RSC | Advancing the Chemical Sciences

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SCIENCE AND TECHNOLOGY

Energy Review Team
Department of Trade and Industry
Response Centre
1 Victoria Street
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RSC response to the Department of Trade and Industry consultation "Our Energy Challenge Securing Clean, Affordable Energy for the Long Term"

Dear Sirs,

The Royal Society of Chemistry (RSC) welcomes the opportunity to comment on the DTi consultation "Our Energy Challenge Securing Clean, Affordable Energy for the Long Term".

The RSC is the largest organisation in Europe for advancing the chemical sciences. Supported by a network of 43,000 members (over 50% of which represent industry) worldwide and an internationally acclaimed publishing business, our activities span education and training, conferences and science policy, and the promotion of the chemical sciences to the public.

This document represents the views of the RSC. The RSC's Royal Charter obliges it to serve the public interest by acting in an independent advisory capacity, and we would therefore be very happy for this submission to be put into the public domain.

The document has been written from the perspective of the Royal Society of Chemistry and consequently our comments relate to only parts of the consultation document.

The evidence submitted was for the most part published in an RSC report entitled "Chemical Science Priorities for Sustainable Energy Solutions" [www.rsc.org/Gateway/Subject/EnvEnergy/].

The RSC believes that the chemical sciences will deliver critical technologies to meet our energy challenge; however, this will only be achieved alongside a clear, co-ordinated and long-term policy framework that offers a level economic playing field to all energy options and that encourages energy efficiency. Our key messages are summarised below:

1. UK energy policy must promote a diverse energy mix and avoid over reliance upon a single energy source.

2. A clear and co-ordinated energy policy is vital. The policy should:
    a. Be long-term;
    b. Not unfairly bias specific technologies but instead provide a level economic playing field for all clean energy technologies; and
    c. Perhaps best be made by an independent, cross-party energy commission rather than the Government of the day.

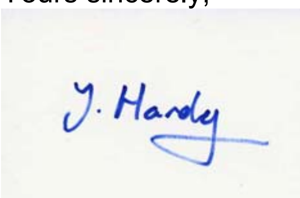
3. Technology will not provide a short-term solution to meet Government carbon emission reduction targets; reducing energy demand is the only way to achieve these targets. The critical sectors to concentrate upon are domestic living and transportation.

4. With sufficient support, the chemicals sciences will be critical in developing clean energy technologies in the medium and the long-term. Technologies will include solar power, fuel cells, hydrogen as a fuel, safe nuclear waste management, carbon capture and storage, energy storage and energy efficient lighting. These technologies will reduce our reliance upon imported energy sources and reduce UK carbon emissions.

5. The RSC believes a UK geological repository for nuclear waste is vital and once the recommendations of the Committee on Radioactive Waste Management (CoRWM) are made the Government must act quickly to ensure the run down in skills is addressed and that facilities and finances are put in place. This must happen **before** any firm decision to build new nuclear power stations is taken.

If you would like further information or need anything in this document clarified, please do not hesitate to contact me.

Yours sincerely,



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1. Annex A - Executive Summary (pg 3 - 6)
2. Annex B - Detailed Response (pg 7 – 27)

ANNEX A - Executive summary

Q.1. What more could the government do on the demand or supply side for energy to ensure that the UK's long-term goal of reducing carbon emissions is met?

- Transportation and energy use in buildings should be the focal point for reducing carbon emissions as they are the major contributors.
- Chemical scientists have developed many of the energy technologies in routine use today and with sufficient long-term financial support will develop future clean energy technologies.
- An independent, cross-party energy commission could take decisions rather than the Government of the day.
- On the supply side, a long-term strategy is required that does not unfairly bias specific technologies but instead provide a level economic playing field for all clean energy options.
- On the demand side, the Government must lead by example and demonstrate carbon reductions in line with UK targets for both their vehicle fleet and buildings.

Q.2. With the UK becoming a net energy importer and with big investments to be made over the next twenty years in generating capacity and networks, what further steps, if any, should the government take to develop our market framework for delivering reliable energy supplies? In particular, we invite views on the implications of increased dependence on gas imports.

- UK energy policy should promote a diverse energy mix with a transmission and distribution network that is capable of dealing with distributed and intermittent energy supply.
- With sufficient resources the chemical sciences will develop alternative energy sources and energy storage mechanisms that will reduce the UK reliance upon imported energy supplies and reduce carbon emissions.
- UK energy policy must prepare industry for maximising the use of other fossil fuels burned in an efficient way or with carbon capture, thus lengthening the lifetime of natural gas supplies for essential non-generation use. Steps must be taken to encourage the use of biomass to minimise CO_2 emissions until carbon capture is commercially viable.
- The UK has great potential for renewable electricity production but significant scientific and engineering challenges remain before some potential technologies are proved viable.

Q.3. The Energy White Paper left open the option of nuclear new build. Are there particular considerations that should apply to nuclear as the government re-examines the issues bearing on new build, including long-term liabilities and waste management? If so, what are these, and how should the government address them?

- There has been a significant run down in nuclear skills and facilities in the UK and without immediate action it will be necessary to import skilled workers. The lack of facilities is hindering UK R&D efforts.
- With significant R&D effort from chemical scientists, future reprocessing technology will be substantially lower in costs and environmental impacts with greater proliferation resistance. The UK has an internationally recognised track record in this field and must ensure that it is part of future international collaborative R&D programmes.
- There are a number of nuclear waste forms that currently have no well defined management option. Urgent support for R&D is required to analyse, test and demonstrate management options for such waste forms.
- The RSC believes a UK geological repository is vital and once the recommendations of the CoRWM are made the Government must act quickly to ensure that the run down in skills is addressed and that facilities and finances are put in place.

Q.4. Are there particular considerations that should apply to carbon abatement and other low-carbon technologies?

- In the short-term energy efficiency and carbon emission reduction using existing technology will have the greatest impact. In the medium and long-term technologies will be developed that will reduce carbon emissions from energy generation.
- The chemical sciences are crucial in reducing the cost and maximising the efficiency of photovoltaic (solar) electricity.
- In order to develop the infrastructure for carbon capture and storage (CCS) a national and international multidisciplinary effort must be mobilised. All new fossil fuel power plants should be built CCS ready. The potential to convert CO_2 into chemicals and fuels should be assessed.
- Significant R&D and investment will be needed before hydrogen becomes a viable and clean fuel.

Q.5 What further steps should be taken towards meeting the government's goals for ensuring that every home is adequately and affordably heated?

- The UK must avoid over reliance on a single fuel as this would increase the impact of supply interruptions and sudden price rises.
- The Government must show leadership and ensure that Government offices are leading examples of energy efficient buildings and are used to showcase energy efficient technologies.
- Government policy must ensure that regulations for new buildings (domestic, industrial and public buildings) demand the highest levels of energy efficiency in both the materials used and the space heating technology employed.
- The Government must ensure that energy efficiency interest free loans are available and widely advertised to the industry and domestic sectors so that buildings are made more efficient without prohibitive financial outlay by the owners.

i. The long term potential of energy efficiency measures in the transport, residential, business and public sectors, and how best to achieve that potential?

- A huge amount of energy is wasted in generation, transmission and during final use. Improvements in energy efficiency are critical for the Government to approach its carbon reduction targets.
- Smart coatings on glass and highly efficient insulation materials could dramatically reduce heat loss in buildings saving money and reducing carbon emissions. With sufficient support, scientists and engineers will continue to develop products and services that are energy efficient.
- The UK chemical industry surpassed its 2004 Climate Change Agreement target. Green chemical technology will be key to improving the energy efficiency of the industry.

iii. Opportunities for more joint working with other countries on our energy policy goals?

- The UK should collaborate with other countries where there is a key opportunity to maximise the speed of technology development. Key technologies include:
    - Natural gas
    - Nuclear power
    - Renewable power
    - Carbon capture and storage (CCS)
    - Hydrogen as an energy source

iv. Potential measures to help bring forward technologies to replace fossil fuels in transport and heat generation in the medium and long term?

- The chemical sciences are responsible for developments that have reduced the environmental impact of vehicles.
- The development of lightweight materials to reduce vehicle weight without reducing safety is a key scientific and engineering challenge.
- Further improvements to the performance of hybrid and electric vehicles will be realised through improvements in battery technology and through lighter construction materials.
- Biofuels, such as biodiesel and bioethanol, have great potential for reducing carbon emissions but it is vitally important that energy used in their production is minimised or derived from renewable resources.
- Hydrogen fuel cell vehicles are hindered because of the cost of power from fuel cells and from problems in on-board storage of hydrogen; these are challenges that the chemical sciences will rise to meet.
- Carbon emissions from air travel are expected to increase, and whilst technology can reduce the emissions per flight, it is much more important to reduce the overall number of flights.
- Biomass fired in dedicated plants, or co-fired in coal burning plants, has a reasonable potential for Combined Heat and Power (CHP) generation; an

estimate would be that around 5% of electricity could be generated by such sources in the medium term.

APPENDIX B – RSC Detailed response to "Our Energy Challenge Securing Clean, Affordable Energy for the Long Term"

Q.1. What more could the government do on the demand or supply side for energy to ensure that the UK's long-term goal of reducing carbon emissions is met?

In General

The RSC welcomes the Governments commitment to reduce carbon dioxide (CO_2) emissions 60% by 2050 as recommended by the Royal Commission on Environmental Pollution[1,2], however, the RSC is concerned that the Government will fail to meet the 2010 target of a 20% reduction.[3] The RSC believes that the ultimate aim of the UK carbon emission policy should be to halt or even reverse anthropogenic carbon emissions. To achieve this, energy policy must be aligned to energy statistics and energy trends and account for the carbon emissions across the full life-cycle of energy generation, including extraction, generation, transmission, use and end-of-life.

The UK energy consumption statistics show that 30% of the energy generated is lost before it reaches end-user and that of the energy that reaches the end-user the majority (over 70%) is consumed in transportation (38%) and buildings (33%).[4] These statistics indicate the following trends:

- Energy losses are significant and reducing them would significantly lower carbon emission;
- Electricity generation captures the headlines but is not the dominant factor in total energy consumption; and
- Transportation and buildings account for over 70% of final end use and should be a focal point for reduction of carbon emissions.

Long-term investment in research, development and demonstration (RD&D)

The Government must support underpinning science and innovative research, development that will deliver the technologies and measures for carbon emission reduction.

Energy Policy

The Government must provide business with the confidence to invest in innovative commercial opportunities and technologies by committing to a long-term policy of reducing carbon emissions. The policy must be clear and should be applicable to businesses of all sizes and types so that there is significant buy-in across all sectors. Energy policy must include a mixture of incentives and regulation.

Current energy policy has had a limited impact because it is confusing and complicated, it spans a number of Government departments and uses numerous policy tools that are sometimes contradictory. The "How to plug the

[1] DTi White Paper – Our energy future – creating a low carbon economy
[2] The Royal Commission on Environmental Pollution's report: Energy - The Changing Climate
[3] The UK Climate Change Programme - www.defra.gov.uk/environment/climatechange/
[4] Geological Society magazine - www.geolsoc.org.uk/pdfs/solutionsfitzgerald.pdf

energy gap" report[5] recommends that a *permanent independent cross-party energy commission should be set up to manage the UK energy and emissions budget, set policy and represent the UK in global energy debate*. The RSC recommends that this suggestion be given serious consideration.

Policy must account for the full life-cycle implications of energy generation, including extraction, construction, transformation, transmission, usage and end-of-life. Only through a comprehensive and transparent process will the environmental impact be known and only then can energy options be compared on an equal basis. This will only be achieved with an intimate knowledge of the chemistry and thermodynamics of energy generation. This process will identify major opportunities for new chemistry such as methodology for highly efficient and low energy in situ extraction. The major challenge here is to develop life cycle assessment methodology that is globally accepted, robust and transparent.

Energy policy must also recognise the impacts of energy options upon air quality, human health and climate change. The Defra Air Quality Expert Group report: Air quality and climate change: a UK perspective[6] is an important source of information here and should be recognised in future energy policy.

Energy supply

The Government has introduced schemes to encourage low carbon emission technologies including the biofuels directive, renewables obligation and clear skies renewable energy grants with varying degrees of success. The RSC believes that low carbon emissions schemes must have clear benefits for the end-user and be widely advertised to maximise their impact.

A significant investment in the materials and infrastructure of the transmission and distribution (T&D) network would reduce energy losses and reduce carbon emissions. The nature of carbon sequestration projects and distributed energy generation require a major redesign in the T&D network.

To reduce the UK's reliance upon imported energy the Government must support the chemical sciences in developing technologies for national sustainable energy production including, biofuels, biorefineries, gasification and pyrolysis of biomass, biogas generation, materials for renewable energy generation, hydrogen production, energy storage (such as battery technology), fuel cells and solar power.

Energy demand

The emissions trading scheme (ETS) gives carbon dioxide (CO_2) a market value and is an incentive for business to reduce carbon emissions. However, the future of ETS beyond 2012 is not guaranteed, hindering long-term business investment in carbon reduction strategies and technologies. A global

5 "How to plug the energy gap" - http://www.geolsoc.org.uk/template.cfm?name=PR60
6 http://www.defra.gov.uk/corporate/consult/airqual-climatechange/index.htm

ETS would provide a world market for carbon trading and provide a fiscal reward for investment in clean energy technology and energy efficiency.

Transport and buildings are major sources of energy use and must be a priority for demand reduction. The Government must implement policy that directly impacts on the energy-use in these sectors. The Government must show leadership and demonstrate significant carbon emission reduction in both its buildings and its vehicle fleet. Such a scheme would increase stakeholder confidence in carbon emission measures and provide valuable data on high impact programmes and technologies. A number of energy efficiency measures are outlined in additional question (i).

Q.2. With the UK becoming a net energy importer and with big investments to be made over the next twenty years in generating capacity and networks, what further steps, if any, should the government take to develop our market framework for delivering reliable energy supplies? In particular, we invite views on the implications of increased dependence on gas imports.

In general

UK energy policy and UK market mechanisms should clearly promote a diverse mix of secure energy resources. Policy must also focus on energy efficiency and reducing demand.

Investments in generating capacity over the next 20 years must focus on efficient and low carbon technologies. New fossil power stations should be built carbon capture and storage ready.[7]

Investments in the transmission and distribution grids must take advantage of modern design and materials in order to ensure that there is minimal loss of energy sources *en route* (e.g. gas leaks) and minimal loss of electricity through the grid. Future investment must also include provision for:

- Accepting renewable power, especially when renewable power is generated intermittently;
- Accepting power from micro-generation schemes; and
- An examination of the potential use of hydrogen as a fuel.[8]

There is a pressing need to develop technology to store energy on a large- and small-scale so energy that is currently wasted is stored efficiently. The chemicals sciences with sufficient funding will deliver future battery technologies, chemical energy carriers (such as hydrogen) and efficient transmission materials.

The chemical sciences will be critical in delivering technologies and processes that will reduce reliance upon imported energy supplies including biofuels, biogas, hydrogen and solar power.

On gas imports

Using current technologies, natural gas emits less CO_2 per unit of energy produced than oil or coal and therefore currently is cleanest fossil fuel option.

Heavy reliance upon the import of a single fuel, albeit from a variety of sources, raises concerns about security of supply including the vulnerability of the infrastructure to accidental damage or sabotage (there are only two pipelines connecting the UK mainland to Europe), the quality of the gas, political stability in gas exporting countries and fluctuations in price.

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[7] House of Commons S&T committee report - Meeting UK Energy and Climate Needs: The role of carbon capture and storage - www.publications.parliament.uk

[8] See response to question 4

The chemical industry was affected by high gas spot prices in the winter 2005/06 and in extreme cases processes were forced to shut down temporarily.[9]

To address these concerns the RSC recommends the following:

- That energy produced from gas (both electricity and heat) is produced in the most efficient way. The application of physical chemistry and chemical engineering will be integral to achieving this;
- That the UK prepares for fluctuations in gas quality by recognising the need for analysis of gas composition, understanding the effect of varying gas properties on mixing and blending systems and develops cost effective purification technologies; and
- In the Norwegian Sleipner field in the North Sea, CO_2 present in natural gas is removed and stored in an aquifer. This technology should be considered for all natural gas supplies that contain significant amounts of CO_2.

Coal power

Coal is a valuable strategic resource in the UK. The lifetime of reserves is far greater than indigenous gas reserves and the use of coal can significantly reduce dependence on imported gas.

When co-fired with biomass, CO_2 emissions from coal are comparable with natural gas on a net energy production basis and so generating electricity through biomass co-firing in existing coal-fired power stations can provide a route to address security of supply issues.

In the medium to long term, carbon capture will be developed for application to coal-fired power stations. There is a greater economic benefit if this technology is used with coal than with other fossil fuels and the retention of coal-fired stations is beneficial operationally because they are amongst the most flexible of plants for responding to changes in load.

There are important issues relating to coal use that can be addressed by chemical scientists. In particular developments are needed in the fields of materials, sensors and controls, combustion chemistry and chemical process modelling to enable the latest developments in clean coal technologies to be implemented at full scale.

Renewable power

The UK has a surfeit of natural resources that can be tapped to provide renewable power including wind, solar, wave, tidal, biomass, heat pumps and geothermal. It has been estimated that by 2050 up to 40% of UK electricity could be generated by renewables.[5]

Certain sources of renewable power such as wind power are available intermittently, often in remote locations and therefore the transmission and distribution network needs updating to accept renewable power; this will

[9] Chemical Industries Association – www.cia.org.uk

require significant capital investment. Energy storage for intermittent sources of renewable power is a key R&D challenge for the chemical sciences, as discussed previously.

There are a number of other key research priorities for the chemical and materials sciences in renewable power, including:

- Developing future generations of photovoltaic cells that are flexible, easily manufactured, efficient, cheaper and have long working lives;
- Improving the efficiency and reducing the cost of solar heating units;
- Improving the design and materials of construction for wind turbines so that they are more efficient, need less servicing and have a longer operational life;
- Improving the design and materials of construction for tidal and wave power units for the same reasons as above;
- Understanding the combustion characteristics of biomass so that efficient and clean systems for co-firing, combined heat and power (CHP), gasification and pyrolysis can be designed;
- Optimising the biofuels processes and supply chains so that energy losses are minimised and carbon reductions are maximised[10]; and
- Improving small-scale generation of biogas electricity at sewage works and landfill sites.

[10] RSC response to EFRA Bioenergy consultation – www.rsc.org/policy

Q.3. The Energy White Paper left open the option of nuclear new build. Are there particular considerations that should apply to nuclear as the government re-examines the issues bearing on new build, including long-term liabilities and waste management? If so, what are these, and how should the government address them?

Nuclear power

Of the 15 nuclear power stations presently operating in the UK, only 1 (Sizewell B) will still be operating by 2023. Without new nuclear power stations electricity generation from other low carbon sources will only begin to contribute to reducing UK carbon emissions once they exceed the current capacity of nuclear power.

State of the art fission electricity generating power plants are:

- A low, but not zero, carbon emission energy source[11];
- Low risk;
- Efficient;
- Less waste intensive than older nuclear power plants;
- Long lived (60 years plant operational life);

Nuclear power gives rise to:

- A legacy of long-lived radioactive waste;
- A significant cost to the taxpayer through decommissioning and long-term nuclear waste management; and
- A perceived risk of terrorist activity, cancer clusters and nuclear incidents (such as Chernobyl).

In the RSC report "Chemical science priorities for sustainable energy solutions" [12] it was identified that there has been a significant run down in nuclear skills in the UK. In particular the RSC is concerned with the lack of radiochemists, nuclear engineers, health physicists, commissioning and decommissioning experts and environmental chemists with an expertise in decontamination. There is also a lack of facilities in which to train future skilled workers. Unless urgent action is taken to address the skills deficiency the only UK option will be to import foreign skilled workers.

If a decision to build new nuclear power stations is made, then an Implementation Study Group should be set up immediately to study all aspects of what needs to be put in place, including the training of appropriate scientists and engineers and the provision of suitably equipped laboratories.

Fuel reprocessing

The chemical reprocessing of used nuclear fuel greatly extends the life of nuclear fuel and reduces the volume of highly active nuclear waste and

[11] Uranium mining, uranium extraction, fuel enrichment and fabrication of fuel rods emit significant quantities of CO_2. For new and decommissioned plant there is high use of energy in construction, treatment, transportation and disposal

[12] RSC report - Chemical science priorities for sustainable energy solutions – www.rsc.org/policy

concentrates it into a form that is manageable. With significant R&D effort from chemical scientists, future reprocessing technology will be substantially lower in costs and environmental impacts with greater proliferation resistance. The UK has an internationally recognised track record in this field and must ensure that it is part of future international collaborative R&D programmes.

Nuclear waste

Until a policy decision on a nuclear waste repository is taken there will remain uncertainties on what final form should nuclear waste needs to be packaged in and this is hindering R&D efforts on waste management options.

In the absence of new nuclear build there is a legacy of nuclear waste and also the waste generated through the remaining lifetime and decommissioning of existing nuclear power stations that must be managed. In the RSC workshop on “Materials for nuclear waste management” [13] several waste forms were identified that currently have no well-defined management option. Urgent support for R&D is required in order to analyse, test and demonstrate management options for such waste forms.

In the RSC workshop it was also noted that the UK has limited facilities for handling and carrying out basic research into highly active and fissile material.[13] In particular it was identified that UK facilities for characterisation of radioactive materials are lacking and that this is hindering UK R&D. This also results in the UK having a weak hand in international, collaborative research partnerships.

It is critical that basic research into understanding and modelling the transport and fate of radionuclides in the engineered and natural environments is carried out and mechanisms be developed for remediation of contaminated sites.

Nuclear waste management

We await with interest the findings of CoRWM regarding long-term management options for nuclear waste. The RSC believes that a geological repository is vital. Other countries, such as Finland, have demonstrated successful models for stakeholder consultation processes and the UK should learn from such examples. We note from our recent workshop that the EU commission considers a long-term nuclear waste management plan to be critical in member states proposals for new nuclear build.[13]

Any wastes arising from building new nuclear power stations would need to follow regulatory guidance with regards to conditioning, packaging, and ensuring that wastes were assessed for future disposability. Waste management and decommissioning issues should be addressed at the beginning of any new build discussions. The involvement of the waste management organisation charged with implementing any policy on long-term waste management in decisions regarding the technical design of new reactors would be beneficial. For example, if the new reactor design were to

[13] RSC workshop – Materials for nuclear waste management – www.rsc.org/policy

give rise to new or novel materials which might have an impact on for example, decommissioning practice or repository safety, early discussions could identify and minimise such impacts.

Once a decision is made, significant collaborative effort, including the chemical sciences, will need to be mobilised in order to identify and characterise sites for the repository, demonstrate the technology in underground laboratories and design storage modules for safely containing radioactive material.

Q.4. Are there particular considerations that should apply to carbon abatement and other low-carbon technologies?

In general
As stated our response to Q1, energy policy must be long-term.

In the short-term, the scope for solving the problem by technology is limited, bearing in mind the enormity of the task, the need for urgent action and the huge costs involved. Priority should therefore be given to energy efficiency and to reducing emissions within the framework of existing technology.

In the medium-term options such as energy efficiency, renewable power, state of the art nuclear power, carbon capture and storage (CCS), hybrid and electrical vehicles, micro-generation, energy storage (such as batteries), hydrogen from fossil fuels coupled to CCS, biomass combustion and biofuels could make important contributions to reducing carbon emissions.

In the long-term a sustainable hydrogen economy and nuclear fusion are options for low carbon energy, however, enormous technical challenges need to be overcome. It is critical that these technologies are proven to have low carbon emissions across their whole life-cycle.

Solar energy
Solar power has the potential to provide a significant proportion of the UK electricity needs. The chemical sciences will be crucial in reducing the cost and increasing the efficiency of solar technology through improvements to current design and manufacture and through the development of the next generation of technology, such as technology that takes advantage of biological methods of harvesting and storing energy from light. The UK has a strong and vibrant research base in this area, in particular in understanding and mimicking photosynthesis systems and also in dye-sensitised and organic solar cells that can be used as coatings on windows and other materials of construction. Ideally it will become routine to integrate solar power into buildings as materials of construction (for example roof tiles) and windows coupled to energy storage and low energy demand devices.

Coal and carbon capture and storage
Burning fossil fuels is the major anthropogenic source of CO_2 in the atmosphere and is the key contribution to climate change. Therefore, if fossil fuels are to continue to contribute to the energy mix in the future then CO_2 must be sequestered permanently.

Coal is in abundant supply worldwide but will only contribute to reducing carbon dioxide when CCS is fully integrated into power generation. China and India will be building numerous coal-fired electricity stations over the coming decades and therefore there is a considerable export potential, if the economics are favourable, for CCS technology. Support must be provided for organisations developing this technology.

Substantial R&D effort is required before CCS is a routine procedure, and this was recognised in the House of Commons Science and Technology report "Meeting the UK energy needs: The role of carbon capture and storage". The RSC endorses the following recommendations of the report:

- The costs of CCS are comparable to other low carbon approaches to electricity generation;
- That capture readiness be made a requirement for statutory licensing of new plant;
- That a concerted effort is made to communicate the risks and benefits of CCS to the public;
- To ensure that geological storage of CO_2 is permissible under international law and to ensure that the regulatory framework is in place;
- That the Government increases investment in research, development and demonstration by an order of magnitude in order to 'pump prime' the initial demonstration projects and that this is part of a long-term incentive and policy framework to give industry the confidence to proceed.

The RSC reiterates the need for R&D in CCS and proposes a number of critical challenges that chemicals scientists in collaboration with others are capable of addressing:

- The development of efficient and appropriate systems to capture CO_2 on both a large and small scale;
- The identification, characterisation, monitoring and demonstration of sites for CO_2 storage;
- The chemical conversion of significantly large quantities of CO_2 into commercially useful products.

<u>Hydrogen as a fuel</u>

When hydrogen (H_2) is burned or used as fuel to generate electricity in a fuel cell, the major by-product is water. Whilst hydrogen is abundant on Earth, it is not abundant in the form H_2 and must be produced in a way that uses energy. Therefore, H_2 is potentially a significant fuel source and the key challenges are to minimise the energy used in producing H_2 and ultimately to produce H_2 from sustainable sources. There are numerous scientific challenges in producing H_2 from several feedstocks, including:[12,14]

- Reforming fossil fuel feedstocks, such as natural gas, to make H_2 and CO_2 – the key challenge integrating this method with CCS;
- Using renewable energy to produce H_2 from water by electrolysis – the key challenge is in the construction of efficient electrolysis cells;
- Thermochemical splitting of water in the next generation of high temperature nuclear reactors – the key challenge is in understanding the fundamental reaction kinetics;
- Biochemical H_2 generation – the key challenge is discovering and developing microorganisms and systems that can achieve this on an economically viable scale.

[14] R. M. Dell and D. A. J. Rand, Clean Energy, RSC Clean Technology Monographs, Royal Society of Chemistry, Cambridge, UK, (2004)

There are also significant challenges in hydrogen separation, hydrogen storage, hydrogen transport infrastructure and fuel cell manufacture and efficiency. A health and safety assessment of a large scale hydrogen generation, storage and distribution system needs to be carried out.

Q.5 What further steps should be taken towards meeting the government's goals for ensuring that every home is adequately and affordably heated?

<u>In general</u>

In order to fulfil the Government's objective of adequate and affordable heating it is important that UK energy policy avoids over reliance upon a single fuel as this raises concerns over security of supply and sudden price rises. The distribution network must be developed and invested in to ensure access to affordable energy for all parts of the UK.

As discussed in Q1, buildings account for 33% of final energy usage. This represents a huge opportunity for reducing carbon emission through energy efficiency and the use of energy efficient technologies. A number of technologies for energy efficiency in buildings are discussed in additional question (i).

The Government must show leadership in energy efficiency and ensure that Government offices are leading examples of efficient buildings and are used to showcase energy efficient technologies.

Government policy must ensure that regulations for new buildings (domestic, industrial and public buildings) demand the highest levels of energy efficiency in both the materials used and the space heating technology employed.

The Government must also ensure that energy efficiency loans are available and widely advertised to the industry and domestic sectors so that buildings are made more efficient without prohibitive financial outlay by the owners.

CONSULTATION ISSUES

i. The long term potential of energy efficiency measures in the transport, residential, business and public sectors, and how best to achieve that potential?

In general

A huge amount of energy is wasted in generation, transmission and at final use. Significant public and/or private investment in energy efficiency is vital because:

- The Government will fall short of its target of 20% carbon emission reduction by 2010.
- The UK government will not meet the carbon emissions reduction target of 60% by the year 2050 without huge improvements in energy efficiency.
- The UK government has calculated that 20% of energy could be saved cost-effectively by investing in energy conservation. This would yield savings of over £10 billion a year; money that would boost the economy when spent on other goods and services.
- There are significant social benefits of investment in energy conservation include creating significant numbers of jobs in energy-related services such as manufacturing and installation of energy saving equipment. Moreover, homes and workplaces would be made easier and cheaper to heat, greatly improving standards of living and comfort.

Good leadership and adequate support from Government will ensure that the chemical sciences have a leading role in improving efficiency in the generation, transmission and use of energy.

Energy efficiency in the home

Domestic energy efficiency measures can play a significant part in meeting UK carbon reduction targets. 40% of energy consumption is used to heat homes, and in turn, 30% of this energy is lost through windows. Buildings, and in particular homes, are much bigger polluters than cars. In fact CO_2 emissions caused by homes are double that of cars.

The development of 'smart' coatings whose properties change according to an external stimulus is of great interest and these products would provide ‘smart energy control’ in buildings. Such a coating would be solar heat reflecting on a hot sunny day to prevent solar radiation heating the occupants of a building, but would be heat insulating on a cold day to prevent heat escaping form a building (it would also ideally have a high passive heat solar gain so as to use solar energy to heat the building). The chemical sciences would play a key role in the development of these products. It is estimated that if all double glazing in the UK was replaced with low emissivity glass the savings would amount to £638 million a year and 9 million tonnes of CO_2 a year.

Highly effective insulation should be encouraged and incentivised for all homes. There is considerable scope for chemists to develop environmentally benign and highly efficient insulating materials that control both temperature and humidity. Natural insulating materials such as wool, paper and natural fibres should be encouraged, and the need for chemicals that inhibit decay and increase fire resistance should be realised.

Domestic appliances that are energy efficient and that do not have a stand-by mode should be encouraged. Policy on domestic lighting in particular must focus on energy efficient lighting in the short term and in the future the chemical sciences will deliver highly efficient lighting systems such as organic light emitting diodes (OLED). With sufficient support science and engineering research objectives for the domestic sector develop innovative, efficient products and services, integrated packages for fuel consumption and energy conservation, efficient ventilation and heating systems, strategies for waste minimisation and recycling, heat recovery and localised energy production from solar power or micro-CHP systems.

Energy efficiency in the chemical industry

The chemical sector has surpassed its 2004 Climate Change Agreement (CCA) target. The chemical sector has improved its energy efficiency by 19.5% since 1998, this is equivalent to an annual saving of around 3.5 million tonnes of carbon dioxide emissions.[15]

There are further significant energy reductions that can be achieved through the use of green chemical technologies as identified in our energy report.[12] In particular the use of intensive high-throughput processing, novel reactor design, advanced separation technologies, catalysts and biocatalysts, alternative energy sources (such as light, microwaves and ultrasound) and alternative feedstocks can significantly reduce energy in chemical manufacture. The recently formed Chemical Innovation Knowledge Transfer Network (where the RSC is the holding company) will be critical in facilitating technology transfer and innovation in the UK chemical industry.[16] On a European level the RSC is a key partner in the European Technology Platform for Sustainable Chemistry (SusChem) that seeks to boost chemistry and chemical engineering research, development and innovation in Europe.[17]

Chemical scientists are involved in advanced manufactured components for high efficiency products and these are a technology that many large UK companies are embracing.

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[15] From the Chemical Industries Association (CIA) - http://www.cia.org.uk
[16] http://ktn.globalwatchonline.com
[17] http://www.suschem.org

ii. Implications in the medium and long term for the transmission and distribution networks of significant new build in gas and electricity generation infrastructure?

The RSC feels that the responses in Q1, Q2 and Q3 cover this point adequately.

iii. Opportunities for more joint working with other countries on our energy policy goals?

Technology platforms and networks
The UK must be an active partner in national, European and international technology platforms, knowledge transfer networks and collaborative research projects to ensure involvement in key developments in energy technologies and energy policy.

The RSC plays a leading role in both the Chemical Innovation Knowledge Transfer Network[16] (where the RSC is the holding company) and the European Technology Platform for Sustainable Chemistry (SusChem).[17]

Natural gas
In light of recent developments in Russia the UK must have in place agreements for natural gas imports that ensure a secure supply in the long-term. The UK could help secure supply contracts by offering to collaborate on gas compression and regas, gas liquifaction and polygeneration to syngas technology.

Nuclear Power
A number of countries are currently considering new nuclear build, or have demonstrated new nuclear power technology. Collaboration with such countries on the process of consultation and on running new nuclear power stations would aid the UK if we commit to a new programme of nuclear build.

A deep geological nuclear waste repository is an option being considered by a number of countries including Finland, Sweden, France, Japan and America. The UK would benefit from collaborating on public consultation protocols and the technological options and implications.

UK involvement in international R&D programmes should be a goal in order to gain access to large programmes and the technology developed and to maintain our influence on a global scale in nuclear fuel cycle issues. National investment in funding and facilities needs to be made in order to gain such leverage.

Renewable power
There are a number of countries considered leaders in different renewable energy technologies including Germany (wind and biodiesel), Austria (biodiesel), America (bioethanol, photovoltaics, and hydrogen), Japan (photovoltaics, hydrogen), Sweden (biomass) and Brazil (bioethanol).

Carbon capture and storage (CCS)
The UK already has collaborative agreements in place with Norway. It is important that CCS projects are demonstrated on a significant scale and this must be facilitated through collaboration. It is also important that Governments agree on international law regarding CCS. There are a number of countries with experience in this field, including America, Canada, France and Norway.

There is the opportunity for the UK to collaborate with others on the development of an oxy-fuel fired boiler, which is a crucial technology for CCS. There is also an opportunity for the chemical sciences in the UK to collaborate with other countries on carbon capture technology, including membranes, adsorbents and solvents.

There are projects concentrating on the conversion of CO_2 into chemicals in America, Japan and in Italy that UK researchers and companies should look to collaborate with. The RSC is organising a workshop on July 27th 2006 to discuss the potential of the UK in this field.

Hydrogen economy

The UK has good research and industrial base for developing hydrogen as an energy vector and there is a need for enhanced research investment to address the long-term technical barriers.

A number of countries have made significant progress in the development of science and technology that might lead to a hydrogen economy. Japan and America in particular are advanced in this area. The UK should therefore seek to collaborate on strategically important areas.

iv. Potential measures to help bring forward technologies to replace fossil fuels in transport and heat generation in the medium and long term?

TRANSPORTATION[12]

The chemical sciences are pivotal in the development of systems that offer significant improvements to fuel and exhaust systems in vehicles; this has been demonstrated through the development of unleaded petrol (eradicating harmful lead additives), detergent additives (that have increased fuel economy and increased engine lifetime), oxygenated fuels (that improve fuel efficiency) and catalytic converters (to reduce harmful carbon monoxide, volatile organic compounds and NO_x emissions).

Reducing vehicle weight

Vehicle performance can be considerably improved by reducing weight through the use of lighter construction materials. The challenge to polymer and synthetic chemists is to create new structural materials and designs that radically reduce vehicle weight without compromising safety.

Systems engineering approach

Personal mobility can be considered a systems engineering problem consisting of the engine and fuel, the transmission system, the vehicle itself including the wheels, the road surface and construction, the refuelling infrastructure and the eventual recycling of the components. This requires a deep understanding of the chemistry and chemical engineering aspects of the fuels, their combustion characteristics, the engine and vehicle shell materials, the control systems and sensors required.

Hybrid and electric vehicles

Recently hybrid vehicles have been introduced to the market place. Further improvements to hybrid vehicles will require lightweight construction materials and technology, efficient low emission engines and improved battery or alternative energy storage technology. Energy storage is a key issue to which chemists and materials scientists have much to contribute. All of these points are equally applicable to electric vehicles.

Biofuels

In early 2003, the European Commission issued a directive promoting the use of biofuels for transport, setting out two indicative targets for EU member states – 2% biofuels inclusion in the fuel pool by December 2005 and 5.75% by December 2010. The UK is currently not on track to meet the 2010 target.

Biodiesel (made from vegetable oil), bioethanol (from carbohydrate fermentation) and conventional fuels synthesised from the gasification products of biomass are key biofuels that need to be exploited to meet the 2010 target. The chemical sciences and engineering disciplines are critical in developing efficient catalysts, separation processes, high throughput systems and additives to maximise the effectiveness and efficiency of biofuels. Biofuels have great potential for reducing carbon emissions but it is vitally important that energy used in their production is minimised or derived from renewable resources. Bioethanol from lignocellulosic biomass (such as wheat straw) could improve the economics and reduce land use needs in the medium term but significant R&D challenges remain for chemists, biochemists and engineers.

Gasification of biomass produces a synthesis gas (syngas) from which fuels such as gasoline and diesel can be produced.

Direct fast pyrolysis of biomass produces a liquid can be stored or transported and delivered to a large processing plant for gasification and synthesis of liquid transport fuels. A further incentive is the potential for production of chemicals from the resulting pyrolysis liquid.

Hydrogen fuel cell

On-board storage of hydrogen is posing significant obstacles to delivering hydrogen-powered vehicles. The development of materials for hydrogen storage is a key challenge for chemical scientists.

The cost of fuel cells versus that of the internal combustion engine is also a problem, with the latter typically costing $30 for each kilowatt of power it produces while fuel cells cost a hundred times more. Technical challenges such as making fuel cells rugged enough to withstand the stress of driving, reducing their size and weight while increasing power density, fuel flexibility and fuel cell poisoning still exist.

Air travel

Air transport is receiving increasing attention because of environmental concerns linked to CO_2 emissions, air quality and noise. Further atmospheric chemistry research into the impact of aircraft emissions in the upper troposphere (extends from about 14 to 18 km) and lower stratosphere (extends from the troposphere to about 50 km) are required. Whilst technology can reduce the emissions per flight, it is much more important to reduce the overall number of flights. To reduce emissions, designs with reduced weight will benefit fuel economy and efficiency. Embedded sensors and controls (in intelligent gas turbine engines) could reduce noise, emissions and costs through more effective diagnosis and maintenance processes. New materials are required (e.g. low-cost composites, corrosion-resistant, damage-tolerant alloys and smart materials) to reduce manufacturing, life-cycle costs and reduce travel time, whilst advanced coatings for the next generation of gas turbine engines are required for improved fuel efficiencies and emission reductions. Multidisciplinary teams of chemists, materials scientists and engineers are needed to develop viable solutions.

HEAT GENERATION

Biomass and biomass co-firing

Biomass fired in dedicated plants, or co-fired in coal burning plants, has a reasonable potential for Combined Heat and Power (CHP) generation, an estimate would be that around 5% of electricity could be generated by such sources in the medium term. A number of UK power stations are currently successfully co-firing imported biomass (such as imported olive waste and milled palm nuts from Malaysia).