

Towards a low carbon future



scientific

DISCUSSION MEETING

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Summary

Meeting future energy needs while tackling climate change is of the utmost importance but the debate on how to achieve this often considers single technologies in isolation. This document is the report of a two-day discussion meeting *Towards a low carbon future* that was held at the Royal Society on 17–18 November 2008¹. The meeting reviewed the current and potential technological options and considers how they can contribute to an integrated energy strategy for the future. The Royal Society has previously commented on how to meet the UK's energy needs, while reducing greenhouse gas emissions (Royal Society 1999, 2002a, 2003, 2005, 2007a).

The key conclusion arising from the meeting was that there is no single best solution in moving towards a low carbon future: an integrated approach making best use of all available technologies is required. Due to the lack of progress in developing renewable energy technologies nuclear power was seen as having a key part to play if the UK is to meet its greenhouse gas emission targets. The pressing need to reduce greenhouse gas emissions was widely felt to be sufficiently great that concerns over waste and security should not prevent new build. A number of areas were suggested that require considerable research to be undertaken now if we are to be able to make full future use of technologies such as renewables, bio-energy and fusion. Non-technological developments were also seen as essential in realising the potential technological developments.

The report describes views expressed at the meeting. It does not necessarily represent the views of the Royal Society. We appreciate the significant input of the steering committee of that meeting, Professor John Shepherd FRS, Professor Brian Launder FRS FREng, Lord May of Oxford OM AC Kt FRS and Professor Jim Skea OBE, for this meeting report. This document has been approved by the Council of the Royal Society. The document was reviewed by a group chaired by Sir Peter Williams CBE FRS, Royal Society Vice-President and Treasurer, and Professor Terry Barker, Professor

Geoffrey Boulton FRS, Sir Christopher Llewellyn Smith FRS and Dr Tim Palmer FRS. The meeting programme is in appendix A.

1 Introduction

Rapid climate change, driven by global warming associated with human activity, was recognised by participants as one of the biggest threats to the long-term future of the human race. Finding an effective way to deal with this threat sets us unprecedented challenges. It requires a holistic vision that can bring together diverse scientific, technical, economic, social and political elements. The disappointing rate of progress over the last decade underlines just how big a challenge we face in implementing an effective response to climate change.

The UK needs to make deep cuts in carbon dioxide emissions while still meeting its energy needs for electricity, heating and transport. This will require future energy sources to be cleaner and sustainable. There can be no single best solution: an integrated approach making best use of all available technologies is required.

1.1 General Context

The UK depends heavily on imports of oil, gas and coal for its electricity, heating and transport needs. To achieve an 80% reduction in UK greenhouse gas emissions by 2050, as recommended by the Committee on Climate Change (2008), implies a mean reduction rate in CO₂ emissions of almost 4% per year. The Committee on Climate Change suggested that an 80% reduction in UK emissions is an appropriate UK contribution to a global reduction in Kyoto greenhouse gas emissions to between 20–24 billion tonnes by 2050 (about 50–60% below current global levels). Both the extent and the rate of change to a low carbon energy economy required to avoid a serious risk of dangerous climate change are therefore very large indeed. Moreover, since much of any CO₂ released today will remain in the atmosphere for 100 years or more, it is vital that every effort be made to make substantial savings in the early years.

1 <http://royalsociety.org/event.asp?id=7991&month=2,2008>

Shifting to a low carbon future represents not only a significant challenge for the UK but also a significant opportunity, especially since the current recession is leading to a re-balancing of the economy. The UK is rich in natural resources such as wind and marine energy which could potentially reduce the use of increasingly expensive and insecure imports of oil and gas. The UK also has world leading expertise that can develop new technologies for the UK and elsewhere, which can provide the basis of valuable exports of expertise and technology to global markets.

It was suggested by participants that it is still possible for the UK to move to a low carbon energy economy on the timetable (a few decades) and the scale needed to make its due contribution to the global effort to contain climate change. For this to happen, urgent and sustained action is needed on several fronts, including the following.

- A sharper focus on retrofitting existing buildings to take advantage of the latest technologies for energy efficiency and savings.
- A switch to much greater reliance on low-carbon means of generating electricity, including natural resources such as wind and marine energy abundantly available in the UK.
- A large increase in support for research and early-stage technological development of low carbon sources of energy. At present energy research represents only a few percent of public research and development expenditure, and less than 0.2% of total global expenditure on energy consumption.
- A major investment in relevant skills. The programme of research, development and deployment of new technologies in the UK will need many more science and engineering graduates who are capable of applying their knowledge to low-carbon energy technologies, as well as post-graduate training directly relating to these technologies. Much more ambitious fiscal and regulatory measures are needed, including a much higher carbon price across all sectors via environmental tax reform or carbon trading schemes.

In sectors such as domestic heating and aviation where demand is relatively price insensitive, additional policy measures will be needed, including incentives and constraints through appropriate regulation. For example, the Royal Society has previously recommended applying economic instruments to all sources of emitted CO₂ (Royal Society 2002a).

Successfully undertaking these actions would put the UK in a position of strength, both at home and in major export markets. There is opportunity here as well as need. Investment in specific low-carbon skills, infrastructure and technologies can not only put the UK at the forefront of tackling climate change but can also give an economic edge.

Participants noted that failure to take sufficient action on reducing greenhouse gas emissions by increasing energy efficiency and the development and deployment of renewables now means that nuclear energy has an increasingly important role in achieving a low carbon energy supply. The Royal Society has previously noted that key questions on safety and security remain and the future development and deployment of nuclear power capacity will require the issue of the secure, long-term disposal of waste to be resolved, and public concerns regarding risk to be addressed (Royal Society 1999, 2002b, 2006 & 2007b).

1.2 Technology

There are **many technical options available** for the short- and medium-term transition towards a low carbon economy, and realistic prospects for the long-term, but **no single technology is sufficient** to provide a solution for all sectors.

Urgent priorities for immediate action that were identified at the meeting included the **decarbonisation of the electricity supply**, which is necessary and is fundamental to progress in other sectors, especially ground transport and domestic buildings. **Major gains in energy efficiency** and savings (especially in buildings) are necessary and possible, sometimes at very low or negative cost, with simultaneous carbon price increases to avoid people and businesses using the efficiency savings to just heat buildings to a higher temperature.

1.3 Urgent research needs

There are a number of areas identified at the meeting that require considerable research to be undertaken now if we are to be able to make use of new technologies in the future. These include:

- **The safe and secure disposal of nuclear waste**, essential for dealing with our existing stockpiles of radioactive waste as well as any future material generated in new generations of nuclear power plants, as previously highlighted by the Royal Society (Royal Society 2002b, 2006 & 2007b). Continued research is also needed now into new and safer ways of conventional nuclear power generation, to ensure that they are available between 2020 and 2050.
- **Renewable energy**, such as waves and tidal currents, solar and offshore wind. Significant research is needed now to ensure that these can be sustainably developed and deployed.
- **Bioenergy**, 'second generation' biofuels such as those from ligno-cellulosic crops (willow, grasses) or intensive and contained culture of marine algae requires further investigation. This research would need to determine whether they will be able to provide the required net greenhouse gas reductions, environmental sustainability and other impacts.
- **Energy storage**, such as lithium batteries and super-capacitors, should be developed over the next 10 – 40 years, to help overcome hurdles such as the shortage of raw materials and cost. Research will also be required into radical new ways to store energy beyond 2050.
- **Nuclear fusion** remains a hugely important area of research with major long-term potential.

2 Decarbonisation of the electricity supply

A low carbon energy future will require vision, commitment and investment from both government and industry. In order to achieve decarbonisation of the electricity supply the government must invest in the development of

new technologies and it must ensure a business and fiscal environment where industry will also invest in developing and implementing new technologies. This should be a policy priority in itself, and not tied to the fluctuating price of fossil fuels and carbon.

This challenge can be seen in terms of the short, medium- and long-term with different strategies required to deliver to the different timescales. Investment is needed now in order to deliver even on a long-term timescale. The technologies that the government should be investing in and promoting are outlined below. These are the technologies on which the future UK energy mix can be based.

2.1 In the short-term (up to 2020)

Major improvements in energy efficiency are possible and essential. However, participants noted that low-carbon energy supply technologies available for immediate deployment are limited to:

- **Renewables:** Including on and off-shore wind, tidal range and biomass. These technologies allow the UK to capitalise on its natural resources. They need to be viewed as a long-term energy solution but the extent to which they can fulfil the UK's energy needs is currently limited by issues of intermittency of supply. At present it is necessary to back up intermittent sources of energy with other (eg fossil-fuelled) power plants in order to maintain a reliable supply of energy when it is needed.
- **Carbon Capture and Storage (CCS):** Full-scale demonstrations at electric power plants can be delivered in the short-term (before 2020) and their construction must be started now (Joint science academies 2008). The UK government can send a strong signal by only approving the building of new coal-fired power stations on condition that operating permits will be withdrawn if the plant fails to capture 90% of its carbon dioxide emissions by 2020 (Royal Society 2008a).
- **Nuclear fission:** The UK needs to reduce greenhouse gas emissions, while still ensuring that we have secure sources of electricity to meet our needs. The diverse mix of

technologies required to meet these needs is likely to include nuclear power. To this end, a new nuclear build programme to supply low carbon electricity should be initiated in collaboration with the electric utilities. These new build nuclear power stations would, to a large extent, merely restore the loss of capacity due to nuclear power plants reaching the end of their lives and being decommissioned in the period up to 2020. The pressing need to reduce greenhouse gas emissions is sufficiently great that concerns over waste and security should not prevent new build. However, the key questions on safety and security must be openly addressed (Royal Society 2002b, 2006 & 2007b). For example, the government needs to maintain an open discussion with the public, that is informed by the best science and engineering, on issues such as the safe disposal of nuclear waste.

2.2 For the medium-term transition (2020 to 2050)

Technologies that have a longer lead time and/or still require further development (at an accelerated rate) were identified as including:

- **Renewables**
 - **Marine energy (waves and tidal currents):** these technologies will allow the UK to capitalise on our natural resources.
 - **Bio-energy:** research, development and deployment policies need to focus on those bio-energy chains which bring significant benefits in terms of reducing net greenhouse gas emissions. All bio-energy chains need to meet to strict sustainability criteria (Royal Society 2008b).
 - **Solar generation of electricity and hydrogen:** This is an area where progress has already been made but where costs need to be dramatically reduced before it can play a major role in the UK. In sunnier places substantial & earlier deployment should be feasible.
 - **Synthetically produced fuel:** eg methanol, for use in transport by combining CO₂ from carbon capture with H₂ from carbon-free

sources, once this is available (Royal Society 2008b). Other fuels may also be produced using carbon-free process energy and the Fischer-Tropsch type process.

- **Carbon Capture and Storage (CCS):** In the medium-term all new power plants and cement works must be fitted with this technology. The UK can play a leading role in the development of this technology across Europe, given appropriate government support. Making retrofitting existing plants economically viable will require the legal, regulatory and financial markets to be changed.
- **Nuclear fission:** a major and continuing nuclear build programme to supply low carbon electricity and replace old fossil-fuel fired plant will be required, until fusion power or other clean sources of energy become practicable.

2.3 In the longer-term (beyond 2050)

Participants suggested that beyond 2050 the use of fossil fuels with CCS and conventional nuclear fission should be progressively replaced by technologies which are not yet mature, including:

- **Solar generation of electricity and hydrogen:** Given successful development these technologies should become widely applicable in the longer-term even in the UK.
- **Advanced energy storage and delivery technology** (including electro-chemical methods): In order to allow for even greater use of intermittent sources of renewable energy (such as solar & wind) new means of storing electrical power are required. These technologies will not only apply to the delivery of electricity to homes and businesses but will also have a role to play in producing better electric cars and in providing the means to charge them.
- **Nuclear fusion and/or fast breeder reactors:** Nuclear fusion remains a hugely important area of research with major long-term potential. Successful investment in new and safer ways of generating nuclear fission power could also provide further energy

beyond 2050, subject to progress being made on nuclear waste.

3 Major gains in energy efficiency and energy savings

There is already a lot of available knowledge and technology to make significant reductions in carbon emissions in the built environment (RICS 2009). Heat loss can be reduced through insulation and design and the introduction of more efficient heating, cooling and energy generation in buildings. Most future low carbon scenarios assume significant reductions in carbon dioxide emissions associated with buildings using existing technologies over the next thirty years. Historically, however, theoretical carbon reductions have not materialised, for example, new buildings often use twice the energy that would be expected.

Participants highlighted the importance of establishing a smart energy grid to deliver electricity in the most efficient way. This will require major investment in the grid infrastructure and the deployment of new technologies such as smart metering.

4 Other critical sectors

There are a number of other sectors discussed at the meeting that will need to be addressed on the path towards a low carbon future.

There are massive challenges around the **decarbonisation of transport**, which have been discussed in considerable detail elsewhere (eg King 2008). This should be achievable by stringent and progressive regulation of fuel efficiency, and a further transition to the use of low-carbon electricity or synthetic hydro-carbon fuel (using CO₂ captured from industrial processes or the atmosphere). It is likely that only incremental progress is possible with aviation emissions through improvements to engines and airframes, through more sophisticated air-traffic control and more speculatively through the use of bio-fuels (Royal Society 2008b). It may also eventually be possible to use synthetically produced

hydrocarbons. Shipping is also a significant (and at present unregulated) sector that needs to be addressed (Royal Society 2008c). In contrast to aviation there are some technical options that are available for deployment now, such as wind-assist, as well as more speculative approaches, including design improvements and upgrades, operational improvements, alternative fuels, and renewable energy technologies (AEA 2008).

The **agricultural sector** is currently responsible for considerable greenhouse gas emissions. New methods for food and non-food crop production and animal husbandry need to be developed and adopted to reduce greenhouse gas emissions.

The impact of many of the factors discussed at the meeting will scale in line with **population** increases.

5 Non-technological developments

The meeting recognised that a low carbon energy future is not just about technological fixes (Joint science academies 2008; Royal Society 2005). The wider political, economic and social context must also be addressed. A **coherent portfolio of policy measures and specific mechanisms** is needed to drive the transition to a low carbon economy. This will require all of the following.

- Effective economic incentives (including a high carbon price, whether this is delivered by explicit carbon taxes (Royal Society 2002) or tight caps in cap & trade schemes such as the EU Emissions Trading Scheme).
- Stringent regulatory measures such as carbon emissions standards, and targeted cap & trade schemes (such as the Carbon Reduction Commitment) for sectors such as transport, commercial buildings and housing where reductions in green house gas emissions are less likely to be easily achieved simply through an increasing carbon price.
- A major and comprehensive programme to improve the energy efficiency and energy savings from the whole of the existing housing stock.

- Public investment in infrastructure, education, capacity building, and research and development and early-stage technological development.
- Targeted public procurement designed to encourage the development and expansion of new-to-market emerging energy technologies.
- Public education and information to promote public awareness of the need for a low carbon energy future and of the measures necessary for its achievement. Public and stakeholder engagement and knowledge transfer to explore preferred or the likely effectiveness, uptake and implementation of policy and regulation options (eg control of energy-intensive products and activities) and to stimulate cultural change towards low-carbon behaviours (in respect especially of energy use, transport and food), such as through:
 - more use of informative labelling and smart metering,
 - interaction between public, professional and civil society organisations, and
 - promoting the connection between civic responsibility and achieving a low carbon future.
- Complementary measures to address the needs of poor or vulnerable households so that policies to combat fuel poverty are compatible with an effective climate policy.
- Close monitoring of public policies that are not explicitly 'green' to ensure that they do not make achieving climate change goals more difficult by subsidising greenhouse gas emissions or 'locking in' high-carbon infrastructure for decades to come (Bowen et al 2009). The regulations governing the energy companies should encourage energy efficiency and savings.

In addition to the creation of incentives, it will be necessary to remove non-market barriers to change. This may include action on issues such as planning, transmission and distribution networks for electricity, and grid access on the supply side. In relation to demand, the provision of information, such as through smart meters, and finance for home energy efficiency improvements may also be included.

Personal carbon allowances have been proposed as an equitable means of capping emissions from some difficult sectors such as households and aviation. More research on the design, feasibility and public acceptability of this approach is needed to establish whether such a scheme could be successfully implemented, either generally or for such specific sectors.

International collaboration is likely to be an effective and acceptable way of promoting many of these changes. The roles of the UN and the EU are clearly crucial, but the promotion and adoption of initiatives by other bodies such as the G8, G20 and the Commonwealth may have a useful complementary role to play.

6 Conclusion

Participants agreed that we have reached a point in time when our existing energy systems are no longer fit for purpose. The continued burning of carbon based fossil fuels on today's scale risks causing catastrophic climate change. These fossil fuels are also a finite resource and will eventually run out. In the short-term they are also subject to major price fluctuations and problems of security of supply.

The world needs new ways to generate our electricity, to heat or cool our homes and businesses and to power our industry and transport systems. The UK, with its world-leading research base and richness in natural renewable resources such as the wind, waves and tides is well positioned to lead the way in developing the technologies we need for the future.

What is required is vision and commitment: the vision to put aside the vested interests of the status quo, and the commitment to large scale investment in research, development and deployment of new technologies, and to take a lead in helping other countries in this endeavour.

This vision must be translated into action, beginning now. The UK still has an opportunity to provide economic and environmental leadership in this area, but will not get a second chance.

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Appendix A: Discussion meeting programme, 17–18 November 2008

Session 1: Energy technologies

Chair: Professor John Shepherd FRS, University of Southampton

A low-carbon energy future: the challenge, context, costs and benefits

Professor Paul Ekins, Kings College London

Coal or climate: is carbon capture a silver bullet or a fig leaf?

Professor Stuart Haszeldine, University of Edinburgh

Integration of wind energy in GB electricity system

Professor Goran Strbac, Imperial College London

Key issues for new nuclear

Professor Robin Grimes, Imperial College London

Session 2: Energy technologies and implementing technologies

Chair: Professor Brian Launder FEng FRS, University of Manchester

Solar energy: current status and future prospects

Professor Philip Eames, University of Loughborough

Bioenergy: a large but challenging opportunity

Dr Ausilio Bauen, Imperial College London

Energy storage: beyond the horizon

Professor Peter Bruce, University of St Andrews and Professor John Kilner, Imperial College London

The evolution of a low carbon domestic energy system

Professor Tadj Oreszczyn, University College London

Session 3: Energy consumers / sectors and open discussion

Chair: Professor Jim Skea OBE, UKERC

UK climate change targets: aviation and the role of the EU ETS

Professor Kevin Anderson, University of Manchester

Decarbonising road transport

Professor Julia King FEng, Aston University

Financing a low carbon energy future: the role of investment and business

Emma Howard Boyd, Jupiter Asset Management

Promoting transition to a low carbon economy: anticipating the sticking points

Professor Andrew Gouldson, University of Leeds

Session 4: Panel discussion

Chair: Lord May of Oxford OM AC FRS Kt

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- **Invigorate** science and mathematics education
- **Increase** access to the best science internationally
- **Inspire** an interest in the joy, wonder and excitement of scientific discovery



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