INNOVATIVE SCIENTIFIC AND ENGINEERING SOLUTIONS FOR THE MANAGEMENT OF CLIMATE CHANGE

NATIONAL SCIENCE AND ENGINEERING WEEK SEMINAR ON THURSDAY 15TH MARCH

Every year during National Science and Engineering Week the Parliamentary and Scientific Committee joins with the Department of Trade and Industry to host an event to bring together leading scientists, engineers and politicians to discuss the contribution of science and technology to the development of public policy. This year the subject chosen for discussion was Climate Change and the contribution of science and engineering to mitigate and manage the potential effects on our national infrastructure.
The joint chairmen were Malcolm Wicks MP, Minister for Science and Innovation, and Dr Douglas Naysmith MP, Chairman of the Parliamentary and Scientific Committee. The meeting, which attracted a capacity audience, was held in the Grand Committee Room, Westminster Hall.

Report by Robert Freer, The Royal Institution of Great Britain

Introduction

Malcolm Wicks MP
Minister for Science and Innovation

Mr Wicks welcomed the audience and thanked the Parliamentary and Scientific Committee for hosting this meeting. He identified climate change as arguably the biggest challenge which has yet faced our civilisation; its effects will worsen some of the world's other great problems such as the insecurity of food and water, poverty, conflict and disease.

Science has helped us understand the problem, we look to engineering to help provide the solutions. Energy generation and its use is an important part of the problem and Mr Wicks said these issues bring together his former role as Energy Minister and present role as Science Minister.

The UK has become a pre-eminent centre of knowledge for climate science and our expertise can contribute to the work of organisations such as the Intergovernmental Panel on Climate Change (IPCC) which has identified human activity as the cause of global warming. We now have to decide what we need to do and how quickly we should do it.

One thing we need to do is to reduce our emissions of greenhouse gases, a transformation which will require research, innovation and ingenuity. Burning fossil fuels, land changes and deforestation are all part of the problem, an increasing problem as world energy demand is expected to increase by over 50% by 2020. We need to achieve substantial cuts in our domestic emissions and show leadership to the EU and to international efforts to do the same. Developing countries such as China and India, where new coal-fired power stations are being completed by the week, are unlikely to use modern technologies to reduce emissions unless they see the developed countries doing so themselves.

The Climate Change Bill is intended to set a long term legal framework for reducing emissions over the next 45 years and provides the means to achieve this objective. This Bill is the first of its kind in the world. It demonstrates the UK commitment to the national transition to a low carbon economy and demonstrates decisive international leadership.

Technological innovation is central to achieving these objectives. We have a number of low carbon technologies ready for deployment, but the barriers to deployment in such instances lie elsewhere than in the technologies themselves. Fossil fuels will continue to play a significant role in energy production and the rapid development of carbon capture and storage is vital. The ambition of the European Commission is that from 2020 all new fossil fuel power stations built in the EU should capture and store CO_2 subject to developing the necessary technical, economic and regulatory framework.

There is also a range of potential renewable sources such as bio-fuels, hydrogen and fuel cells but further research, development and demonstration work is needed to accelerate learning and cost reductions. The Stern report concluded that global research spend needs to double and deployment incentives for the new technologies increase by up to five fold.

In January 2006 the Government established the Energy Research Partnership, a public-private initiative to galvanise the efforts and investments of Government, business and the research community to add cohesion to energy research and improve the impact of funding. Following this in September 2006 the Government launched the prospectus for the Energy Technologies Institute, another public-private initiative with a budget of up to £1bn over ten years. And last year the Chancellor announced a new Environmental Transformation Fund to support low carbon technologies. These initiatives will provide the UK with world class means for delivering energy technology research to underpin practical deployment.

National Science and Engineering Week is an opportunity to celebrate the role of science, engineering and innovation in securing our energy future, and through that, our economic and social well being.

How can we safely dispose of CO_2 released by the combustion of fossil fuels for power generation?

Professor Martin Blunt
Head, Department of Earth Science and Engineering, Imperial College

Professor Blunt considered the two main challenges facing the world this century to be global warming and the acidification of the oceans caused by the emission of CO_2 into the atmosphere.

The CO_2 emissions from fossil fuel power stations can be reduced either by reducing demand by improved energy efficiency or by replacing fossil fuel power stations with nuclear power and renewable energy sources. But there is another option: carbon capture and storage (CCS) that involves the separation of CO_2 from sources such as fossil fuel power stations and injecting it into deep underground geological formations. Since 85% of the world's energy is supplied by oil, gas and coal this technique has considerable potential, especially in developing countries such as China and India which rely on coal-burning power stations to fuel their economic growth.

Of the potential sites for storage the deep saline aquifers have the greatest storage potential. The International Energy Agency has estimated that up to 10,000 Gt of CO_2 (1Gt=10(12) kg) could be stored world wide in aquifers, which is equivalent to many centuries of CO_2 emissions at the current rate of around 25 Gt per year, equivalent to 7Gt carbon per year.

For comparison, each person in the UK is responsible for 10 tonnes of CO_2 per year. And if 1Gt carbon per year (ie 15% of current emissions) was stored underground at a density of 600 kg per m^3 the volume of CO_2 injected would be similar to current world oil production.

Injection into depleted oil and gas fields has benefits associated with enhanced oil and gas recovery but the storage potential is less, and injection into abandoned coal seams has a storage potential which is smaller still.

The North Sea is an attractive possible site for CO_2 storage. The sea bed has relatively well characterised geological formations and the Department of Trade and Industry and the British Geological Society have estimated that aquifers under the North Sea have a storage potential of 700 Gt CO_2 compared with 13 Gt in the gas fields and 6 Gt in the oil fields. But the first application of CCS in the UK is likely to be in the mature oil fields with an existing pipeline infrastructure where it will offer the benefit of enhanced oil recovery (EOR).

CO_2 injected deep underground has liquid-like properties with a density slightly less than water. At typical reservoir temperatures and pressures CO_2 is miscible with the light oils found in the North Sea and the injection of CO_2 sweeps out the remaining oil.

CCS is a new technology but the component operations, separating CO_2 from the other gases and underground injection, are well established in the oil industry. There are some 70 CO_2 injection projects world wide, most of them in Texas where natural underground sources of CO_2 have been used in EOR schemes for 30 years. In the North Sea the Sleipner project has been running for ten years and several other projects are being considered.

One of the major concerns in any storage project is the potential leakage of the CO_2 into the atmosphere. In the oil and gas reservoirs the overlying geological strata are impermeable, but the integrity of the cap rock of saline aquifers is less certain. One way to prevent leakage is to inject water with the CO_2: the water traps the CO_2 in the micro-scale pore spaces of the rock and renders it immobile. Leakage is a possibility mainly during the initial injection. Over a long period of time the CO_2 will dissolve in the water and may react with the rock precipitating carbonate. Brine containing dissolved CO_2 is denser and will sink slowly.

At Imperial College a cross-departmental team of research workers is studying CCS in collaboration with Shell as part of the Shell-Imperial College Grand Challenge Programme on Clean Fossil Fuels. One component of this work is the design of injection to render the CO_2 immobile, which includes the use of advanced computer simulation to predict where the CO_2 is likely to travel. The UK has a golden opportunity to take a lead in CCS working with the oil industry to demonstrate carbon storage with EOR.

Power Generation from the Barnsley Seam by Clean Coal Technology (IGCC) and Carbon Capture and Sequestration (CCS)

Richard Budge
CEO, Powerfuel plc

Mr Budge said the Hatfield Power Project aims to be the first fully commercial coal-fired power station in the world with carbon capture. It is to be located at the Hatfield colliery in South Yorkshire, which has access to up to 100 million tonnes of British coal, and is located within a cluster of local power stations. Planning permission and a Government Consent (the only Section 36 for a coal fired IGCC station) have already been obtained and the likely cost of the project should be £1.2 billion for 900 MW. Our timetable is to commence generating power from the beginning of 2012.

The IGCC power station, incorporating carbon capture from the outset has the ability to produce both hydrogen for transport use and "syngas" for possible pipeline export to other local natural gas stations for power generation or injection into the national gas grid.

The Hatfield IGCC is one of several being planned in the vicinity of Humberside; the others being EoN and Conoco, making this region an outstanding contender for centralised investment in CO_2 pipeline infrastructure for export into the North Sea.

In recent years we have had Energy White Papers that have been superseded before publication because the process has been to seek widest consultation rather than identify the obvious. It is difficult, if not near impossible, to forecast commodity prices for energy. All that is needed is to state the obvious that the UK needs to maintain a mixed diverse energy portfolio to avoid becoming too dependent on any one source of energy.

This extended consultation must not be allowed to continue and we trust that the Government and Treasury will, sooner rather than later, sign up to a more secure energy policy for the UK which is sufficiently prescriptive to underpin future investment.

We believe that coal gasification is the cheapest form of CO_2 capture because with pre-combustion capture the process captures low volumes at high density whereas with post combustion capture there are large volumes of exhaust gas to deal with.

I strongly support the replacement of nuclear plant with new nuclear because if the Government is serious about reducing greenhouse gases there is no choice. I just wish someone would decide the timetable and get on with it.

I do not support wind farms because they operate for less than 30% of the time and therefore by definition they must be a bad investment and very expensive for electricity consumers.

Our proposal is to capture a large volume of CO_2 from a cluster of potential power stations in the Humber Region and pump it through a pipeline to the North Sea oil fields to increase the recovery of oil from those oil fields which are nearly depleted. This process of Enhanced Oil Recovery (EOR) should recover an extra 7% to 10% and extend the life of the oil fields. At present about 40% of oil is recovered from an oil field. Estimates suggest that EOR is a viable proposition at $35 to $40 per barrel, ie less than the present $60 per barrel but more expensive than alternative investments for the oil companies.

The oil companies need the Treasury to put in place the necessary fiscal policies to encourage them to invest in EOR in the North Sea. The increased petroleum revenue tax will be of significantly greater value to the country than any taxation loss resulting from financial incentives to the oil companies.

Another risk that has a negative impact on investment decisions is the volatility of the primary CO_2 price. When CO_2 was trading at just under €30 investors were considering commercial projects purely on the basis of CO_2 capture, but the present price of €5 isn't sufficiently attractive for new investment. The European Trading Scheme (ETS) and the Government must underpin the price of CO_2 guaranteeing a realistic price for CO_2 that will make future developments viable.

Coal gasification produces 99.4% pure hydrogen which when mixed with a small amount of nitrogen is known as synthetic gas (syngas). Syngas can be injected into the national gas grid as an alternative to imported gas and when fired through conventional gas turbines emits only water vapour.

The hydrogen could also be used in transport to kick start the hydrogen economy. Powerfuel's Hatfield Colliery could produce sufficient hydrogen to fuel 2,000 buses in the inner cities of Doncaster, Rotherham, Sheffield, Leeds and York. Gaseous hydrogen is not a long term solution for transportation but is a viable medium term alternative until the hydrogen cell technology is better advanced.

At present half of the world's gas is in the hands of Gazprom and the National Iranian Gas Corporation, and a further 20% is in the Middle East and North Africa, all countries which are potentially politically unstable, whereas coal is spread around the globe with no geo-political dominance. We need coal in our energy mix to improve our security of supply and coal gasification offers the lowest commercial cost capture of CO_2 and provides an alternative to imported gas.

But we need to stop talking about EOR and get on with it. The oil companies and the Treasury need to complete their negotiations quickly to allow developments to begin in the North Sea.

At Hatfield we have sought to bring together real joined up policy and we trust it will be supported by energy policy in the future for the benefit of UK plc.

Beyond Petroleum?

Dr Steven E Koonin
Chief Scientist, BP plc

Dr Koonin said he would concentrate on the use of biology and of the biosciences to manufacture transport fuels. The rationale for developing the energy biosciences is simple and compelling. Biology is the most rapidly developing of the sciences and will produce some novel technologies.

All life and about 80% of the world's energy is based on carbon and over the 3.5 billion years of evolution nature has developed multiple solutions to meet our energy challenges. So far most of the funding for the biosciences has been for medical work, there have been far smaller investments in agriculture, materials and chemicals. The field of energy biosciences is largely open territory.

There are many potential large scale applications for energy biotechnology including carbon sequestration and bio-remediation of land but this presentation will concentrate on bio-fuels.

For transport purposes it is very difficult to find a better fuel than liquid hydrocarbons. Based on volumetric energy density and gravimetric energy density gasoline is about fifty times better than the best batteries available at present, and we have the technical processes to convert a range of carbon sources into hydrocarbon fuels suitable for transportation.

The most promising carbon source is biomass. During growth plants absorb CO_2 from the atmosphere and produce carbon as cellulose. This carbon is harvested and processed as biofuel and when it is burnt it returns the CO_2 to the atmosphere. The cycle is carbon neutral except for the energy used in the manufacturing process and in the distribution of the fuel.

The natural circulation of CO_2 from plants to the atmosphere and back to plants is many times greater than the man-made input of CO_2 into the atmosphere.

The key questions concern the costs of biofuel, the supply of the raw materials, the environmental sustainability of the process and the energy balance.

Using these criteria ethanol made from maize is not an optimal fuel. 1 MJ of ethanol requires 0.9 MJ of other energy to make it and the CO_2 emissions are only 18% less than for petrol. Its energy and environmental benefits are limited.

Manufacturing bio-fuels brings together the process and production chains in the petroleum industry and in the agricultural industry. Sugar cane from Brazil is a better raw material for ethanol based on the fuel yield per acre of land and for the same reason the best plant for making bio-diesel is oil palm. Plant breeding and genetic modification over the years has strongly increased crop sizes, resistance to drought and crop yields.

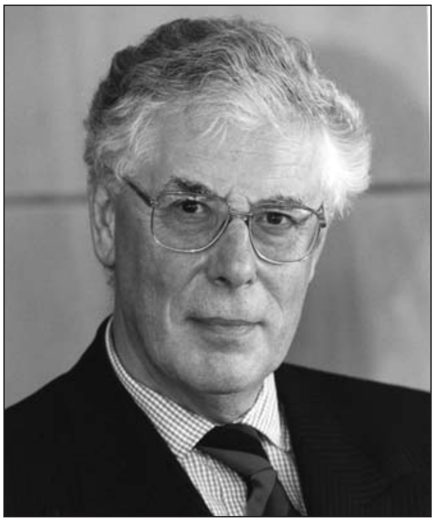
One of the most productive of the energy crops is Miscanthus, a grass which grows to a height of 11 feet in one season and yields 17.5 tons/acre.

Ethanol is only a first generation bio-fuel; butanol, a hydrocarbon with a higher carbon number than ethanol, is a more suitable bio-fuel. It is easily blended into petrol, it can use the existing fuel infrastructure, can be used in higher blend concentrations than ethanol and has an energy content closer to that of petrol than does ethanol.

The BP Energy Biosciences Institute is a new research organisation dedicated to explore the application of biology and biotechnology to energy issues. It is located at the University of California - Berkley and has partners at the University of Illinois Urbana-Champagne and Lawrence Berkley National Laboratory. It will bring together BP, academia, biotechnology firms and Government in a $500 million commitment for 10 years starting in June 2007.

Innovative Nuclear New Build for Sustainable Power

Dr Robert Hawley
Vice Chancellor, World Nuclear University



Dr Hawley said nuclear power is alive and well around the world. Today there are 435 nuclear power reactors in 31 countries (58 in France alone) supplying over 16% of the world's electricity demand. There are a further 28 plants under construction, 64 planned and 158 proposed, several of them in America. Nuclear capacity has significantly and constantly increased with upgrades and plant life extensions. Dr Hawley said he wanted to demonstrate how nuclear power improves the security of our electricity supply and especially how it contributes to the reduction in the build up of greenhouse gases and hence to global warming. This is important in the UK because electricity generation from coal and gas is responsible for 33% of our emissions.

The global demand for energy is increasing as a consequence of population growth, commercial development and urbanisation. And the use of electricity will increase faster than primary energy demand.

How is this demand for electricity to be met? At present the world demand is heavily dependent on fossil fuels (coal 39%, gas 17% and oil 8%). Most of the rest is supplied by hydro and nuclear. At present coal produces twice the quantity of CO_2 that oil or gas does but nuclear produces only 0.4% that of coal. Building more nuclear power stations is one of the few realistic options we have of reducing carbon dioxide emissions. In the OECD countries electricity from nuclear power stations has already saved more than twice the CO_2 emissions set by the Kyoto targets.

The economics of new nuclear build have improved dramatically in recent years. Power stations in Japan and Korea are being built to time and budget, and since the fuel cost is only about 15-20% of the total operating cost, nuclear power is better insulated from increasing fuel costs than is a gas fired station where the fuel is about 60% of the operating cost.

The design of modern nuclear power stations has also improved. Future power stations are a simpler design, have higher plant availability, shorter outages and lower maintenance costs. Also the fuel is used more efficiently resulting in less waste. Modular design concepts with factory built modules mean that the power stations can be built quickly with site activities reduced to 36 months.

There are a number of new reactor designs being developed, but for the UK there are two significant contenders, the AREVA EPR and the Westinghouse AP 1000, both light water reactors. An AREVA EPR with an output of 1600MW is being built in Finland and another is planned in France as a prototype for replacing their existing reactors.

The Westinghouse AP 1000 has the advantage of passive safety features, relying on gravity, natural circulation and compressed gas. And compared with the earlier generation of nuclear power stations it has far fewer components and requires smaller buildings. In December 2006 Westinghouse signed a contract to build 4 reactors for the Chinese, the biggest international reactor contract in history.

Very High Temperature Reactors (with coolant temperatures up to 1,000ºC) offer the exciting possibility of producing hydrogen by hydrolysis as well as generating electricity. A potential source of hydrogen at a reasonable price created without emitting CO_2 makes the use of fuel cells for transportation a realistic proposition. This design has the benefit that during periods of light load the excess power could be diverted to the electrolysis plant. The power station need not then be restricted to supplying only the base load but can be used to supply some of the peak load electricity which commands a higher price. This would further advance the economics for nuclear power generation. An experimental VHTR is operating in Japan and the US intends to build a test reactor by 2015.

There are other successful reactor designs. For instance, 7 Boiling Water Reactors in Japan developed by GE/Toshiba/Hitachi are producing 8.2GW but future significant developments in water cooled reactors are unlikely, whereas gas cooled reactors are serious contenders for the future because of their modern design, inherent safety and ability to produce heat and electricity.

A design of high temperature gas reactor uses helium at high temperature as the coolant and is equipped with a direct cycle gas turbine conversion system. High temperature reactors have ceramic cores and have a high thermal efficiency.

Another design is the pebble bed modular reactor which is being developed in South Africa. This is more efficient than other reactors and has an output of 165MW (compared with 1,000MW for the AP 1000) which makes it more attractive to developing countries.

Fast breeder reactors are potentially interesting because the fuel from fission reactors is used to breed more fuel, but the experimental ones at Dounreay and in France have been shut down due to technical difficulties.

In the more distant future is the possibility of electricity from thermonuclear fusion in which the nuclei of deuterium and tritium are joined at a very high temperature. Both constituents are readily available and this design offers the prospect of electricity for a very long time ahead. The physics has been demonstrated in the Joint European Torus (JET) at Culham and a prototype International Thermonuclear Experimental Reactor (ITER) is being built at Cadarache in France. It is due to be commissioned by 2016.

Nuclear power is not only alive and well, it has a significant future. And the UK Government now realises this.

The Role of Wind, Wave and Tidal Energy in Securing Clean Energy Supplies for the UK

Maria McCaffery
Chief Executive, British Wind Energy Association

Energy Resources for energy from wind, waves and tidal streams

A map of mean wind speeds over Europe shows much of Scotland and its offshore waters within the area of highest mean wind speed and most of the rest of the UK within the second highest area.

The potential for wave energy is greatest west of the Hebrides in the north west of Scotland and in the south west of England, whereas the tidal stream energy is mainly concentrated in the Pentland Firth between Orkney and the Scottish mainland. In this one area alone there is estimated to be between 50% and 60% of the UK's total tidal energy resource. Other areas of potentially high tidal stream energy are in pockets around central southern England, the Severn Estuary, Anglesey and the west coast of northern England.

Technical development

Onshore wind is the leading technology at present. The present design of wind turbine has developed from the "Danish concept" of a three-bladed, horizontal axis, tower mounted, up-wind device. The first wind farm in the UK was built at Delabole in Cornwall in 1991 but since then the rated capacity of the machines has increased some ten fold and the present designs are for machines of 2MW rated capacity. Machines in the planning stage are approaching 2.5MW rated capacity.

The cost per kW of these machines had been falling until last year, but prices started to rise again in the second half of 2006 and in early 2007 due to the rising cost of materials and to rising demand on the manufacturers. The price tax credit in the US is a key factor in the market dynamics. The total rated capacity of the onshore machines is now 2GW and wind farms with a further rated capacity of 8GW are in various stages of development. Offshore wind farms are being developed combining the technical developments of the onshore machines with the marine engineering skills developed in the exploration of the oil and gas fields. Offshore a total rated capacity of 9GW is being planned.

Machines to harness wave energy and energy from tidal streams are still at an earlier stage of development but there are some promising devices at the demonstration stage which may progress to commercial development.

Issues and barriers facing the industry

The industry needs a robust economic, regulatory and political framework to enable it to contribute to the Government's objective of generating 10% of the national electricity supply from renewable resources by 2010 and to secure the long term future of the industry.

The economic support provided by the Renewables Obligation in its revised form is vital to the continuation of wind energy and other renewable developments, but there are problems with capacity and access to the National Grid. Many wind farms are located in areas remote from population centres and hence from the existing grid which would have to be extended and increased in capacity to connect to the wind farms. Developers consider it is unreasonable for them to bear the cost of these extensions which would undermine the viability of many renewable energy projects.

Ironically Scotland has a national policy in support of wave and tidal energy development but no grid capacity to accommodate it, while in south-west England there is capacity to spare but no firm policy for development.

The greatest area of concern is with the planning system, the proportion of wind energy projects being consented has fallen and the time taken to secure a determination at all is now over three years in many cases. Changes in the planning system require primary legislation and may not be in place for years. Meanwhile planning delays are threatening the achievement of the 2010 target and also the crucially important investor confidence needed to maintain, let alone improve, our performance in the fiercely competitive global market place.

In conclusion Dr Naysmith thanked the speakers for their presentations and Peter Simpson, Annabel Lloyd and their colleagues in the DTI for putting the programme together.

In discussion the following points were made:

Revision of the OSPAR and London treaties, cost of retrofitting EOR, energy efficiency of sequestration, other potential IGCC sites, MSW as a biomass source, subsidy for wind energy, competition between nuclear and wind energy, public opinion about nuclear, improved battery performance, price volatility of bio-fuels.