distribution Network Operator

[27] *A Strategy for Developing Carbon Abatement Technologies for Fossil Fuel Use:* Cleaner Fossil Fuel Unit (DTI), February 2005.

37. Therefore the government should take an active role in ensuring there are energy options which are feasible, and in having the right policy framework to execute these options. This applies particularly to options which face significant regulatory hurdles and long planning cycles, such as nuclear generation, major tidal schemes[28] and offshore generation.

38. Government should establish and empower an appropriate body, whether this be a Department or Agency, to inform, assess, monitor and review energy matters. The body should be required to report publicly and independently, perhaps on an annual basis, on progress and delivery against the UK's key energy goals. The body's remit should encompass research and development, to ensure that an appropriate portfolio of R&D activity is underway consistent with meeting UK energy requirements over the medium to longer term. This remit will need to extend further than that of the Energy Research Centre, in order to ensure and facilitate effective participation in many European and international large-scale research programmes[29].

39. The CST recommends that there be institutional changes aimed at coordinating research funding, achieving greater leverage from participation in international programmes, particularly in Europe, and evaluating the outcomes of government investment in the energy sector[30]. With these objectives in view, Government should review its strategy for funding energy R&D in the university sector.

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[28] Annex: A33

[29] Annex: A34

[30] Annex: A35, A36

Annex

A. Collapse in RD&D and training

A1. Post-privatisation, energy RD&D has fallen, and the private sector's investment horizons have shortened, leading to short term thinking and asset-sweating. The UK's regulatory framework[31] is seen not to provide sufficient incentive for longer term RD&D. Yet climate change and other drivers require a step change in efforts and investments by the private sector to achieve a rapid and radical shift towards a low carbon energy economy. The UK government's investment in energy RD&D is approximately 10% of that in France (20% Germany's, 60% of the Netherlands', and 50% of Italy's)[32].

A2. It is widely acknowledged that private sector investment in energy RD&D is low compared to other countries and to the scale of the challenges faced, most notably in relation to low carbon technologies.

A3. UK Government Energy R&D spend has fallen to around 5% of the 1974 (pre-privatisation level) as shown in Figure 1. *Source: DTI Energy Group.* Although IEA trends are also downwards, the UK figures contribute significantly to this trend.

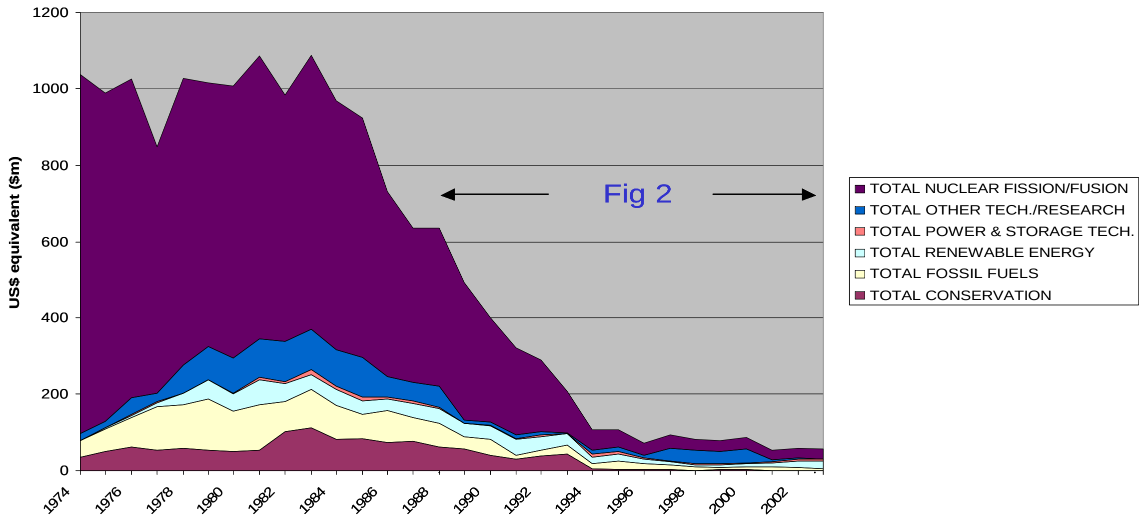

Figure 1. UK Government Energy R&D expenditure 1974 – 2003.

A4. R&D investment during 2003 fell to one sixth of the 1990 level. A similar trend may be seen in the independent statistics from the DTI Energy Group (Figure 2) showing government energy R&D spend, and Ofgem (Figure 3) showing collaborative R&D spend by the energy companies.

[31] Ofgem regulates pricing, which includes R&D investment.

[32] http://energytrends.pnl.gov/

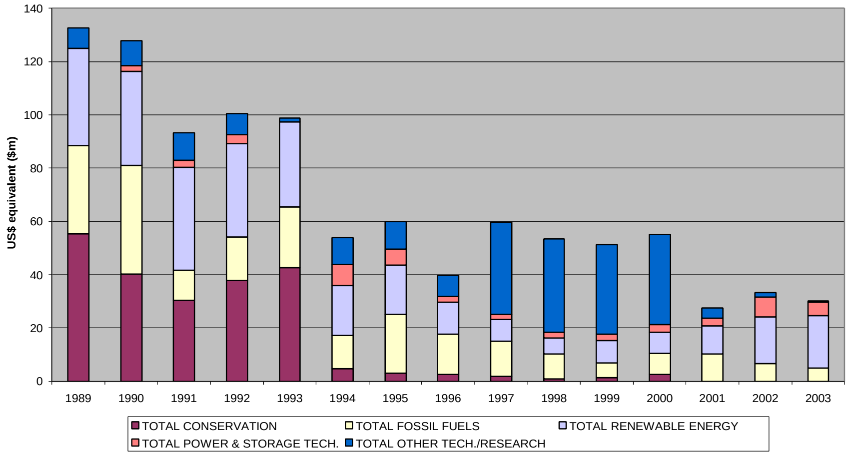

Figure 2. UK Government Energy R&D expenditure (exc. nuclear) 1989 – 2003.

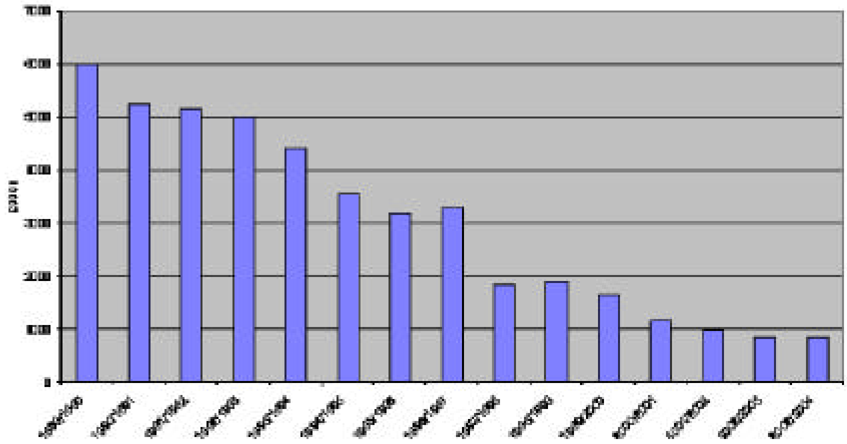

Figure 3. Collaborative Industrial R&D spend since 1990 (Ofgem).

A5. We agree with the Royal Academy of Engineering's comments[33] below.

> Industry needs to play a leading role in engineering research. The UK economy is deeply dependent on the health of industrial R&D. However, UK companies invest substantially less in R&D than their international competitors: according to the 2002 R&D Scoreboard, UK companies averaged an R&D intensity (R&D as a percentage of sales) of 2.2%, compared with a US average of 4.3%.
> Moreover UK is one of only a few advanced economies in which business spending on R&D fell in proportion to Gross Domestic Product (GDP) during the 1990s, although there are signs that the situation may now be improving. Government has recently expanded its R&D tax credits scheme, which should help to stimulate investment in R&D. However, the causes for the relatively low R&D spend of UK industry need to be thoroughly investigated and comprehended, and additional measures may be necessary to specifically resolve these issues.
> Government needs to address the factors which are currently inhibiting business expenditure on R&D and introduce measures to stimulate industrial research spending. These should include:
>
> - Increasing the Government funding available for technology demonstrator projects and long term speculative research based in industry;
> - Exploring benefits to be gained from further tax credits and other fiscal incentives likely to augment business expenditure on R&D;
> - Expanding support for small and medium sized enterprises, for example through Regional Development Agencies and Corporate Venturing UK.
>
> *"The Future of Engineering Research"*
> *The Royal Academy of Engineering, Aug 2003*

A6. A RD&D levy may offer a solution to help facilitate industry investment. The concept and practicalities of a levy should be explored, liaising with industry and Ofgem to assess whether a voluntary or legislative approach is required. Ofgem is likely to be opposed to

[33] "The Future of Engineering Research", The Royal Academy of Engineering, Aug 2003

a levy, having introduced an Innovation Funding Incentive (IFI) of £1m or £2m p.a. per company (0.5%) with 'use it or lose it' conditions. IFI has been built into the pricing structure for the next 5 years[34]. Ofgem demands a pre-event assessment of RD&D spend to achieve value-for-money for consumers.

A7. The funding of energy RD&D initiatives by government is highly fragmented. Some recent examples of this diversity are as follows.

a. The **DTI Technology Strategy** (November 2004) has £370 million funding from 2005 to 2008 in order to drive forward the Government's innovation agenda. Part of this funding will promote the further liberalization of international energy markets and the use of sustainable energy to secure a diverse range of future energy supplies. It includes a Collaborative R&D funding element of £8m for new and renewable energy sources (April 2004) and £7m for energy research (Nov 2004).

b. Since 2001 EPSRC, ESRC, NERC and BBSRC have funded **the Sustainable Power Generation and Supply programme (SUPERGEN)** at a level of £25m over 5 years. SUPERGEN is currently in its 4th annual round.

c. **Towards a Sustainable Energy Economy (TSEC)** is a programme which has an overall budget of £28m for 2003-6 to achieve a lead in research on sustainable energy so that the UK may access a secure, diverse and competitive energy supply, while meeting the challenge of global warming. TSEC is funded by EPSRC, ESRC and NERC.

d. **Carbon Trust**'s annual funding amounts to approximately £50m a year in grants from DEFRA, the Scottish Executive, the National Assembly for Wales and Northern Ireland Assembly. This has been increased by £20m in 2006/7 and £40m in 2007/8 from landfill tax receipts.

e. Following the publication of the White Paper, the **Sustainable Energy Policy Advisory Board (SEPAB)** was established by DTI to provide Ministers with a source of expert independent advice on energy policy. This Board has discussed security of supply; energy efficiency; more integrated energy policy-making; and communication of energy policy.

Development of renewable energy will receive £60 million in each year up to 2007-08 to deliver projects identified under the **Renewables Innovation Review**.

In the March 2005 Budget statement, the Chancellor announced the formation of an Energy Research Partnership. This is intended to achieve some convergence in research funding amongst government departments.

In addition to the R&D programmes above, there exist multiple programmes for the development of energy sources or fuels. Examples of these are shown below.

a. In April 2004, the **DTI Technology Programme** call for funding included support for the development of new and renewable energy sources and for research into distributed generation that connects renewable energy technologies to the existing electricity network as outlined in Para.A6. This funding round also included fuel cells, wind, wave and tidal power, photovoltaics, and energy crops.

b. The DTI announced a further round of the **Technology Programme** in November 2004 of which nanotechnology applied to the energy sector has a share of £15m funding. This includes, for example, novel materials for photo-voltaics and fuel cells, new batteries, hydrogen storage materials, sensors, coatings for gas and steam turbine blades and new catalysts.

c. In February 2005, Defra is making available a total of £3.5 million for **biomass development** over 3 years, with a maximum grant of £200,000 per producer or business.

A8. The UK Energy Research Centre (UKERC)[35], set up in April 2004 after the White Paper, lacks significant funding and its work concentrates on social issues rather than engineering and physical science. It has a £13m share of TSEC funding. TSEC is a distributed centre and will be at the heart of the UK's sustainable energy initiative, looking at new ways of reducing our reliance on fossil fuels by introducing an integrated whole-systems approach to energy research, taking account of environmental, social, economic and technological factors. The UKERC research programme began in October and its activities will ramp up during the first quarter of 2005.

[34] Worth around £60 million over the five year period of the price control

[35] http://www.ukerc.ac.uk/

A9. More could also be done to clarify the role of regional organizations, regional clusters and the devolved administrations in supporting energy research.

A10. The Power Academy has been established to form an Engineering Scholarship Fund for students that would like to study Electrical Engineering at 3 UK universities.[36] This fund will contribute to the supply of a trained workforce and a substantial increase in undergraduate applications has already been seen. Further support should be given to training at postgraduate level.

A11. We agree with the DTI High Level Energy Group that "the training and competence of the workforce must not be ignored. There could well be research required to identify/predict the training needs which might arise from the development of new technology, and the knock on effects for relevant professional institutions and degree courses (for example). HSE has particular concerns on whether the UK will have sufficient trained people to deal with nuclear matters in future."[37]

A12. We agree with the Royal Academy of Engineering's statement on *National research strategy,*

> "Government has to combine short term research priorities with longer term objectives that safeguard the integrity of the national research infrastructure. In addition, Government must retain a sufficient research capacity of its own to inform policy making on a wide range of vital topics, both now and in the future. Considerable complexity is imparted to these tasks by the multiple routes for dissemination of Government funds to scientists and engineers. It would therefore seem that the UK would benefit from having a national research strategy to identify UK strengths and vulnerabilities and promote effective distribution of resources throughout Government departments and agents and the wider research community."[33]

A13. In considering all of the above, the need for a coherent and substantial UK domestic research programme to underpin UK participation in collaborative research cannot be overstated. Such a programme must engage and bring together industry and academia in a way which is clearly integrated and structured to bring out the best from each sector.

A14. A paper by the Chief Scientific Adviser's cross-government energy group 'A strategic framework for Energy research and Development for the SR2004 period' has identified the hydrogen economy, CO_2 sequestration, renewables and future networks as priority areas for energy research for the future.

A15. We recognise the importance of being an 'intelligent customer'. The UK must preserve a core capacity for research, not least because through maintaining a degree of personal involvement in the research work, a company is invested with the ability to be an 'intelligent customer' which includes an ability to understand any regulatory impact of a particular procurement route.. Industry will only be able to fully exploit the results of outsourced research if it retains sufficient competence to understand what is being researched and how to apply it to marketable products.[38]

A16. Management of energy-demand profiles by electricity suppliers is possible, but is not currently implemented owing to the lack of suitable demand-side equipment. This would achieve a 'negative-generation' option by shedding load during peak demand, if incentives were provided to consumers.

A17. Distributed energy storage will make existing transmission networks more reliable by acting as temporary sources of energy over a period of seconds to a few minutes. A recent installation has demonstrated 40 MW of power for 6-7 minutes, or 27 MW of power

[36] The Power Academy has been formed by the following partners; Electricity Network Companies, CE Electric, Central Networks, EDF Energy, National Grid Transco, Scottish and Southern Energy, Scottish Power, United Utilities and Western Power Distribution, EA Technology, the Universities of Strathclyde, Manchester and Southampton and The Institution of Electrical Engineers (the IEE).

[37] DTI High Level Energy Group report February 2004.

[38] "The Future of Engineering Research", The Royal Academy of Engineering, Aug 2003

for 15 minutes[39] using NiCd storage. In Japan, an installation using NaS cells can deliver 8 MW for 7 hours which permits significant load-levelling[40]. If such storage were deployed at a small wind farm, this would overcome many of the drawbacks inherent in wind generation.

A18. Ofgem has introduced the concept of Registered Power Zones (RPZ). Other developments such as smart metering could be introduced if the regulatory and pricing arrangements provided sufficient incentive to the utility companies.

A19. The Technical Architecture Project[41] is a cross-sector project working with the energy sector to address 'joined up thinking' for the networks of 2020 and beyond. An open workshop[42] held in 2004 was fully subscribed. The work is being co-ordinated through the DG Technical Steering Group and is led by the Institution of Electrical Engineers (IEE). The IEE group was selected as it has strong manufacturer representation.

B. Large-scale non-carbon electricity generation

A20. Data[43] (Figure 4) shows emissions from power stations are now increasing following 10 years of reduction, mostly achieved by the shift from coal to gas. Only the energy sector has made a significant contribution to carbon reduction in the past 15 years. When this trend is coupled with a steep projected rise in emissions from road and air transport, the challenge to reduce carbon emissions over the next twenty years is severe.

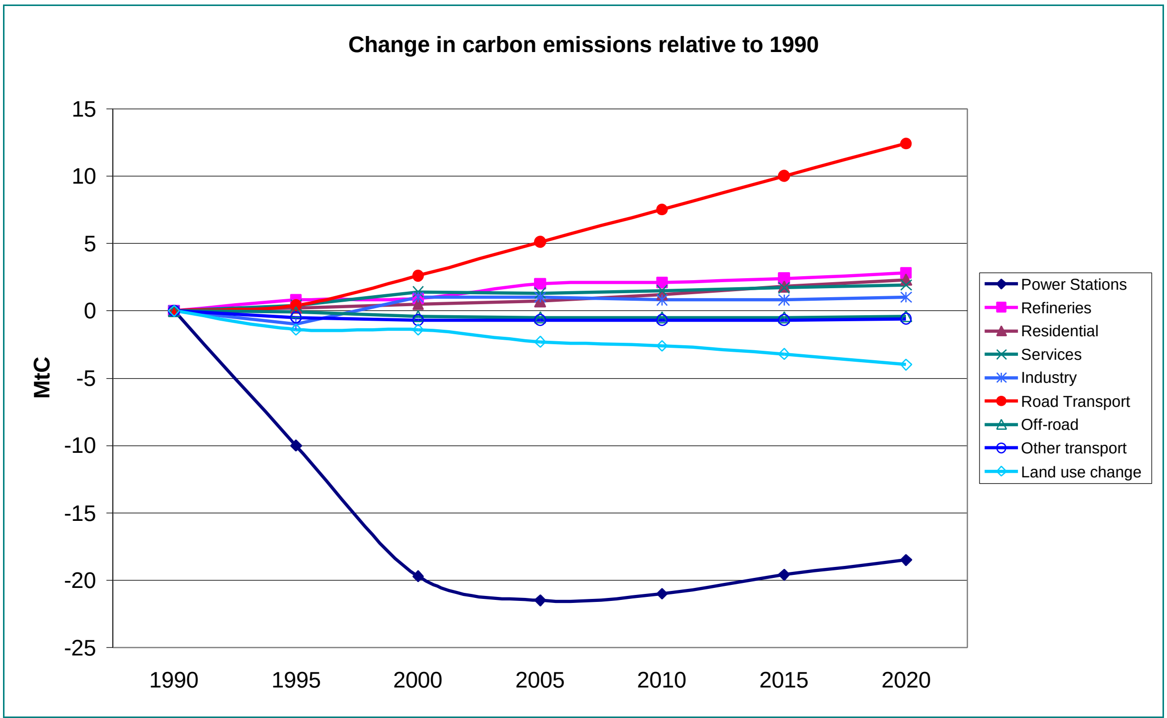

Figure 4. Sources of Carbon generation (1990 - 2015)

A21. In 2003, the UK generated 396 TWh of electricity[44] of which 88.7TWh was generated by the nuclear industry. The potential increase in carbon emissions, if the whole of the nuclear generation capacity were replaced by gas is 9.7 Mt per annum at 2003 rates.

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[39] BESS (Battery Energy Storage System) in Alaska, USA at a cost of US$30-million, http://www.saftbatteries.com/140-General/PDF/60-2003.doc

[40] http://www.bpa.gov/Energy/N/Tech/EnergyWeb/docs/Energy%20Storage/NGK-Paper.pdf

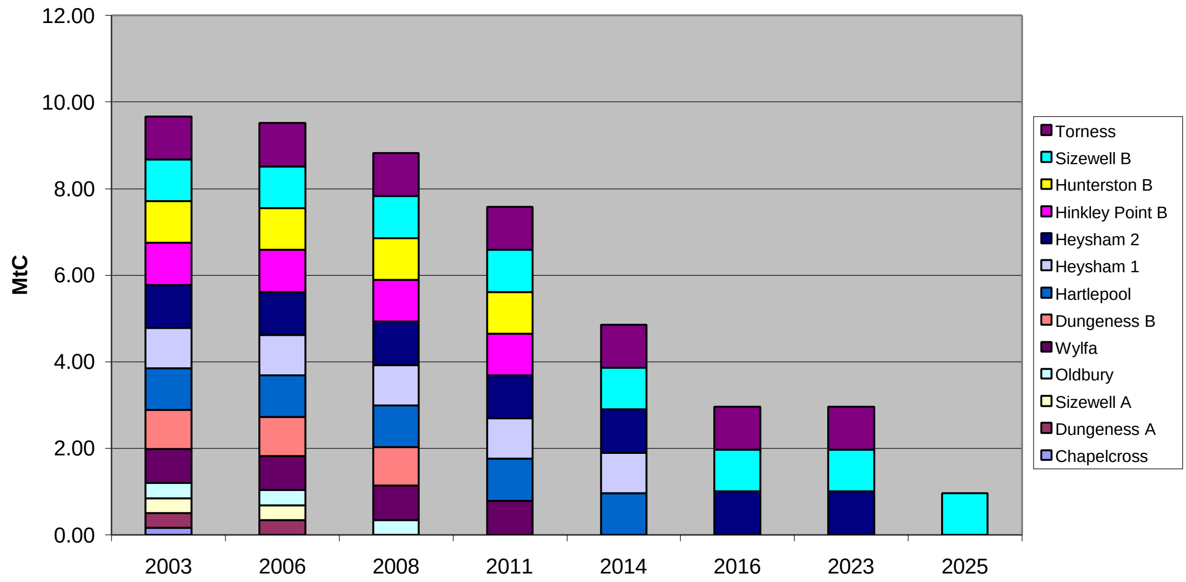
[41] The Technical Architecture is one of the projects initiated by the Distributed Generation Coordinating Group in conjunction with Ofgem, DTI and the IEE.

[42] http://www.iee.org/OnComms/pn/powersysequip/dn_event.cfm

[43] http://www.defra.gov.uk/environment/climatechange/draft/section6/03.htm

[44] DTI Energy Group

The falling level of carbon-free electricity from nuclear generation over the next twenty years is shown in Figure 5.



a. Nuclear closure dates from DTI Energy Group website
b. Assumes nuclear to be replaced by gas-fired generation
c. Assumes 400g CO_2 for each kWh of gas generation[45]
d. Assumes electricity supply equals 86.6% installed capacity over the year.

Figure 5. "Carbon saving" arising from nuclear energy (2003 - 2025)

A22. Whilst wind generation has been successfully demonstrated in many locations in the UK, the issues of integrating wind power with existing generators have not been widely publicised. This may lead to unrealistic targets being set for new renewable energy sources or it may divert investment away from the energy infrastructure which is needed to fully exploit renewable energy sources. E.on (Germany), have published a report[46] showing the contribution of wind power to the grid for a full 12 months in 2003. The maximum simultaneous wind power infeed from the windfarm was just under 80% of the installed capacity. The average annual infeed was less than one sixth of the installed capacity. In any year, for over 50% of the time, the wind power infeed was less than 11% of the installed capacity. This is why the provision of backup generation is important. If the backup generation uses fossil fuels, as is likely, then the reduction in carbon emissions achieved by the use of wind energy will be less than that commonly quoted.

A23. To date, wind developments have tended to be in the areas where electricity infrastructure exists. This has limited the costs of extending the distribution networks, but has led to the identification of potentially huge transmission reinforcement costs. If the government is to achieve its aspirational target of 20%, developments will need to take place away from existing grid infrastructure which will cause a further increase in costs. This is particularly true of the wave and tidal resource, which tends to be remote from existing network.

A24. A key underpinning issue in relation to keeping the technologies open is to develop options for increasing the level of private sector RD&D funding in each of the technology areas.[47]

[45] CO_2 is 44/12 = 3.67 times heavier than carbon per molecule

[46] E.on Netz Wind Report 2004

[47] "The Future of Engineering Research", The Royal Academy of Engineering, Aug 2003

Keeping the options open

A25. The White Paper identified the need to keep open a range of options in addition to those given priority at the time. These include the use of fossil fuels with carbon sequestration, tidal power, nuclear power, and the development of hydrogen as an energy vector.

A26. Developments in science and technology by industry, and also government funding for example through the Science Base, are key to underpinning each of these options and ensuring they remain open. A realistic option capability for any technology means, amongst other things:

- having a skilled and experienced workforce available, should the option be called upon;
- technologies ready for deployment on practical timescales;
- a market framework which allows the technology to be delivered effectively
- physical resources and infrastructure readily able to be put in place if not already there;
- planning, regulatory and other approvals consents achievable on similarly realistic timescales;
- a broad level of public acceptance

A27. These options must be accompanied by a broad roadmap – a national research strategy - of how the future may evolve in the context of the energy market, which takes account of different potential outcomes over the full timeframe of the period in question. Given that the White Paper places great emphasis on a 2050 target, it is important to ensure that forward plans are consistent with a long-term vision, and not just a medium-term view. This approach also requires regular tracking of progress and challenge to the assumptions made.

A28. The practical measures which must be taken to ensure that the various contingent options can be considered to be kept "open" are set out below taking nuclear and tidal energy as examples of technologies with long-term investment concerns. Other technologies, such as hydrogen storage, come into this category.

Nuclear

A29. There are a number of practical steps that Government needs to take to create the necessary conditions to allow new nuclear build to proceed on a viable basis should this requirement arise in the future (i.e. to effectively open up the nuclear option). These are:

- *Economic instruments.* The uncertainties currently associated with nuclear costs and market prices in general mean that nuclear is not currently viewed as an attractive option for potential investors and private sector operators. A study should be undertaken to explore potential financial instruments to overcome these factors.
- *Regulatory processes.* Nuclear power is unique among candidate technologies for UK electricity generation, in that it carries a specific technical hurdle and time delay – namely the requirement for licensing of the reactor systems to be deployed.
- *Government policy on the final disposal route for nuclear waste.* Confidence needs to be gained and trust won, that waste arising from new plant can be managed in a safe, environmentally acceptable way, in conjunction with swift development and implementation of a waste management policy. There are few successful examples of programmes to 'reassure the public' on contentious issues, especially nuclear. Most have back-fired. Engagement via informed dialogue (not with pressure groups and media headlines) is much more likely to be effective.

- *Nuclear skills.* Further steps are needed to follow through recommendations from the DTI's 2002 Nuclear Skills study, in particular:
    - Promotion of the nuclear sector to encourage recruitment,
    - Encouragement for engineering, sciences, technology and mathematics in schools, and provision of nuclear educational material in schools,
    - Introduction and promotion of modern apprenticeships,
    - Re-establishment of nuclear modules in higher education.
- *Investment in nuclear R&D.* R&D effort is needed to sustain the UK's position and influence on new reactor technologies and to sustain an appropriate level of skills for a new build programme. Future reactor technologies (e.g. HTR's) offer the potential to provide a carbon free energy source for the efficient production of hydrogen. Supporting R&D for such technologies can help the transition towards a hydrogen economy.
- *Public engagement initiatives.* Any move to build new nuclear power stations has the potential to be highly controversial, both at the national level and local to the sites. The government recognises this and has already committed itself to carrying out public dialogue and publishing a white paper setting out its proposals before any decisions are made. The public dialogue should be framed within the wider context of climate change and security of supply. It should engage with the diverse nature of public interest, which is likely to encompass issues such as the disposal of nuclear waste and national security.
- *Operational factors.* The best location option for any new build is on or adjacent to existing nuclear sites. Action might be necessary to ensure suitable sites are not 'lost' by default. Similarly cognisance needs to be given to ensuring the current UK nuclear industry support infrastructure does not decline to a point where it would be unable to support a future build programme.

A30. An opportunity exists for the UK to participate in an international research programme to develop the next generation of nuclear reactors. The UK participates in the GIF[48] out of which is expected to emerge a co-ordinated programme of long-term research aimed at developing possible "new generation" nuclear reactors for 2025 and beyond. Participation in the GIF has strong support from Sir David King, Sir Keith O'Nions and Lord Sainsbury as part of keeping the nuclear option open (KNOO). This requires funding of approximately £5m pa.

Tidal

A31. Tidal barrage electricity generation would add to the diversity of UK generation and reduce carbon dioxide (CO_2) emissions. As robust civil structures, tidal energy barrages would guarantee secure, predictable and sustainable energy supplies, free of atmospheric emissions, for at least 100 years.

A32. Although peak generation times would vary throughout the day with the tidal maxima, this could be accommodated because the times are known in advance, some storage can be incorporated, and barrages at different geographical locations have tidal maxima at different times during any 24-hour period. Support for a specific form of barrage, the tidal lagoon, has come from Friends of the Earth.[49] A lagoon has significantly higher costs than a barrage owing to the greater length of its retaining wall. As a result, the generation of CO_2 during construction would be higher for a lagoon than a barrier.

[48] Generation IV International Forum

[49] http://www.foe.co.uk/resource/briefings/severn_barrage_lagoons.pdf

A33. Tidal technology is available and has been demonstrated successfully for more than 30 Years at la Rance in North France (230MW) but larger schemes such as the Severn Barrage (8640MW) supplying 17TWh/y[50] could take up to 10 years to build and commission. Earlier work[51] has identified a total of 8 sites around the UK with a total resource of 45 TWh/y. There are also environmental concerns, the severity of which depend on the siting and nature of the barrage although it is almost certain that many impacts could be ameliorated to some degree by technology or design. Previous research and development work on tidal power was carried out between 1978 and 1994 at a cost of £12 million and so we already have a very high degree of understanding of both the technology and the potential for its deployment in the UK.

UK electricity mix

So that the above arguments on energy sources can be seen in context, Figure 6 shows the sources of electricity generation used in the UK during 2003.

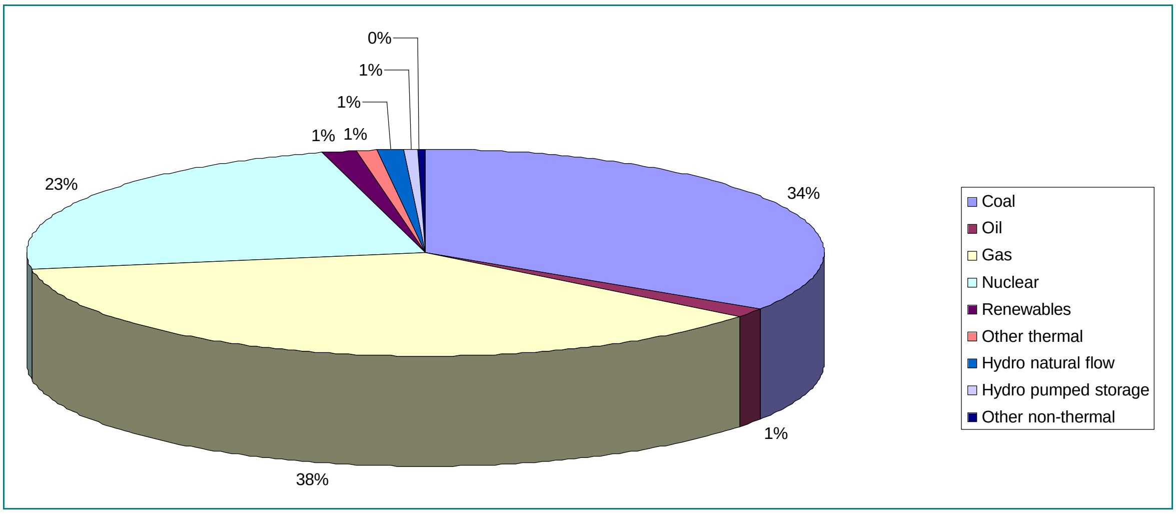


Figure 6 UK electricity supply in 2003

C. Institutional issues

A34. An umbrella group, subsuming ERC, could play a role in encouraging more international links to maximize UK involvement in large-scale research especially within Europe. Such an organization could coordinate and target all the UK's energy RD&D programmes to overcome the present diversity in funding mechanisms which currently exist (see A7).

A35. Generally, the relative economic costs of pursuing different options are compared to the benefits gained from each option before deciding funding priorities. This methodology has not always been followed in the development of renewable energy sources. The true economic cost of low-carbon electricity generation technologies should not only include the cost of transmission but exclude direct or indirect subsidies. Where a diversity of funding sources exists, it is likely that a relatively uneconomic technology may be receiving support. An institutional structure as described in the paragraph above could make strategic and cost-effective recommendations for RD&D funding.

A36. To achieve a global decrease in CO_2 emissions, investment in low-carbon technology which can be used in many places worldwide may be a better proposition than attempting to exploit very high-technology methods with the potential of only a low market penetration potential.

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[50] 6% of the UK's annual electricity demand

[51] http://www.dti.gov.uk/energy/renewables/publications/pdfs/technologies/tech8.pdf