The Royal Academy of Engineering

Developing a sustainable energy strategy

Report on a programme of energy seminars

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ISBN: 1-903-496-30-6

July 2006
Published by
The Royal Academy of Engineering
29 Great Peter Street, London, SW1P 3LW

Tel: 020 7227 0500 Fax: 020 7233 0054
www.raeng.org.uk
Registered Charity Number: 293074

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Foreword

The Royal Academy of Engineering launched this series of Energy Seminars in November 2004 in order to lead the debate on energy policy. For the first time since the start of the Industrial Revolution, the availability of cheap and reliability energy is no longer assured. The world is also facing the additional challenge of needing to address climate change brought about by burning fossil fuels and releasing carbon dioxide into the atmosphere.

The seven seminars covered all the major forms of energy conversion, energy efficiency, infrastructure and security of supply and provided an in depth understanding of the issues in each of these areas. The information gathered in this way served to inform the Academy's response to the Government's Energy Review that took place between November 2005 and April 2006.

The problems we face in delivering clean energy reliably require new engineering solutions within a policy and economic framework that will encourage timely investment enabled by appropriate government intervention. We make some observations in this regard in Chapter 3 of the report.

The Energy Review, published in July 2006 set out a policy framework that builds on the White Paper published in February 2003. It is important that a robust implementation programme is put in place if the goals set out in the White Paper and the Review are to be realised. Many of the issues that need to be addressed are covered in this series of seminars.

P C Ruffles, CBE RDI FREng FRS

1 Introduction

The world is facing restricted and uncertain access to energy supplies arising from a combination of the geographical concentration of resources, the different interests of consuming, producing and transit countries and the perceived risks to investment by international companies. Global demand is growing, notably as the developing countries industrialise, whilst the burning of fossil fuels is having a growing impact on climate change with potentially disastrous consequences. Thus, as the 21st century unfolds, primary energy is becoming more expensive as fuel prices increase due to global competition for fossil fuels and low carbon and carbon free technologies are introduced. Since the start of the industrial revolution the UK has been insulated from some of these concerns due to: an ample supply of indigenous coal; the subsequent pioneering development of nuclear power in the second half of the 20th century; and more recently the availability of North Sea oil and natural gas. However as we look to the future we will no longer enjoy these advantages and so a sustainable long-term energy strategy is required that will be robust against a range of future scenarios.

Accordingly the Royal Academy of Engineering ran a programme of seven seminars which have examined different aspects of the energy scene focussed on the period through to the year 2020. Consequently the hydrogen economy and nuclear fusion were not addressed. Sections 4 to 10 of this report contain the background to each seminar, a summary of the individual presentations and the key issues arising out of the presentations and subsequent discussion. In Sections 2 and 3, the Steering Group discuss the key issues raised by the seminars and draw some conclusions regarding the way forward.

The subjects covered by the seminars and the seminar chairmen were:

Topic	**Date**	**Chairman**
Energy Demand	November 2004	Professor David Fisk, CB FREng
Renewables	February 2005	Dr David Lindley, OBE FREng
Fossil Fuels	April 2005	Professor Alan Williams, CBE FREng
Infrastructure	June 2005	Dr Malcolm Kennedy, CBE FREng FRSE
Transport and Oil	July 2005	Mr John Baxter, FREng
Nuclear Fission	September 2005	Dr Brian Eyre, CBE FREng FRS
Security of Supply	November 2005	Professor Nigel Lucas, FREng

The Steering Group was chaired by Mr P C Ruffles, CBE RDI FREng FRS with the seminar Chairmen as its members together with Sir David Wallace, CBE DL FREng FRS FRSE representing the Royal Society so as to ensure complementarity between these seminars and the work of the Royal Society on energy.

2 Overview and Discussion

2.1 Summary of the White Paper

The UK Government published its Energy White Paper "Our energy future-creating a low carbon economy" in February 2003 which forms the backcloth to any debate about energy in the UK at the present time. As stated in the White Paper, the primary focus of this policy was to shift the UK decisively to a low carbon economy to address the concerns of climate change whilst at the same time addressing the implications of reduced domestic production of oil, gas, coal and nuclear power. Within the next 20 years, the UK will be dependent on imported energy for three quarters of its primary energy needs.

Three challenges were outlined in the White Paper:

The first challenge was **environmental**. Climate change is happening and the challenge was to put ourselves on a path to cut the UK's annual carbon dioxide emissions – the main contributor to global warming - by some 60% by about 2050, as recommended by the Royal Commission on Environmental Pollution, with real progress by 2020[1].

The primary means proposed for achieving this objective was greatly improved energy efficiency combined with the use of renewable energy and gas fired power stations to replace nuclear power and coal for electricity generation, together with a move to more efficient vehicles, low carbon fuels and hydrogen for transportation. Renewable energy was expected to satisfy about 10% of electricity demand by 2010 and 20% by 2020.

Nuclear fission and clean coal technologies with carbon capture and storage (CCS) remained as options for the near to medium term. In the longer term nuclear fusion was assumed to replace electricity generated from fossil fuels whilst hydrogen was seen as the primary alternative for land transport.

The second challenge was the **decline of much of the UK's indigenous energy supplies** - oil, gas, nuclear and coal giving rise to concerns over security of supply. The approach to addressing this problem was through using a diverse range of energy sources, suppliers and supply routes.

The third challenge was to **update much of the UK's energy infrastructure** over the next two decades as old infrastructure is phased out and replaced by new infrastructure suited to renewables, gas fired plant and distributed power. This will require massive investment in both gas and electricity supply networks.

The White Paper also states "we are determined to promote **competitive energy markets**, in the UK and beyond... in order to raise the rate of sustainable economic growth and support our industrial and business competitiveness". It goes on to say, "We will continue our commitment to competitive energy markets and use of market based instruments to deliver our wider energy policy goals".

We agree with the challenges identified in the White Paper and now consider the options for meeting the challenges based on the information gathered at findings from the seminars and particularly the engineering considerations impacting on these options.

2.2 Climate Change

Climate change is a global problem facing everyone in the 21st century due to greenhouse gas emissions from human activity, the most significant of which, in quantitative terms, is carbon dioxide produced by burning fossil fuels. Globally a total of 7 billion tons of carbon (GtC) per annum is currently being emitted into the atmosphere and this is increasing year on year. These emissions are raising the carbon dioxide concentration, which at present is approximately 380ppm and rising at about 2 ppm per year. In the absence of any action, the concentration level is expected to continue to rise as global economic activity increases. In the mid-1990s the EU proposed that the aim should be to limit the global

[1] *"Our energy future – creating a low carbon economy"; DTI Energy White Paper; February 2003. (Note: these targets use 1990 as a baseline)*

temperature rise to no more than 2°C, in order to stabilize the climate and avoid the most severe consequences. At the time this equated to about 550ppm but recent work suggests this may be closer to 450ppm.

The global nature of climate change means its effective management requires international solidarity. In this respect the unwillingness of the USA, which contributes 24.3% of the total carbon dioxide emissions, and Australia to commit to setting targets to reduce carbon emissions is a concern, although the USA does have city and state environmental improvement programmes. To date 163 countries have signed and ratified the Kyoto Protocol, which requires them to put in place policies to reduce greenhouse gas emissions. Of the countries that signed Kyoto about 35 developed countries, known as Annex 1 countries, have agreed binding targets, which will reduce their combined emissions by about 5% below 1990 levels in the commitment period 2008 to 2012. Under the Kyoto Protocol the UK, which produces 2.1% of global carbon emissions, has a commitment to reduce greenhouse gas emissions by 12.5%. In its 2000 Climate Change Programme the UK Government committed to a more challenging domestic target of reducing carbon dioxide emissions to 20% below 1990 levels by 2010. The 2003 Energy White Paper reiterated this and added a longer term objective of a 60% cut in emissions by 2050.

UK Energy Demand

In the 2003 White Paper assumptions, primary energy demand was forecast to remain essentially constant after taking into account the historic trends in efficiency savings of typically 1% per annum and the additional measures introduced by the White Paper. In setting its targets for CO_2 savings the White Paper assumed that policy measures in place would double this rate to 2% per annum. For example, in transport the savings were to be realised by reducing the carbon content in fuels, increasing vehicle fuel efficiency and the greater use of public transport. It is difficult to establish the extent to which these policy measures are working. It is however clear that there are real barriers to reducing demand, particularly on the domestic consumer side, since energy costs are a relatively small part of peoples' budget (apart from the fuel poor) and upgrading of housing on a sufficiently large scale is a slow process likely to occur over several decades.

Progress with Renewables

The Government renewables policy is focussed on achieving 10.4% electricity sales from new renewable sources by 2010-11 and 15.4% by 2015, mostly to be supplied by wind with a small contribution from biomass. The instrument used to realise the policy is the Renewables Obligation which provides the financial mechanism through to 2027 and obliges the 12 electricity suppliers to source 3% of their electricity sales from renewables in 2002-03 rising annually in line with the above targets. At the end of 2004, total renewables capacity (including large hydro) in the UK was 3.86GW which contributed 3.7% of electricity sales.

The Renewables Innovation Review identified onshore and offshore wind as the only viable technology to meet the 2010 target and indicated that wind power would make the dominant contribution through to 2020. These targets require about 10GW wind capacity to be introduced by 2010.

As of November 2005, 1.3GW of wind capacity had been installed and a further 0.7GW was under construction. Therefore a further 8GW needed to be installed in four to five years to meet the 2010 target, ie approx twice the rate achieved so far. The major barriers to wind energy are associated with obtaining planning approvals and delays in reinforcement of the grid system to enable major development of the Scottish wind energy resource and offshore developments around the UK. The costs associated with offshore wind also make this a less attractive investment than onshore wind at this time.

Carbon Dioxide Emissions - Current Status

Progress in meeting the carbon dioxide emissions targets since the White Paper was published in 2003 has been disappointing due to faster economic growth and lower energy efficiency savings than targeted. This has led to higher energy consumption which together with slower than anticipated introduction of new renewable energy has opened up a gap in demand that has been filled by coal with its intrinsically higher level of carbon emissions. Currently our carbon emissions are 5MtC above the national targets albeit we are below the Kyoto commitments. Thus, with good economic growth, we conclude that demand, including efficiency related factors will remain higher than current central forecasts and that the projected rate of introduction of low and carbon free energy will not be met. Therefore in the near term, there is a real possibility that the carbon emissions targets will be exceeded. However, with new initiatives there is still time to meet the longer-term goals.

Options for the Future

Recognising that there will always be some uncertainty in forecasts, it is important that any future strategy contains an element of contingency to ensure that it is robust against several different scenarios. It appears that none of the number of options considered to date to meet the carbon targets is sufficient to address this extremely difficult problem. Undoubtedly more can and needs to be done to reduce energy demand through efficiency savings in space heating, electrical supply and transport and to accelerate the rate of introduction of renewable technologies.

Through engineering advances, individual product efficiencies will continue to improve, but in a buoyant economy this improvement may not be as rapid as increased ownership and use. Agreement on challenging product performance standards, coupled with a clear informative message for purchasers could accelerate the market. There also remains a legacy of earlier technologies (such as boilers and electric resistive heating) that could be upgraded with more vigour. There are longer term technologies, such as the substitution of energy delivery grids by hydrogen technology, but these would not make an impact within the timeframe addressed by this report.

However these approaches alone will be insufficient. Therefore other options will need to be considered, notably those associated with electrical power generation, which will deliver significant long term benefits and are in many ways the easiest to implement. These include nuclear power, clean coal including CCS and the wider use of combined heat and power (CHP) including embedded generation in buildings.

Transport

Transport represents 33.1% of UK energy consumption of which 73.8% is on road and rail[2]. Air transport represents about 22.9% but is growing more rapidly than the remainder such that by 2030 it is forecast to grow to three times current levels. In the near term lightweight hybrid vehicles using batteries for energy storage are gaining momentum with a number of manufacturers developing this option. Biofuels offer worthwhile benefits particularly since the infrastructure conversion costs associated are minimal. Fuel cells are seen as a longer term solution within a hydrogen economy but the technical challenges are still significant for both the vehicle and the means of producing and distributing the hydrogen. The energy used in hydrogen production will be substantial and will need to be provided from carbon free sources, notably nuclear power. Air transport is particularly challenging and whilst the industry is making substantial investments to improve aircraft and engine efficiency it is difficult to see how fossil fuels can be replaced other than by biofuels.

Nuclear Power

The evidence presented at our Nuclear seminar demonstrated that the often quoted concerns over safety, economics and waste management are over stated. Experience related at the seminar indicated that, aside from the Soviet Union, the safety performance of nuclear power has lived up to the very high standards demanded of it by the regulatory authorities during 50 years of international experience. Furthermore, western nuclear reactors are now becoming available that are simplified in design and provide enhanced protection against safety related failures.

Since the last UK reactors were built, great progress has been made in building nuclear plants to time and cost. Specifically, the construction time for a modern large (1200-1500MW) Light Water Reactor (LWR) nuclear plant is around 48 months with a specific capital cost of $1500-1600/MW. In addition, the costs of decommissioning nuclear power stations together with associated waste management costs have received considerable attention internationally and there is a wide measure of agreement on the levels. Whilst significant when incurred, much of the expenditure is deferred until beyond the end of power station life, which for a modern Pressurised Water Reactor (PWR) is expected to be 60 years and thus the impact on costs of electricity generation is small (<10%). The accepted process internationally for managing the end of life costs is to have a secure decommissioning and waste management account established at the start of power station life. For example in the USA the accumulated fund relating to their civil nuclear stations has currently reached $27 billion.

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[2] *DTI DUKES 2005*

Capacity factors for existing LWR plant have increased considerably in recent years with 90% being typical. Thus in many industrialised countries including the USA and France, the cost of generating electricity by existing nuclear power stations is competitive with other base load generating technologies. The first Franco-German designed European PWR (EPR) is under construction in Finland and France is committed to the construction of its first EPR at EDF's Flamanville site, marking the start of a long term programme to replace its present fleet of PWRs as they reach end of life. Moreover a group of US utilities has expressed intent to order new nuclear stations and are working with the Nuclear Regulatory Commission to achieve construction licences.

Nuclear waste management remains an important challenge. This is particularly true in the UK where there exists a substantial legacy stemming from our 60 year history of developing nuclear technology across a broad front, including for defence applications, compounded by a lack of a strategy for long term disposal. In the context of potential new build in the UK it should be noted that the nuclear waste created by a modern LWR is a small fraction (~10%) of that from our existing gas cooled reactors. Several other countries with significant nuclear power have made progress in establishing a long term strategy for managing nuclear waste in a safe and sustainable manner. This is exemplified particularly clearly (although not exclusively) by Finland with their plan for deep underground storage which was presented at the seminar. As a matter of priority, now that CoRWM has reported, it is essential that agreement is reached in establishing a clear strategy for nuclear waste management in the UK that takes full account of international experience.

An important issue not considered at the seminar is the fuel cycle and reprocessing. The UK played a pioneering role in developing reprocessing technology and operated two plants at Sellafield. With the decline in incentive to reprocess and recycle the separated uranium and plutonium on resource grounds, the questions surrounding the fuel cycle and reprocessing do not have an immediate bearing on whether to embark on a programme of building new nuclear power plants. However, a sustainable long term strategy for nuclear power could require fuel recycling, both in minimising accumulated levels of actinides and in optimising the energy obtained from the natural uranium resource. Thus it would be prudent to keep open the option of reprocessing spent fuel from nuclear reactors in the longer-term and ensure that disposal in the meantime permits retrieval.

The seminar highlighted three impediments to renewed private sector investment in nuclear plants:

- Inconsistencies in the market framework for incentivising long term investment in carbon free technologies.
- Lack of confidence in the long term consistency in the regulation framework for safety and the environment.
- Uncertainties and timescales for planning approval.

These are the areas where Government action is needed in order to provide the right environment for private investment.

Reducing Carbon Emissions from Clean Coal and Natural Gas

Worldwide coal reserves are widely distributed throughout the world and are expected to satisfy demand for at least the next 150 years. Coal can be burnt directly or used to produce liquid and gaseous fuels including hydrogen and is therefore an important source of energy for the future. Given the security of supply concerns associated with natural gas (the Russia-Ukraine experience in early 2006 was a wake up call) the UK may need to increase coalfired generation. However current coal fired plant produce typically twice the CO_2 emissions of a combined cycle gas turbine plant and require pollution control measures to reduce emissions of sulphur and nitrogen oxides (NO_x and SO_x). Coal gasification and much higher efficiencies will reduce carbon emissions but not eliminate them.

Recognising that both coal and gas will continue to be important fuels for many years to come, CCS will be an important technology to mitigate climate change. Because of the high level of carbon emissions associated with burning coal a number of initiatives are underway either to remove carbon prior to combustion by gasification or to remove it from the combustion products. The appropriateness of the technology will vary according to the local conditions as the CO_2 will need to be transported from the power station to the storage site. In the UK, storage could be under the North Sea with the CO_2 transported via pipe lines similar to those used to transport the gas in the first place. It could also be transported in tankers and ships. Current cost estimates indicate that CCS in conjunction with high efficiency coal and gas power plants could be comparable economically with renewable energy as a means of carbon free generation.

2.3 Security of UK Energy Supply

The UK is now a net importer of gas and will become a net importer of oil by 2010 with over 75% of UK energy supplies being imported by 2025. Security of supply of gas is in large part a European issue because a significant proportion of our gas will come from Europe or transit Europe from countries beyond. Its availability can be affected by both the originating and transit countries and a market which is not fully transparent and liberalised. We have already seen a dispute between Russia and Ukraine which led to temporary gas shortages in other parts of Europe and shortages of gas supply in Italy from Russia during a period of cold weather. Thus we have to be concerned about the external dimension to security of supply as well as internal concerns related to the reliability of distribution systems for gas and oil and the transmission and distribution for electricity.

Considering first the external dimensions of energy supply, the White Paper places great emphasis on renewables and natural gas as the primary sources of energy for power generation. Whilst security of supply can to some extent be assured by the use of multiple sources of gas and storage, it seems unwise to pursue a strategy where over 75% of electrical energy and 40% of total energy supply is dependant on natural gas much of which will be delivered by pipelines, particularly when other options exist. Equally oil, which will remain the primary source of energy for transport for the foreseeable future also comes from some less politically stable parts of the world. Thus greater diversity in primary energy sources is required to minimise the impact of any disruptions. Additionally, there is an urgent need to align the interests of producing and consuming countries into a financial framework that provides acceptable rewards for producers and affordable and reliable supplies for consumers.

The concerns over security of supply do not only relate to considerations external to the UK. Supply interruptions can be minimised by adequate storage facilities onshore and by adequate margins in the electricity supply network to deal with peak demand and unforeseen events. Within the UK and Europe there is a compelling need to develop a clear and coherent approach to the measurement and provision of security of supply and to reconcile it more effectively with the practice of regulation. The approach of targeting incentives needs to be focussed on reward for the attribute that is sought, eg, security or being carbon-free.

There is concern that the market may not provide sufficient timely investment to ensure security of supply as this depends upon signals of capacity shortage transmitted through price. The level of price required to signal this scarcity can be very high. For example, the annual cost of a gas turbine may be £50/kW/yr; if the target is to reduce power outages to no more than one hour a year then the marginal plant needs to be rewarded in that hour with prices of £50/kWh. Very high prices are observed in spot markets and balancing markets and this does suggest that the pricing mechanism works to indicate scarcity. What is not so clear is that it will work in time and only experience is likely to show whether it does or not. A good practical example is gas supply to the UK. At present the supply is close to capacity, more investment will be commissioned in 2007, but shortages next winter cannot be excluded. Currently, we observe that vertical integration is proceeding rapidly in energy markets and has replaced a truly competitive system by an oligopoly. Vertically integrated suppliers and producers may plan their systems in a manner that is more akin to practices in a centralised system. They may invest to meet forecast demand and depend less on price signals than does a truly competitive market. The behaviour of this partially reintegrated and partially competitive market, and in particular the influence on security of supply, is not well understood and requires monitoring and demand management.

2.4 Infrastructure

The infrastructure, to supply natural gas from the UK continental shelf, to distribute it and to transmit and distribute electricity in the UK, has remained largely unchanged for many years. Only modest extensions have been required to accommodate the switch from coal to combined cycle gas turbine electrical generating plant. However the reduction of gas from the North Sea and an increase in the quantity of gas purchased from sources outside the UK will require massive investment in gas pipelines and storage facilities particularly if security of supply is to be assured. At the same time the move to renewable generation, which by its nature will be widely distributed and mainly located in coastal and northern regions, will also require considerable investment in electrical supply system infrastructures both in terms of local distribution systems and the national grid. There is increasing evidence to suggest that the development of substantial levels of renewable generation will be inhibited if current planning and regulatory processes related to the construction of new high voltage transmission circuits are not speeded up. The development of the new infrastructure required should anticipate demand.

Local electricity distribution systems have for many years been subject to systematic asset replacement on account of age and also advances in technology. Corresponding asset replacement within the high voltage national grid system, which in its present form dates largely from the late 1960s, is now also required.

The infrastructure and other requirements associated with carbon capture and storage need to be considered assuming fossil fuels remain part of the diversified energy mix. This should include a thorough understanding of the costs of extracting the carbon from the fuel or exhaust gas, transporting it to the storage location and the geological implications of storage.

2.5 Competitive Energy Markets

We are already seeing energy prices increase in the oil and gas markets due to supply shortages and whilst the current situation might represent a peak there is little doubt that the overall trend in world prices will be upwards. At the same time a value has been determined for carbon emissions through the EU carbon trading scheme. These two effects have served to narrow the cost differences between the use of the different energy sources . Therefore choices should be based, in the first instance, on considerations of security of supply and carbon emissions, but with cost always being an important factor.

The challenge that Government faced in its review of energy policy was one of setting a clear direction based on the need to address climate change and security of supply supported by market instruments that will incentivise the private sector to invest in line with the policy. This is particularly the case in electrical generation and the infrastructure that supports it where the investments are large and long term in nature and where the private sector will understandably be cautious. Thus the upgrading of electrical generating capacity and infrastructure may appear later than when it is needed giving rise to interruptions in electrical supply in the short term

Market instruments are necessary in order to deliver policy objectives in a liberalised market. It is however important that these should be simple and coherent and aimed at achieving a desired result. For example, the Renewable Obligation for electricity generation is a direct subsidy to renewable energy, which is not in itself of interest. Renewable energy brings with it security and low emissions of carbon dioxide which are the real desired attributes. Other technologies with these attributes are denied support or are supported unequally; nuclear power being the prime example. A better intervention is to provide direct credits for the desired attributes. The mechanisms for this are largely there to address climate change in the form of the European Trading System (ETS) for carbon credits.

Similar intervention to promote security of supply needs to be developed. It is a much harder problem to analyse than climate change because, whereas carbon emissions from any technology are easily measured, its security is not. It is unlikely that anything as precise as the ETS could be developed to reflect security, but some analytical effort is necessary to ensure that interventions to promote security are broadly coherent. This would involve assessment of the likelihood of interruptions, the depth and duration, the costs of shortage and the costs and performance of mitigating measures. At the moment there is no rational basis on which to design any such policy but it needs to be provided.

3 Conclusions

Throughout the seminars we have addressed the three concerns of **climate change, security of supply and affordability**. These have to be interpreted within the context of a fully liberalised market. Of these concerns, affordability is the least important because we can live with higher energy prices provided they are on a level playing field with the other industrialised nations. Fuel poverty is a social problem and should be addressed accordingly.

Security of supply and climate change are to some extent reinforcing objectives as the move to renewables, nuclear power and clean coal with CCS for electrical power generation would meet both objectives and take pressure off oil and gas reserves making the management of fossil fuel resources easier for longer. Improvements in energy efficiency in space heating and transport are also reinforcing and can potentially lead to real cost savings, particularly if the total life cycle is taken into account.

The information provided by the seminars and elsewhere points to the following conclusions:

Availability of Technology

New and improved technologies are essential to address the concerns of climate change and security of supply. The critical clusters of technology being: nuclear; carbon capture and storage; energy efficiency including low energy buildings and vehicles; renewables; and energy storage. We need all of these, it is not a matter of choice.

Nuclear power is a proven low carbon source of energy that is capable of delivering on a large scale. Ample experience exists to demonstrate that a modern nuclear power station can be built to schedule at predictable costs subject to timely planning approval and licensing. We recognise that there are hurdles to be overcome, notably those relating to public perception and setting the right environment for private investment but these issues have to be grasped if we are to have a sustainable future.

Carbon capture and storage has the potential to make a significant reduction in carbon emissions from fossil fuels and in so doing can ensure that coal, with its wide availability, remains a significant proportion of the energy mix. It is necessary that an objective critical assessment of the technological challenges and associated costs is carried out. The UK should continue to invest in clean coal technology including CCS.

International Collaboration

International collaboration is essential to tackle the management of the climate change with leadership from Europe in the absence of the full participation of the USA. The solutions will depend on technology with the targets for CO_2 reduction forming the basis for driving the technology.

Presently the energy market in Europe is semi-liberalised, thus allowing a large degree of manipulation. It is necessary that the relationship between the liberalised market and the higher objectives of public policy are resolved.

A Coherent and Robust Policy

It is essential that a wide range of scenarios is examined so that the resultant policy is robust against forecasting inaccuracies and unforeseen events. These scenarios should be supported by rigorous evaluation of technical requirements, risk assessments and the investments needed for effective implementation, noting that energy requires large front end investment that will not materialise in liberalised markets unless the policy reflects a wide and durable consensus.

Market Instruments

The market incentives should be internally coherent and not just targeted at preferred technologies such as renewables. There needs to be a much simplified set of measures that address the desired results and not the preferred remedies. These should be developed as the main basis for support of carbon free technologies and direct support to particular preferred technologies should be phased out. Similar mechanisms are required to ensure security of supply.

Planning

While it is clear that energy provision cannot operate outside the planning system, the planning process has a differential effect on the type of generation investment that is likely. There is strong evidence that the process has slowed the expected rate of the introduction of renewables and grid reinforcement and would have a comparable effect on new nuclear construction.

Investment

There is every reason to believe that private investment will be forthcoming given the right economic and commercial conditions. The problem is more one of whether the energy supplies will follow in a timely manner. The possibilities and costs of combining market forces and policy intervention to provide security in energy supplies need to be fully assessed also taking into account the technical risks associated with the various alternatives.

This is particularly the case for investment in the gas and electrical transmission and distribution systems where it is essential that government and the regulators sets a clear direction for the primary methods of electrical generation and the levels of security of supply that it expects to achieve.

In summary we welcome the fact that the Government has carried out a review of Energy Policy at this time. We believe that the forthcoming energy White Paper needs to give Security of Supply and Climate change equal priority and that the policy should be robust against several possible scenarios. The market instruments including regulation need to focus on desired outcomes whilst the planning process needs to be streamlined so as to reduce the timescales for effective implementation.

4 Energy Demand and Carbon Emissions

Chairman: *Prof David Fisk, CB FREng*
Speakers: *Dr Terry Barker, Cambridge University*
Dr David Vincent, Carbon Trust
Dr Brenda Boardman, Oxford University
Adrian Gault, Department of Trade and Industry

4.1 The Context of the Long Term

The scope of this series of seminars invited us to project future energy demand over timescales that would never be contemplated for most other consumer sectors. The turn-over time of the capital stock that consumes energy, from boilers to iPods, is relatively fast, typically 5-10 years, compared with energy supply investment. Even in buildings with long life structures, the heating or cooling sources have lifetimes of only 10-15 years duration. The final consumption of energy is also a sector where product innovation and fashions change very much faster than in the supply side. Dramatic changes in energy consumption for specific uses can occur very rapidly, as in the conversion to flat screens in desktop computing, prompted by factors often unrelated to energy costs. In the past, the core industrial activities of largely isolated economies provided a firm predictable base load of demand, but with globalisation and specialisation in many industrial markets even this is no longer true. Take for example the case of one energy intensive industry, steel production. Two thirds of national consumption is of steel made abroad, and around half of national steel production goes for export. Making projections of future energy demand for such industries requires difficult judgements about future competitive advantage. In the UK this is not made any easier by the prospect of increasing dependence on imported fuels at world prices. A similar type of projection uncertainty would arise if the enlarged EU were to eventually result in the net inter-State labour migration on the scale seen in the US.

For all these reasons, and more, demand side commentators feel much more comfortable in considering a range of 'scenarios' of future energy demand during the next few decades rather than making point forecasts. The real imperative for making long range forecasts is to assess the business case for new capital investment in energy supply, and more recently to assess the plausibility of taking legally binding environmental targets. There is heavy front-end loading of costs when accessing new sources of primary energy, even when it is imported, and similar investments are needed to produce secondary energy sources such as electricity. Payback periods and commitments on acidic emissions and greenhouse gases typically invite us to look over a 10-20 year horizon. As Terry Barker pointed out in the course of his review of the energy demand sector, 'energy demand' is a collection of intermediate products consequential on some other more fundamental need like thermal comfort or access. No one consumes energy for the sake of it. The less of an intermediate product you need the richer you are. The stark fact is that energy investment creates a commitment to deliver over a period much longer than the demand side of the market has a real commitment to consume. This nervous tension underlies much of the controversy around energy projections over the last 20 years and the degree to which they are thought to under or over estimate future demand.

4.2 The European Demand for Energy

One change of mindset for the UK consumer that has yet to be fully accommodated is that the majority of the primary energy consumed by 2030 will have been bought in world markets and imported by sea, grid or pipeline. This is not to say that security of energy supply is a new consumer issue because fuels are imported. The 1972 Three-Day Week and the 2000 'tanker drivers' dispute' were both serious disruptions of supply but of domestic origin. A nuclear power station or a North Sea gas terminal both need willing staff to operate them. But when planning to buy energy in a world market, it is necessary to have a clear picture of what other non-UK energy consumers are doing. For this reason the demand seminar began with some thoughtful reflections by Dr Terry Barker of Cambridge Econometrics on current projections of EU energy demand.

Dr Barker took as his basis the IEA 2004 World Energy Outlook that has (enlarged) EU primary energy consumption projected to increase by around 20% over the next 30 years, with a similar increase in installed generating capacity. These IEA projections were of necessity the 'business as usual' case, with considerable embedded uncertainty as to price elasticities, but also uncertainties in the broader context. The EU single market directive of July 2004 would gradually result in unbundling of network activities. In January 2005 the European Union's trading scheme in carbon emissions began. All this has led to considerable uncertainty as to how the future market would be shaped.

4.3 UK Emissions Projections

Adrian Gault next explored the DTI's most recent carbon emissions projections for the UK. These projections cover the next 20 years and have been undertaken as part of the review of the Government's Climate Change Programme. The UK was currently emitting just over 150 million tonnes of carbon (MtC) per annum down from almost 170 million tonnes in the early 1990s. The projections pointed to emissions of over 140 million tonnes by 2010. All sectors except transport were projected to fall over this period. As Professor Brenda Boardman pointed out in her session, this drop reflected significant changes in the UK's energy structure since underlying these projections was a gradual increase in UK population to over 60 million. Currently carbon emissions are running 5 million tonnes per annum higher than earlier projections made in 2000 in part reflecting a higher coal burn in power stations and a buoyant economy. The new government projections indicated that this overshoot should be recovered by 2008 by the UK Climate Change Programme.

Of course widely accepted projections tend to be self-fulfilling or self-defeating. Climate change is a context in which many governments (but unfortunately not all) feel pressed to commit their nations to the greatest that can be achieved within plausible scenarios. In some cases these actions have gone with the flow of the market. For the UK the introduction of gas into power generation in the 1990s had a strong economic logic that was hardly noticed by final consumers. Few rail commuters realise they have arrived at work in the morning on gas powered transport. However other potential demand side changes have found markets more resistant to change. For example, a significant part of the demand side reductions in the Climate Change Programme is substitution of electric space heating by gas. The fate of electric heating (and cooling) in 2030 has a non-negligible effect on power generation load factor and even the peak load demand for gas (substituting electric storage heating by an efficient gas condensing boiler actually frees up peak gas), but purchasers of new flats still find themselves faced with electric heating as a fait a complis. Was this past experience of sluggish adoption of energy efficient technology likely to continue? David Vincent summarised some of the Carbon Trust's recent findings on the new and emerging drivers of the shape of energy demand.

4.4 Future Demand - Soft vs. Hard

The Carbon Trust saw a number of factors for change in the demand side. There was likely to be increasing international concern about emissions of greenhouse gases leading to government interventions in the market in one form or another. There could be erratic supply of oil given the geopolitical context of some of the main suppliers, which could feed through to gas prices. High prices for primary energy may reflect competition for a relatively inelastic supply from rapidly developing countries, and indeed significant US energy imports. While all these factors might have argued for shading down future estimates of energy demand growth in Europe it needed to be born in mind that energy was usually only a small cost compared with other running costs for most enterprises and homes. In the UK the average family spends more on alcohol than fuel and power for the home. So most of the brunt of any increases in fuel costs is borne by the 'fuel poor' (eg, those on low incomes) or energy intensive industries where energy costs are large compared with other running costs. For everyone else energy consumption is an indirect consequence of other consumer choices.

On Brenda Boardman's estimates the price elasticity of the poorest domestic energy consumer was five times that of the richest. This may explain why Carbon Trust studies find consumption is often 25-50% higher than it need be to achieve the same level of service. Based on Carbon Trust data, approximately 50% of the currently cost-effective savings can be achieved in the top two or three energy intensive sectors . By 2010 Carbon Trust figures suggest that primary energy and CO_2 emissions associated with retail buildings will overtake that associated with industrial buildings. Retail has a much faster capital stock turnover. Brenda Boardman looked at the domestic sector in more detail and what would be necessary to transform the efficiency of the market. The analysis by her group showed that if growing international global emissions meant that governments needed to contemplate 'brave decisions' on the supply side there were effective large scale supply side measures that could be undertaken. These included a much faster replacement programme of our existing 19th century housing stock, and proportionately much tougher action on higher energy consumers.

4.5 Exploring the Uncertainties

This chapter began by pointing to the uncertainties in future energy demand when viewed over long time periods. Nothing illustrates this more than a revisit to the year 2000 forecasts made in the 1978 Department of Energy Green Paper on Energy Policy (Cmnd. 7101).

	1978 forecast for 2000	Actual 2000
Primary Energy (TWh)	4000	2800
Electricity capacity England & Wales (GW)	110	60
Transport (TWh)	490	430

The discrepancy cannot be explained by the assumed rate of GNP growth which is not far from the actual 2000 figure nor by the projections of population or number of households which were, if anything, underestimated. The 'error' is less in the forecasting methodology, which is not greatly different from that used today, but in the external events which disrupted the basic assumptions. Not least amongst these disruptions was the greatly increased availability of natural gas. Indeed the 1978 projections reflected the widely accepted belief at the time that some substitute natural gas would have to enter the gas network around 1995. With the arrival of gas there was a consequent decline in coal. But apart from these supply side changes there were also significant demand side surprises. Possibly the most significant was the withdrawal of electricity from non-premium low-grade markets like space heating. At the same time the service economy grew significantly in proportion to the energy intensive manufacturing sector. No one anticipated information technology or the new power demands that it would make on the economy. The actual primary energy outturn in 2000 was, in fact, close to an alternative projection made in 1976 by the Royal Commission on Environmental Pollution in its report, Nuclear Energy and the Environment. The Commission focussed on the 'rational use of energy', but the Green Paper concluded its projections were 'unwise' and should not be relied upon. It was the same Commission in a later guise that suggested the UK carbon dioxide emissions might be 60% of their current value by 2030.

4.6 Demand-side Disruptions?

Are there similar disruptive events on the demand side that are not within conventional forecasts which might affect the risk management of supply side investment? Some have been hinted at already, and others are touched on in later chapters. None are 'certain' and could be legitimately omitted from a 'business as usual' scenario, but disruptions relating to dependability, technology, migration, and environment are possible determinants of a different demand side structure.

A failure in security of supply in any product, or 'dependability' as it might be termed from the demand side perspective, always creates new market opportunities. There is little point trying to rank risks, but as identified in later chapters, transport is the least diversified energy sector. Over the period since the 1978 forecasts it has become the strategic stimulus of a modern economy. With the benefit of cheap fuel and improved infrastructure the largely unchanged number of journeys/capita now cover longer distances, faster, with little possibility of modal substitution. Without oil, distribution systems of goods and people fail totally. Later chapters reference potential supply responses (eg, biofuels). Much smaller events in the US have seen a distinct change in vehicle purchasing patterns by American motorists. If the demand side response to an 'event' in international oil supply was a rapid diversification of transport modes to other fuels (eg, gas, batteries or fuel cells) there are significant implications for the projections. This would not be as with changes in modes of space heating, shifting the same primary fuel from secondary application to another. Rather it would involve finding some fraction of several hundred TWh from other primary energy sources. If that could be done then the new sources would themselves be very different animals. For example as a rough estimate the transport sector holds about 5-10 TWh of primary energy 'in store' on board vehicles. That scale of 'buffer', about the order of pumped storage supply to the electricity grid, accessed by say the power sector would rewrite the operation of the system.

A similar argument could reflect demand side response to grid electricity failure, with the integration of much more local generation into the network. During the August 2003 New York black out, Central Park remained brightly lit thanks to its experimental fuel cell power source. At the most, simple communal heating with limited CHP could use the marketing opportunity to displace resistive electric space heating in flats and other communal developments. A further technology drift yet to be factored into load factor forecasts is the new ability to access non-essential electrical loads at the local level. The traditional assumption has been that electric demand outside of thermal storage is 'required with the switch'. In fact the electricity market since 1978 has embraced a substantial inertial load (eg, refrigeration) that has none of the time criticality of the light switch but at present cannot offer its inertia for sale to other users.

UK energy consumers are becoming more mobile in two different senses. Globalisation of markets, brought about by the cheapness of long distance transport, has meant that high energy consumers are in competition at the global scale. Over the last 20 years it was easy to be confident that proximity to North Sea gas ensured a substantial petrochemical industry (a significant part of the current manufacturing economy). But the future is not so clear, notably how European industry will rationalise or how much the future economic growth will come from the large UK service sector. A further complication is the new mobility of labour throughout an enlarged European Union. In the US these economic migrations are substantial. The State of Texas is currently projecting a doubling of its population by 2030 while Ohio is hardly projecting any growth at all. However net migration depends on relative economic performance. As an illustration of the uncertainty, achieving 'demographic balance' in Europe could influence long term energy demand projections in the UK by around ± 20%.

Action to abate greenhouse gas emissions is often represented as wise government intervention conveniently modelled by a shadow 'carbon tax'. The projections invoke changes in the supply side mix, and typically less response from the demand side with the exception of the 'fuel poor'. But much of current energy consumption is a consequence of other purchasing decisions by consumers relating to their desires and aspirations. So it is difficult to believe that when climate change is widely accepted as a reality that implicit fossil fuel emissions will not become entangled in marketing strategies. Based on UNDP figures, the 'life essential' consumption of electricity is around 4MWh/yr/capita. Above that, and North America uses over 10MWh/yr/capita, there is not much variation in the value of the 'Human Development Index'. If indeed the kind of global emissions reductions envisaged by the Royal Commission were to materialise by consent in 2030, it is difficult to contend that these were just the consequence of heroic government intervention. At least in participatory democracies, underlying choices would presumably change (or equivalently new products aggressively marketed).

4.7 Conclusion

There is a noticeable asymmetry in debates about energy supply and demand. Energy supply is usually associated with high technology industries, but demand often just with better loft insulation. In fact consumer demand products have today probably higher technology and are more innovative. Creating energy supply is often associated with large single decisions, and changing energy demand with persuading 100,000 consumers to each turn off one light bulb. In fact single large decisions take a very long time in a participative democracy, whereas consumer products (the 5 million personal music players sold in the first three months of 2005 being a case in point), can take place very rapidly. Base load supply is seen as the premium technology in a supply context but the least valuable to the average consumer - who wants 240 volts at 3am? Some of this asymmetry is a relic of 'predict and supply' philosophy of the nationalised energy industries which presupposed consumer choice and generally over-supplied capital investment. Liberalised energy markets are very different. If the climate change coin drops as a fashion connotation, or if central energy supply becomes associated with erratic supply we could expect a substantial change in the character of the market over the next 30 years. It seems that '1990s business as usual projection' is the least probable bet. But the conclusion from this seminar points to a wide spread of bets for 2030 between governments still struggling unsuccessfully against a background of continued accrual of energy consuming products, with greenhouse gas emissions growing at 1-2% per year, to a 'brave new world' where it was largely the market responding to a new context that brought around a comparable rate of reduction in CO_2 emissions with no loss in service or product. Although energy projections are notoriously unreliable (compare the actual with the 1978 Department of Energy projections for 2000) it is hard to think of a time when the potential projected spread was wider for the investor in energy supply. Thus in determining energy policy it is important that the Government considers a wide range of scenarios and considers options that have built in contingencies to deal with the worst cases.

5 Renewable Energy

Chairman: *Dr David Lindley, OBE FREng FRSA*
Speakers: *Dr Andrew Garrad, Garrad Hassan & Partners*
Paul Jordan, The Carbon Trust
Megan Bingham Walker, Department of Trade & Industry
Kathryn Newell, Department of Trade & Industry
Richard Ford, British Wind Energy Association

5.1 Background

The Energy White Paper[1] set a target of achieving 10% of UK electricity supply from renewable energy sources by 2010. The Renewables Obligation provides the financial mechanism to support this aspiration through to 2027 and obliges the twelve UK electricity suppliers to purchase 3% of 2002-03 electricity supplies from Renewable sources increasing to 10.4% by 2010-11 and 15.4% by 2015-16.

The Renewables Innovation Review[2] published by the DTI and The Carbon Trust in February 2004 suggested that installed capacity of about 10GW of onshore and offshore wind farm capacity will need to be installed to meet the 2010 target. The same review suggests that about 20GW of onshore and offshore wind farm capacity would be required to meet 2020 aspirations of achieving 20% of electricity from renewable sources.

As of the end of 2004, total renewables capacity in the UK totals 3,864.9MW and generated 14,171GWh of electricity as shown in Table 5.1. This was equal to 3.7% of electricity generated in the UK.

Table 5.1: Capacity of, and Electricity Generated from Renewable Sources

(source DTI web site: http://www.dti.gov.uk/energy/inform/dukes/dukes2005/07main.pdf)

Renewables Source	Installed capacity (MWe)	Generation (GWh)
Wind:		
Onshore	809.4	1,736
Offshore	123.8	199
Shoreline Wave	0.5	-
Solar Photovoltaics	8.2	4
Hydro:		
Small scale	184.0	282
Large scale (1)	1,406.3	4,648
Biofuels and wastes:		
Landfill gas	722.2	4,004
Sewage sludge digestion	119.0	379
Municipal solid waste combustion	307.4	971
Other	184.3	927
Total biofuels and wastes	1,332.8	
Total Capacity	**3,864.9**	
Co-firing	146.2	1,022
Total biofuels including co-firing		7,302
Total Generation		**14,171**
Non-biodegradeable wastes		583

Notes:
1. Excluding pumped storage. Output resulting from refurbishment is RO eligible.

[1] *Energy White Paper: Our Energy Future - Creating a Low Carbon Economy, DTI, 2003. Available at http://www.dti.gov.uk/energy/policy-strategy/energy-white-paper/page21223.html.*

[2] *Renewables Innovation Review, DTI and Carbon Trust, 2004. Available at http://www.dti.gov.uk/energy/energy-sources/renewables/policy/government-renewable-energy-policy/renewables-innovation-review/page15308.html*

The Renewables Innovation Review identifies onshore and offshore wind energy as the only scaleable and economically viable technology able to fulfil the required renewables growth to 2010. Furthermore it suggests that wind power, both on and offshore is likely to continue to be the dominant renewable technology out to 2020. The Review examines the status of other technologies that will be required to meet the 2050 carbon emissions reduction targets and looks at the potential contributions that might be expected from wave and tidal energy, biomass and photovoltaics (PV) in this time frame.

This seminar attempts to review the current status and prospects and to identify any technical, institutional and other barriers that may impede progress in meeting the targets set by the White Paper.

5.2 Wind Energy

The seminar opened with Andrew Garrad providing an overview of the technical, commercial and market development of this technology. In the two decades of development since the early 1980s wind turbine power ratings had increased, he said, from 60kW to 5MW and rotor diameters had increased from 12 to 120 metres, a rotor swept area equal to two football pitches.

During this period many rotor configurations had been built and tested and these have included one, two and three bladed horizontal axis turbines, vertical axis designs, stall, and full and partial span pitch controlled horizontal axis rotors. In the last five years however, a design consensus had emerged with almost all turbines manufactured offering a pitch regulated three bladed horizontal axis rotor with a variable speed drive. One manufacturer offers a direct drive that has eliminated the need for a gearbox.

Development of the turbines has incorporated ever increasingly sophisticated control technology and intelligence that have contributed to increased performance, increased reliability and lower costs. Experience gained in building and operating many thousands of turbines has enabled machine operational availability of 97% or greater to become commonplace. The technology is now considered by banks providing loans to be proven and commercial. This fact taken together with short construction times and low risks and with the support of government policies that legislate in favour of renewables in the USA, China, Canada, Japan, India and the EU countries has made wind energy the fastest growing energy resource in the global electricity sector. In the UK many of the electricity suppliers including NPower, E.ON, Scottish Power, Scottish and Southern and Centrica are owners of wind farms and Shell, Statkraft, Catamount, Tomen, Fred Olsen, Falcke, Total and other major companies look like enlarging the potential pool of investors in UK offshore and onshore wind farms

With larger penetrations from wind energy in countries such as Germany, Denmark and Spain into sometimes relatively weak grids, forecasting the output of wind farms has assumed increasing importance for some locations. Dr Garrad provided examples of forecasting work carried out by his own company that looked six hours ahead and that indicated excellent predictive capability. He emphasised that this area of work was at an early stage, though it is now in use by wind farm operators and utilities in Denmark, Germany, Spain and the USA.

Total installed global capacity is now approximately 48GW as of mid 2005 with new capacity of about 8GW installed in 2004, equal to a world market of about $8 billion. Dr Garrad estimated that with other associated services to the industry, the wind energy business was worth about $12-13 billion in 2004.

One of the consequences of rapid development of the market and of the technology is the continuous lowering of costs such that onshore wind farms in Europe are built for a typical turnkey cost of about 900 euros/kW and generate electricity at sites where annual average wind speeds are 8m/sec or more at less than 6 euro cents/kWh.

Dr Garrrad explained how the industry had matured with the emergence of half a dozen turbine manufacturers that now dominate the market along with the involvement of major power industry players such as Siemens, GE and Mitsubishi. The UK wind industry already employs a considerable number of people in the development, manufacturing, consultancy and O & M sectors as well as in the provision of project finance and legal and insurance services. The manufacturing sector includes a rotor blade manufacturing facility on the Isle of Wight employing more than 600 and working a 3 shift 365 day/year operation, a wind turbine assembly plant in Scotland employing more than 200, the world's largest wind energy consultancy employing approximately 150 and several large wind farm developers and constructors that together employ some hundreds. UK based project finance teams have arranged bank debt for projects in the UK and overseas in excess of $2 billion whilst a UK investment company, Doughty Hanson, owns the worlds largest wind turbine rotor blade manufacturer, LM Glasfiber A/S.

Current installed wind energy capacity in the UK is more than 1,300MW as of November 2005, with an additional 700 MW under construction. Adding a further 8GW of capacity by 2010 to meet government targets is likely to be very challenging. The major barriers arise as a result of an under resourced planning system, the potential for increased public opposition to wind farms as more are built and the need for reinforcement of the grid system to enable major development of the Scottish wind energy resource and the major offshore developments around the UK coastline. More than 16GW of grid connection applications for onshore wind projects in Scotland were lodged as of mid 2005, and in addition, licenses have been awarded to pursue the development of 6.7 – 8.7GW of offshore wind farms in UK waters.

Dr Garrad emphasised that National Grid plc has stated that the 10% target for renewables is acceptable from a system operator's perspective, ie that the so-called system effects of intermittent power are entirely manageable within the context of the normal variations of demand and generation on the grid.

5.3 Photovoltaics

In a recent review of the PV industry[3], Maycock reported that world production of PV materials totalled 1,195MW in 2004. This represents a 57% increase (434MW) on 2003 manufacturing output. Japanese companies Sharp (324MW) and Kyocera (105MW) maintained first and second places in the league table of manufacturers with UK based BP Solar in third position with 85MW and Shell Solar in sixth position with 65MW. It appears that most of the growth in the year resulted from a 250MW growth in the grid connected market and large increases in sales in Japan and Germany. Kathryn Newell, referring to the Sarasin Sustainable Investment Solar Energy Report of November 2004, said that the three biggest markets for solar PV are Japan, Germany and the USA. The same report is very positive about the future for PV. It predicts that global cell production will continue to increase until about 2008, when it will flatten out before picking up and exceeding 5,800MW. It forecasts that the total market will grow from 2.2GW in 2010 to 5.8GW in 2020, with cell production capacity increasing by 13% per annum.

About 85% of the world PV cell and module production, Maycock reports, was based on sliced single crystal and polycrystalline cells and only 47MW of amorphous silicon was produced in 2004, during which 3MW of copper indium diselinide (CIS) and 13MW of cadmium telluride (CdTe) were produced. It seems likely, he suggests, that single crystal and polycrystalline silicon cells will continue to dominate the PV market for some years to come. Kathryn Newell agreed with this view on the basis that the technology was reliable and well understood with scope still for improving manufacturing methods. She referred to a PV–TRAC report published by the European Commission in September 2004 that estimated that there was an opportunity to improve efficiencies by 15 – 20%. The same report looked at new and emerging technologies that can make an impact on cost and efficiency and identified sensitised oxide cells and multi – junction cells as the most mature. It suggested that organic solar cells are considered to have the most potential to reduce costs though current prototypes are unstable and of low efficiency at this stage of development.

According to Maycock, the installed cost of grid connected PV systems has continued to decrease and for California installations in 2004 installed prices have been reported to be about $7,000/kWp.

Total European PV cell and module production increased to 314.4MW in 2004 and about 300MW of PV were installed in Germany in 2004 largely as a consequence of the Government's support scheme which under a new January 2004 law extended the buy back rates which vary according to application from 45.7 to 62.4 Eurocents/kWh.

Kathryn Newell, summarising the UK PV RTD programme, said that the DTI is funding research, domestic and large scale field trials, a major demonstration programme and collaborative work with the EU and the IEA. She referred to the Renewables Innovation Review that had highlighted the issues for PV in terms of the potential contribution that PV was likely to make. Because current costs are high the solutions are seen to lie with the next generation of technologies. The

[3] *Paul Maycock: PV Market Update. Renewable Energy World. ISSN 1462 – 6381, July – August 2005, Vol. 8, Number 4 pages 86 – 99*

focus of DTI RTD support is on cost reduction and improved performance with approximately 12 funded projects with an annual budget of about £2.64 million.

A separate field trials programme has a budget of £10 million covering 40 projects that include demonstrations on groups of houses and large-scale public buildings. These include new build and retrofit and both social housing and private developments. Projects are to be monitored for two years to assess performance.

A complementary demonstration programme closing in March 2006 has a budget of £31 million and has as its objective the raising of awareness in the UK and to generate investment in the UK PV industry and to establish a sustainable PV market in the UK. Average costs of the most recent projects funded under these programmes are £6,500/kWp with a lowest cost of £4,040/kWp.

Current total installed PV capacity in the UK was about 6MWp at the end of 2003 with about 2MW being added to capacity in that year. Annual average solar insolation in the UK is low (about half of that in Madrid for example) and the UK has less than 1% of global installed capacity. Nevertheless, Kathryn Newell said that the DTI see the outlook for the future as encouraging with over 50 products available in the UK and with three new manufacturing and/or assembly plants producing PV roof tiles, module assembly and a glass/glass facility.

5.4 Marine Technologies

Paul Jordan, in outlining the technical and commercial prospects for this resource, said that the UK practical resource potential for wave energy has been estimated as equivalent to 2,000 to 4,000TWh/year, the mid range of this estimate being equivalent to about ten times the UK electricity demand of around 300 to 330TWh/year. In addition to these wave energy resources, the Carbon Trust estimates that the UK tidal stream resource is such that 22TWh/year could be extracted from the top 10 UK sites.

The Renewables Innovation Review concluded that if the right support was introduced to accelerate technology development and growth then 5% of electricity could be derived from marine renewables installed in UK waters by 2025. This would be equal to carbon savings of around 6-7 million tonnes of CO_2/year or the displacement of 2GW of coal fired generation.

Though there are a number of devices under development, development and commercialisation of wave and tidal stream devices are at an early stage at present.

One of the leading wave energy devices is the Pelamis, designed and manufactured by Ocean Power Delivery Ltd. A 750kW pre production machine is under test at the European Marine Energy Centre in Orkney. An order has been placed for three of these machines for a wave energy project to be completed in April 2006 at Agucaoura, off the coast of Portugal and it seems likely that a similar or larger scale project will built in UK waters sometime in late 2006 or early 2007.

The leading UK tidal stream technology is being developed by Marine Current Turbines Ltd. A 100kW prototype has been under test for about a year at a site off Lynmouth in North Devon. In December 2005 the company received further investment from EDF Energy and a grant from the DTI to build a larger turbine on Strangford Lough in Northern Ireland.

The principle challenges for the commercialisation of both tidal stream and wave energy centre around the need to identify the means to finance early stage demonstration projects at a time when these first projects are two to three times more costly than onshore wind generated electricity. In 2004, the DTI announced a £42 million marine support scheme for early demonstrations over the next three years. An offer has been made to provide a 25% capital grant in addition to a £100/MWh additional tariff for the first seven years of project life on top of any income from the Renewable Obligation Certificate mechanism.

Thereafter the challenges that must be overcome if marine renewables are to play a significant role include the need to identify and characterise suitable sites and obtain the necessary consents to use these sites and the need to lower the capital operations and maintenance costs significantly so as to demonstrate financial viability.

Several initiatives have been launched to assist in exploiting the UK's current lead in technology development with the objective of building a UK based manufacturing base. The European Marine Energy Centre on Orkney has been built to provide four different wave energy devices with a berth to allow testing in the sea at full scale. The South West Renewable Development Agency is also advancing a project to construct a so called Wave Hub which it is hoped will be commissioned by the end of 2006.

5.5 Biomass and Waste

Biomass is obtained from organic matter, either directly from plants or indirectly from industrial, commercial, domestic or agricultural products, There are many potential biomass resource streams and biomass can be converted to heat, power and transport fuels in a number of ways depending on its sources. These processes can include thermo-chemical (combustion and the steam or hot water cycle, gasification and pyrolysis), biochemical (anaerobic digestion, fermentation or distillation, and hydrolysis) and chemical and physical (esterification and densification).

According to Domac, Richards and Segon[4], globally, biomass use amounts to nearly one billion tonnes of oil equivalent, a level comparable to the consumption of natural gas or coal. This makes it the largest renewable energy resource in use today. About 10% of the world's primary energy is derived from biomass used in developing countries, often in traditional ways that mean that such use is unsustainable as unprecedented population growth in these regions is depleting existing resources.

There are several examples of large-scale application of technologies to create sustainable applications of biomass. Kottner[5] reports that in Germany, the introduction of the first feed in law[6] in 1991 has led to the rapid growth in the number of new biogas installations in agriculture such that cumulative capacity is now approximately 2.5GW. These installations were initially in the 30-50kW range but recent plants have individual capacities of 300MW to 600MW. The renewal of the German Renewable Energy Act (EEG)[7] in August 2004 has provided motivation for farmers to invest in new and bigger biogas plants. A bonus is given for generation derived from energy crops (the NaWaRo-Bonus) of 6 Euro cents per kWh for installations up to 500kWe. This is designed to encourage farmers to generate electricity from crops they produce themselves. The farmers can process their own products into electricity safe in the knowledge that they have a guaranteed feed in price for the next 20 years. This compares favourably with marketing their crops as raw material for food or feed production.

In Austria, the woodchip heating market has also increased dramatically over the last decade such that over 5000 domestic pellet boilers were sold in 2003 according to Rakos[8]. Until recently, the US was the world's largest pellet market, consuming slightly less than 1 million tonnes annually. Sweden has now overtaken the US, producing 1.1 million tonnes of pellets in 2004. The Swedish pellet market has been dominated by the use of pellets in large district heating plants that converted from coal to biomass.

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[4] *Domac J, Richards K and Segon V;- 6381, Old fuel for modern times. Renewable Energy Worlds. ISSN 1462 - 6381, July – August 2005, Vol. 8, Number 4, Pages 114- 123.*

[5] *Kottner M; Planning matters-Germany's on-farm power from biogas, using energy crops and farm waste. Renewable Energy World. ISSN 1462 – 6381, July – August 2005, Vol. 8, Number 4, Pages 188 – 195.*

[6] *A legal obligation on utilities to purchase electricity from renewable sources*

[7] *http://www.bmu.de/english/documents/doc/3242.php*

[8] *Rakos C; Hotting up – The wood pellet heating market. Renewable Energy World. ISSN 1462 – 6381, July – August 2004, Volume 7, Number 4, Pages 152 – 161*

The use of biofuels for transport is quite rare in nearly every country. Ethanol is by far the most widely used biofuel for transportation worldwide-mainly due to large production volumes in USA and Brazil. Fulton[9] reports that fuel ethanol from corn has been used in transport in the US since the 1980s and US production of fuel ethanol is over 20 times greater than production in any other IEA country and is rising rapidly. Even so, ethanol production represents less than 2% of transport fuel in the USA (around 10 billion litres of fuel per year) while in Brazil it accounts for about 30% of gasoline demand. In Brazil, production of fuel ethanol from sugar cane began in 1975, peaking in 1997 at 15 billion litres but declining to 11 billion litres in 2000 as a result of shifting policy goals and measures. Production of biodiesel is highest in Europe, with France, Germany and Italy the main producers. European countries produce more biodiesel than fuel ethanol, but the total production of both fuels is fairly small in comparison to ethanol production in Brazil and the US.

Recently, there have been numerous efforts to expand the use of biofuels in both IEA and non IEA countries. In early 2003, the European Commission issued a Directive promoting the use of biofuels and other renewable fuels for transport.

The Directive sets out two indicative targets for EU Member States - 2% biofuels penetration by December 2005 and 5.75% by December 2010. These targets are not mandatory, but governments are required to develop plans to meet them. The US and Canada are considering legislation that could lead to several fold increases in biofuels (especially ethanol) production over the next few years. Australia has recently implemented blending targets (where a biofuel is mixed with a traditional fuel) and Japan has made clear its interest in biofuels blending. Several non IEA countries, such as India and Thailand, have recently adopted pro-biofuels policies. In Latin America, major new production capacity is being developed, in part with an eye towards exporting to an emerging international market in biofuels.

In the UK, the Biofuels Corporation was the first biodiesel company to be listed on London's Alternative Investment Market (AIM) and according to Cameron[10] it is in the final stages of constructing what could be Europe's largest biodiesel production facility at Seal Sands, near Middlesborough. Once completed, the new £28 million facility will have an annual output of around 250,000 tonnes of biodiesel, equivalent to 284 million litres and representing about 1.5% of total UK diesel consumption (at 2003 levels). The plant will use vegetable oils such as soy, rapeseed and sunflower to make its biodiesel. The majority of these vegetable oils will need to be imported (initially at least) as there is not yet sufficient local stock available. Current UK production is around 90,000 tonnes per year so that this new plant represents a major increase in the size of the UK production capacity.

Megan Bingham Walker summarised the status of development and commercial prospects for this resource. The economics for some schemes can be marginal, she said, even with the support of the Renewables Obligation, and in many cases the fuel supply chains for energy crops are underdeveloped although co-firing has contributed to developing these.

The planning system can create delays and complexities in the process to build biomass plants and further difficulties arise as a result of the split in responsibility between various government departments. Policy on waste, rural diversity, energy, heat and electricity all have an impact on bioenergy and they all sit in different parts of both the DTI and Defra.

At the end of 2003, bioenergy used for both heat and electricity generation accounted for 87% of the renewable sources in the UK. The majority of this came from landfill gas and waste combustion but smaller amounts also came from sewage gas, domestic wood and industrial wood. Electricity produced from biomass accounts for 1.5% of total electricity supplies in that year [see Table 5.1].

Government, according to Megan Bingham Walker, sees bioenergy as having the potential to make a significant contribution to both heat and electricity in the future. It is expected that biomass should contribute to the 2010 target through co-fired biomass and landfill gas, with a limited contribution from dedicated biomass. By 2020, government estimates that biomass could provide up to 6% of electricity supply, which does not include electricity from the

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[9] *Fulton L; Driving ahead – biofuels for transport around the world. Renewable Energy World. ISSN 1462 – 6381, July -August 2004Volume 7, Number 4, Pages 180 – 189.*

[10] *Cameron A; A refined solution- the UK shifts towards biodiesel. Renewable Energy World. ISSN 1462 – 6381, November –December 2005, Volume 8 , Number 6, Pages 98 – 105.*

combustion of municipal solid waste. Biomass offers the advantage of non intermittency but may be constrained by the resource. The Renewables Innovation Review concluded that the main challenges in taking biomass forward are not technology issues but they are related to the establishment of fuel supply chains.

Megan Bingham Walker outlined a number of major government support schemes to support bioenergy. The Bioenergy Capital Grant Scheme is a joint initiative funded by the DTI and the New Opportunities Fund to support biomass fired heat and electricity generation plants. Support for energy crops and the creation of fuel supply chain infrastructure is available through Defra's Energy Crop Scheme and the Bioenergy Infrastructure Scheme. There is also Defra's Advanced Energy from Waste Demonstration Programme, which supports the role of energy from waste in meeting targets for the diversion of waste from landfill under the EU landfill directive, alongside other initiatives which would make greater use of recycling waste minimisation.

New initiatives, she said, were underway to further stimulate bioenergy in order to meet the 2010 target and the 2020 aspirations. One of these initiatives was the Ben Gill Task Force of one year duration that was to set out a plan to stimulate biomass supply and demand. It subsequently reported in October 2005 and concluded that biomass (fuel from biomass, crops and waste) could reduce carbon emissions by almost 3 million tonnes/year if used to provide heating. The carbon savings would be equivalent to taking 3.25 million cars off the road. The Task force estimated there could be 20 million tonnes of biomass available annually and suggested several ways to develop the industry. They concluded that one of the biggest barriers to progress is ignorance.

In response to calls for the establishment of a renewable heat obligation, she reported that DTI and Defra had jointly commissioned research work to look more carefully at the renewable heat and CHP market. The study carried out by Future Energy Solutions was subsequently reported in November 2005. The study concludes that renewables could contribute an additional 6TWh/year to the heat market in 2010, increasing to 34.9TWh in 2020 (equal to 0.8% and 4.7% of total heat demand).

5.6 The Costs of Integration

Richard Ford started by saying that there is a widespread, but mistaken, belief that operation of an electricity system with inputs from variable renewable resources, such as wind or wave energy, cause problems. A common misconception is that other plant must be held in readiness, to come on line when the output from the wind or wave plant fails. This may be true in an island situation, with wind the principal source of supply, but modest amounts of wind within an integrated system pose no threat. They do not add significantly to the uncertainties in predicting the balance between supply and demand, and so changes in their output only marginally influence the need for reserves.

The efficiency of integrated electricity systems depends on the aggregation of demand and generation. At one end of the spectrum, the minimum demand from a single house is a few watts, the average is about 0.5kW and the maximum is 5 to 10kW - 10 to 20 times the average. If each household met its own maximum demand of say 5kW, 100GW of plant would be needed for this sector alone. Aggregation smoothes variations in demand from all sectors so nationally the maximum demand is around 60GW about 1.5 times the average demand. As demands are added and smoothed, savings in generating plant are realised and load prediction becomes easier.

It is often suggested that 'spinning reserve' (part loaded thermal generation, whose output can be increased or decreased) needs to be scheduled to 'cover' for fluctuations in output from a wind plant or other intermittent source, This is true up to a point, but the reserve only needs to cover the extra uncertainty, not the whole of the uncertainty due to the wind or waves.

National Grid plc has summarised the key issues relating to smoothing as follows:

Based on recent analysis of the incidence and variation of wind speed we have found that the expected intermittency of wind does not pose such a major problem for stability and we are confident that this can be adequately managed.

It is a property of the interconnected transmission system that individual and local independent fluctuations in output are diversified and averaged out across the system.[11]

The reason that modest amounts of wind cause few problems (or costs) for system operators is that extra uncertainty imposed on the operator by wind energy is not equal to the uncertainty of wind generation, but to the combined uncertainty of wind, demand and thermal generation, said Richard Ford. With wind supplying 10% of UK electricity, estimates of the additional reserve capacity are in the range 3 to 6% of the rated capacity of wind plant. With 20% of electricity from wind, the range is 4 to 8% approximately. Estimates of the 'extra costs of intermittency' are mostly close to figures provided by the National Grid. Accommodating 10% wind on the UK system would increase balancing costs by £40 million per annum (£2/MWh of wind), and 20% wind would increase those costs by around £200million per annum (£3/MWh of wind). Estimates from other studies, including work by or for PacifiCorp, the Bonneville Power Administration and the Electric Power Research Institute yield similar results. For 5% of electricity from wind, the extra costs are within the range $1.7 -$3/MWh, and with 10% from wind the range is $3 -$5MWh.

Considerable efforts are being made to improve the accuracy of wind and wave forecasting, as this has the potential to make significant reductions in the costs of extra balancing. Some researchers claim that these can possibly be halved. In the UK, under NETA, generators commit themselves to predictions of generator output only one and a half hours ahead. This allows UK wind farm operators to predict their output with greater confidence than their western Danish counterparts where the system operator, Eltra, commits itself to purchasing energy based on forecasts made up to 36 hours ahead.

A separate issue in the context of economic appraisals of intermittent renewable sources is the capacity credit of the resource. The capacity credit of any power plant may be defined as a measure of the ability of the plant to contribute to the peak demands of the power system. Capacity credit here is defined as the ratio (capacity of thermal plant displaced)/(rated output of wind plant).

Numerous studies have shown that wind plant (and by implication wave plant) can displace thermal plant. National Grid plc has estimated that 8,000MW of wind plant might displace about 3,000MW of conventional plant and 25,000MW of wind, (20% penetration), would displace about 5,000MW of such plant.

5.7 Concluding Remarks

The challenges of achieving the 2010 target for renewables set by the Government are considerable. In Scotland, National Grid plc has considered three scenarios for Renewables. They have considered implementation levels of 2,000MW, 4,000MW and 6,000 MW and have estimated that network investments of between £500 million to £1,500 million will be required. Their calculation is that this investment equates to about £250/kW overall. For England and Wales based on an assumption that 1GW is installed onshore and a further 5GW is installed offshore in addition to 2GW installed in Scotland they estimate a range of costs for transmission reinforcement and upgrades for England and Wales of between £275 million and £615 million. This equates to onshore network investment between £50/kW and £100/kW. Offshore network costs are additional and estimated at around £150/kW. Ofgem agreement to funding these investments has been sought.

The barriers to onshore wind farm development were acknowledged in the Renewables Innovation Review that listed the main barriers as the need to provide network connections, public opposition, opposition from the MoD and other aviation interests, and the planning system. The review estimated the costs of the required grid upgrades for 10% penetration by 2010 at between £1.125 to £1.28 billion and upgrades for the 2020 scenario at between £1.384 to £2.351 billion. Distribution upgrades would cost a further £443 to £601 million for the 2010 target and £330 to £1,000 million for the 2020 target. The Review concluded that planning consents for both transmission and distribution investments needed to be in place rapidly to allow construction of these upgrades to start in 2004. **Delays in achieving consents and building these new facilities are probably the major barriers to achieving the 2010 renewables target.**

Just prior to the publication of the Review a new planning guidance note [PPS22][12] was published and there is some evidence that the success rate for wind farm planning applications has improved in England. Planning approval rates

[11] *NGC Seven Year statement, March 2004. (see http://www.nationalgrid.com/uk/library/documents/sys_04/default.asp?action=&sNode=SYS&Exp=Y)*

[12] *http://www.planningportal.gov.uk/england/professionals/en/1021020428382.html*

reported by the British Wind Energy Association are given in Table 5.2. They indicate a substantial fall off in approval rates in Scotland. If the 2010 target for wind power is to be met there is a requirement on Government to investigate the reasons for this fall off in approval rate and take appropriate action.

Local Planning Authority and Section 36 applications in:-	**Approvals in 2004**	**Approvals in 2005**
England	70% (12 projects)	74% (of 13 projects)
Northern Ireland	Not Available	100% (of 1 project)
Scotland	100% (8 projects)	35% (of 21 projects)
Wales	61% (3 projects)	0% (of 2 projects)
Section 36 applications in England and Scotland		100% (for 2 projects in each of England and Scotland)

Table 5.2: Planning Decisions for Wind Farm Applications in the UK in 2004 and 2005

It has been suggested that a major problem arises from a shortage of resources and expertise at the planning level to deal with all the applications that are made.

Given that renewables provided 14,171TWh of electricity in 2004, equal to 3.7% of total electricity (Table 5.1) and assuming that Government aspirations for the use of biofuels are met (ie, 6% of electricity by 2020 compared with about 1.9% in 2004) the balance of the 10% government 2010 target would amount to about 5% of total electricity generation. This could be met by the installation of an additional 7.5GW of new wind farm capacity operating at an average capacity factor of 27.6% (the average capacity factor for all wind plant operating in the UK over the last 7 years). Of this new capacity about 700MW is already under construction leaving a target installation rate of about 1.4GW/year if the 2010 target is to be principally met by wind energy. Given the need for major grid reinforcement and the increased difficulty in obtaining consents in Scotland, this installation rate represents a major challenge. To a large extent the achievement of the target also depends on whether the major off-shore wind farm projects proceed within this time scale.

In the discussion, questions were raised as to why the Severn Tidal Barrage and other tidal schemes which had been researched so much in the 1980s, had seemed to have been dropped from the list of options for renewable electricity in the UK. It was suggested that if flood protection and other benefits were taken into account, the economics of the Severn and other schemes would now look more attractive than was previously the case. The Severn project was capable of peak generation of at least 7.2GW and could generate around 13TWh/year equal to about 3.5% of UK electricity requirements.

6 Fossil Fuels

Chairman: *Professor Alan Williams, CBE FREng*
Speakers: *Mike Rolls, Siemens Power Generation*
Dr Geoffrey Morrison, International Energy Agency Clean Coal Research, UK.
Nick Otter OBE, ALSTOM Power
Dr Paul Zakkour, ERM Energy & Climate Change Practice

6.1 Background

Fossil fuels are the main source of energy in the UK, with coal and natural gas the major fuels for electricity generation. Fifty years ago coal was the main fuel for power generation but in the 1970s there were worries about the effects of acid gases, particularly oxides of sulphur and nitrogen (SOx and NOx), being emitted and this resulted in the installation of Flue Gas Desulphurisation (FGD) and low NOx burners to a number of power stations.

Since the 1970s, the price of UK coal increased because the deep mines became more geologically difficult to work, whilst cheaper internationally traded coal became more readily available. Political barriers to the use of North Sea natural gas were removed, and it became increasingly available, easy to distribute, produced less pollutants and was cheap. At the same time large combined cycle gas turbines (CCGT) became available resulting in an expansion of the use of natural gas. The net effect was the decline in the use of coal, especially UK coal, in conventional power stations and the increase of natural gas for power generation in CCGT units. In the last 10 years this has been accelerated by more stringent regulations relating to power station emissions of acid gases and the newer requirement to reduce carbon emissions. In the early 1990s the fuel industries were denationalised and as a consequence the UK coal industry diminished in size from about fifty pits in the 1990s to the present situation where there are six working underground mines (and three that are moth-balled) together with some open cast mine activity. Initially only coal was under environmental pressure because of the greater carbon content than natural gas, but increasingly this now applies to natural gas.

The world coal reserves are large and are available from a number of diverse geographical sources. There remain considerable indigenous reserves and there are extensive open cast coal reserves that could be used rapidly in an emergency, and deep mined coal could be used in the longer term. Coal is readily stored and can be used to underpin other sources of energy. The situation with natural gas is more complicated and has been discussed in other lectures. Essentially the world gas reserves are considerable but are dependent on a more complicated supply chain, and are not so readily storable.

Fossil fuels could still be used if there are zero or near-zero emission requirements but at a considerable cost and a loss in efficiency. Whilst control of most of the environmentally unacceptable pollutants is readily achievable, control of carbon dioxide is more difficult because it is a major component of the combustion gases and the separation and storage are expensive operations. The question of carbon capture and storage (CCS) had been examined by the DTI and a report has been issued subsequent to the seminar[13]. However, in the event a General Election was called and consequently the contents of the report remained confidential although some reference was made to the nature of the arguments.

The seminar on Fossil Fuels was directed at the generation of electricity, consequently the use of petroleum was not considered in this meeting but was addressed at the seminar on Oil and Transport. Given below are the main points raised in the opening talks and the discussion.

6.2 Efficient Electricity Generation from Gas

The first speaker was Michael Rolls. He commenced by stating that gas fired combined cycle plants emit roughly half the CO_2 of conventional coal-fired generation, and since emissions are now driving the market, carbon pricing can only

[13] *A Strategy for Developing Carbon Abatement Technologies for Fossil Fuels Use, DTI/Pub URN 05/844 June 2005*

increase the value of efficiency. After 2010, under current plans, there would be a significant increase in the use of natural gas with some increase in renewables. Coal usage has been predicted to decrease more or less linearly from now until 2020 but could fall away rapidly after 2008 as plants, opted out under the Large Combustion Plant Directive, are retired. There is a considerable amount of gas available but UK gas production is dropping. After 2005 we will not be self-sufficient, and by 2012-13 we will be producing only about half the gas that we need as a country.

The market drivers were classified into three elements: capital cost, performance and ownership costs, but only the first two were discussed. A number of things have been done by industry to reduce capital costs, the most important of which is probably standardisation. The central power block can be standardised down to the cable trays, including where they are sourced. Multiple purchase agreements can drive down prices, delivery times and risk. The next in importance is improved performance and operational flexibility. As well as enhanced efficiency in turbines and steam cycles at peak output these include maintaining efficiency at part load. Faster start up times and loading rates are also being offered both of which are important commercially.

Gas-fired CHP was considered and it was pointed out that it is presently unattractive for regulatory and legal reasons, and most of those have been unintentional. Thus there are no significant CHP projects currently under construction in the UK even though the Government has a target of 10GW by 2010,

Finally the future challenges for gas turbine and steam turbine plant were outlined which included continuous improvement of the existing range. A major challenge is to develop and use materials that will survive in high temperature conditions with minimum or no cooling.

6.3 Clean Coal Technologies

Geoff Morrison outlined the R&D activities in some of the major coal-using countries in the world. As a background to that he considered the role of coal in the world energy outlook. The IEA's World Energy Outlook shows that fossil fuels will continue to account for about 90% of the growth in energy between now and 2030. Electrification rates will rise but, despite that the total number of people without electricity will fall only slightly, from 1.6 billion to around 1.4 billion.

He considered Roadmaps and activities for six major coal consuming countries:

Canada has a number of programmes in place with the intention to build a pulverised coal CO_2 capture-ready plant by 2010.

USA is undertaking a number of initiatives:

- Vision 21: This sets long-term strategic goals to build a high efficiency coal plant with near zero emissions and with energy costs which are 10-20% lower than they are today.
- Clean Coal Technology, (CCT): The President's Clean Coal Research Initiative which is a $2 billion programme over 10 years. It will also be looking at hydrogen from coal, with CO_2 integrated capture and storage.
- Clean Coal Power Initiative: This is the demonstration part and there are around 10 projects already underway under this programme.
- FutureGen: This is a $1 billion project over 10 years. There is a poly-generation plant producing hydrogen and electricity, with near-zero emissions with carbon capture and storage.

Japan has a similar programme of clean coal technology, with the C3 programme (the Clean Coal Cycle initiative) launched in 2004. Gasification will be the main core technology, but they are also looking at oxy-coal combustion with Australia.

Australia, in collaboration with Japan, launched a large programme about a year ago – the COAL 21 programme. This will use oxy-coal combustion and result in a demonstration plant capable of producing 150,000 tonnes of CO_2 a year for geological storage.

China has massive orders for new boilers (87 GW of new, sub-critical pulverised coal capacity was built in 2003). The supercritical market is very large and their policy is for the rapid deployment of the technology. In 2003, 26GW of large boilers were ordered – this is 93% of the world's supercritical pulverised coal market. They have plans for a 450MW Integrated Gasification Combined Cycle (IGCC) demonstration plant. The technologies which the Chinese see as important are: ultra-supercritical power generation; pollution control technology; IGCC, which is important for the future; and eventually poly-generation – the Vision 21 type US plant.

India is interested in IGCC and supercritical pulverised coal plants, but most of their plant at the moment is sub-critical. India is looking at fluidised bed rather than entrained bed for gasification because of their very poor quality coals

In his final remarks, he stated that there are the two principal technology options. Supercritical pulverised coal leading to ultra-supercritical steam conditions is one of the most important technologies. In the longer-term IGCC could become the leading technology. In his opinion there is very little difference between the efficiencies of ultra-supercritical pulverised coal and IGCC and we need to develop both these technologies

6.4 Carbon Capture and Storage (CCS)

In his introductory remarks Nick Otter emphasised the fact that a broad approach was needed for CO_2 reduction but the overriding issue is to be able to use of fossil fuels without emitting CO_2 to the atmosphere which would involve capture and storage of CO_2.

In the UK, the DTI is establishing a carbon abatement technology strategy for fossil fuels and a programme for power generation and the high-energy industrial processes is being developed. Such an approach will need to address CO_2 storage and the protocol issues raised in the final lecture. Also there is a strategic link between clean fossil energy and hydrogen where, if CO_2 is captured in the appropriate manner, it can result in the production of hydrogen and hence lead to the hydrogen economy that could well involve fuel cells. This highly strategic issue is being addressed by the European Commission in Framework 7. Similarly in the UK, the DTI has performed a series of techno-economic (Markell) studies under a series of scenarios. All the results from scenarios indicate that carbon capture and storage will be required after 2010 at the level of up to 25Mt CO_2/year.

Nick Otter then considered the strategy put forward by The Advanced Power Generation Technology Forum (APGTF) which is a carbon abatement strategy for zero emission fossil fuel power generation. The strategy is set in the longer term context, out to 2030 and beyond, and a way of getting from today to 2050.

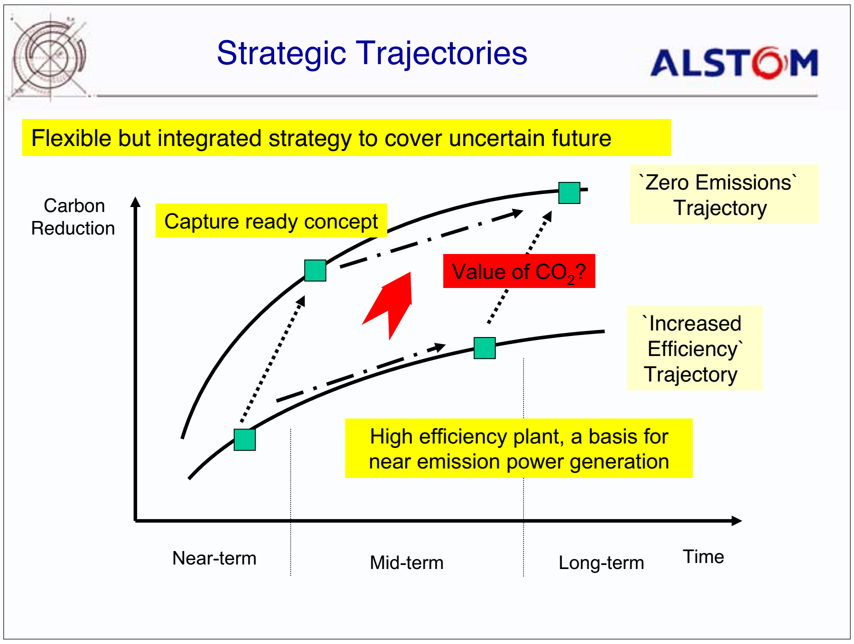

Figure 6.1: A Flexible but Integrated strategy to Cover an Uncertain Future

A schematic diagram in Figure 6.1 shows that, by addressing carbon abatement reduction in stages, a trajectory that increases the prime mover efficiency can provide the basis for a zero emissions trajectory (the higher line) that involves capture and storage. The most highly efficient plant and components are required to offset the detrimental impact of capture on the overall performance of the plant. The lower trajectory could be regarded as the line of least regrets and is certainly one that China is currently following. Such an approach, in the case of coal, can be aided by the utilisation of biomass which gives significant decreases in carbon emission as shown below in Figure 6. 2.

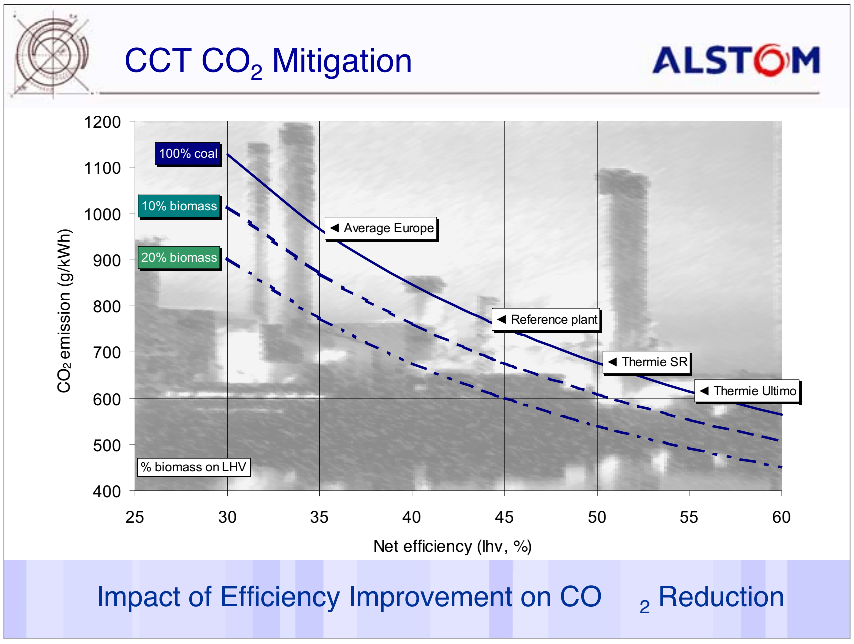

Figure 6.2: The Effect of Biomass on Reducing Carbon Emissions from Coal Fired Power Stations

Carbon abatement for zero emission power generation has to be long-term goal. In a free market timing will be paced by the value of CO_2 as determined by emissions trading or similar mechanisms as this will have a significant impact on the decisions for economic investment. Clearly, however, whatever approach is taken, CO_2 reduction will evolve in stages from increased efficiency, fuel flexibility and repowering, and subsequently to near-zero emission with CO_2 capture and storage.

In the UK there has been a major consultation exercise by the DTI as part of the development of the carbon abatement technology strategy. A report and a set of recommendations had been issued which are summarised below:

- It covers coal and gas – recognising the global importance.
- It is supporting the proposition that there should be an industry-led research, development and demonstration programme as recommended by the APGTF for which there is very strong support in the public consultation.
- The international aspect is fully recognised. It would be necessary to try to establish some key demonstrators – certainly Europe-wide and worldwide – and there is the desire that at least one is in the UK.
- A programme of £20 million per year could be forthcoming from the DTI. Once again, having some kind of longevity in such an approach would be important.

In terms of international needs and actions, an important forthcoming programme in Europe is the 7th Framework Programme where the energy part is likely to have two of its nine major themes as global climate change and energy. Within energy 'Clean Coal Technology' and 'Zero Emissions from Fossil Fuels' have been identified as two important areas.

In addition to Europe, the UK has several bilateral arrangements with Australia, Canada and the US. The DTI is now looking at further ones with China and India.

Nick Otter then summarised the technology. First there are the efficiency issues; Mike Rolls had talked about gas turbine technology which is a particularly important prime mover because of the fuel flexibility issue. There are major programmes in Europe addressing the hydrogen combustion issue. Other discussions have been concerned with CO_2 capture options. This analysis goes through to transportation and pipelines. There are a number of storage requirements which link to the public perception issues, and safety and security of such technologies. If it is going into the trading scheme, then it has to be verifiable and it has to be environmentally acceptable. He then considered CO_2 enhanced oil recovery and the geological storage potential and stated that the methods are well known.

In conclusion Nick Otter felt that although there are technical and other issues to be addressed, the above approach to the clean use of fossil fuels had tremendous potential and if global climate change is to be addressed seriously, this aspect had to be included in any plans .

6.5 The Impact of the Regulatory Framework

Paul Zakkour first considered the legal considerations for carbon capture and storage (CCS) which are covered by the following agreements:

- The OSPAR Convention (1992): This is the current instrument guiding international cooperation on the protection of the marine environment of the North-East Atlantic. It combined and up-dated the 1972 Oslo Convention on dumping waste at sea and the 1974 Paris Convention on land-based sources of marine pollution. The work under the convention is managed by the OSPAR Commission, made up of representatives of the Governments of 15 Contracting Parties and the European Commission, representing the European Community.[14]

- The London Convention (1972): An international treaty that limits the discharge of wastes that are generated on land and disposed of at sea. Currently there are 81 Parties to the Convention (ie, states that have signed, ratified, and otherwise acceded to it).[15]

- UN Framework Convention on Climate Change (UNFCCC)(1994): This treaty sets an overall framework for intergovernmental efforts to tackle the challenge posed by climate change. It recognizes that the climate system is a shared resource whose stability can be affected by industrial and other emissions of carbon dioxide and other greenhouse gases. The Convention enjoys near universal membership, with 189 countries having ratified.[16]

- Kyoto Protocol (1997): This significantly strengthens the UNFCCC by committing Annex I Parties to individual, legally-binding targets to limit or reduce their greenhouse gas emissions. Only Parties to the Convention that have also become Parties to the Protocol (ie, by ratifying, accepting, approving, or acceding to it) will be bound by the Protocol's commitments. 163 countries have ratified the Protocol to date. Of these, 35 countries and the EC are required to reduce greenhouse gas emissions below levels specified for each of them in the treaty. The individual targets for Annex I Parties are listed in the Kyoto Protocol's Annex B. These add up to a total cut in greenhouse-gas emissions of at least 5% from 1990 levels in the commitment period 2008-2012.[17]

Neither OSPAR or the London Convention had considered the idea of carbon storage when they were drafted.

A recent report prepared by Norway and the United Kingdom and reviewed by the OSPAR Offshore Industry Committee and the OSPAR Biodiversity Committee[18] concluded that geological storage of CO_2 was feasible, provided risks to the marine environment were evaluated and the sites were appropriately monitored for leakages . It was also concluded that CCS is consistent with OSPAR if the CO_2 is pumped in from a land-based source. Hence, CCS is acceptable under OSPAR .

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[14] *http://www.ospar.org/eng/html/welcome.html*

[15] *http://www.londonconvention.org/*

[16] *http://unfccc.int/2860.php*

[17] *http://unfccc.int/essential_background/kyoto_protocol/items/2830.php*

[18] *http://www.ospar.org/eng/doc/Placement%20of%20CO2%20in%20subsea%20geological%20structures.doc*

Under the London Convention, the definition of waste becomes a key issue, and whether CO_2 is a waste (it is not in the European waste classification scheme). There is therefore a good deal of interpretation required over that. It is worth noting that Enhanced Oil Recovery (EOR) is allowed under both the London Convention and OSPAR.

In the Framework Convention for Climate Change parties are asked 'to promote enhancement of CO_2 sinks' but the means are not elaborated on, so by implication CO_2 storage is covered. Under the Kyoto protocol parties are required to 'develop policies and measures that support CO_2 sequestration'.

A number of Regulatory issues apply to the carbon capture plant. For example since the exhaust stream is no longer diluted by CO_2 the measures of air quality will need to be revised under the Large Combustion Plant Directive and other air quality standards or alternatively addressed in a site permit. Another question to be addressed is whether CO_2 capture is considered the best available technology as this is not clear from the IPPC guidance notes. The IPPC directive requires energy to be used efficiently whereas CCS uses energy to extract the CO_2 and pump it to the storage site. It is not very clear as to whether this is considered acceptable.

There are also on-site health and safety considerations for handling large volumes of solvents and gases, as well as the waste issues. For storage sites environmental impact assessment is likely to be required. There might need to be an emergency plan in place on how to deal with a large release of CO_2 from a storage site. Both the UNFCCC and the Kyoto protocol require accounting of emissions and sinks of greenhouse gases. Therefore, captured and stored CO_2 will need to be measured and monitored for releases. As such, the operator is likely to be required to make a commitment to monitor, quantify and report any seepage from a storage site, back to the host government. The leakage could then be included in their national inventory.

The two main forms of incentive are either through the EU emissions trading scheme (ETS), or project-based Clean Development Mechanismmechanisms under Kyoto.

The Clean Development Mechanism (CDM) is one of the so-called flexible mechanisms under the Kyoto Protocol. The Protocol provides for a CDM in Article 12 as a means for companies to undertake projects in countries without a Kyoto target (non-Annex I Parties, ie, developing countries) which reduce their emissions of greenhouse gases and contribute to sustainable development. Such projects are then credited with Certified Emissions Reductions (CERs) which can be used for compliance either by Governments retiring them to help meet Kyoto targets, or by companies surrendering them to help meet their allocations under the EU emissions trading scheme.[19]

This this is not a cap-and-trade scheme but it is a project-based scheme, and the project is credited on a fixed cycle. This creates problems when trying to reconcile those long-term capital losses back within the seven year crediting period.

There is the need to prove 'additionality' and then also to develop an acceptable emissions monitoring plan for a project. There are some political issues concerning the potential deployment of unproven technologies in developing countries, and this is likely to feature on the agenda for China and India. CCS has to be in there as a toolbox of things that can help mitigate emerging economies' CO_2 emissions over the next 25 years.

[19] *http://www.defra.gov.uk/environment/climatechange/internat/kyotomech/cdm.htm*

Some key milestones for CCS projects under emissions trading schemes were set out in Figure 6.3.

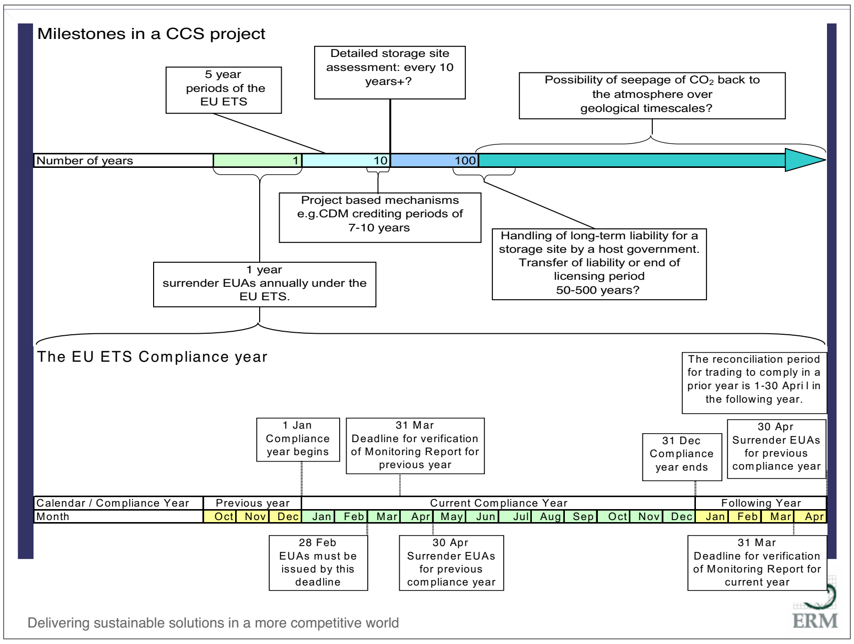

Figure 6.3: Milestones in the CCS project

Dr Zakkour focussed on some of the incentive mechanisms in the UK for CCS which are summarised in Figure 6.4.

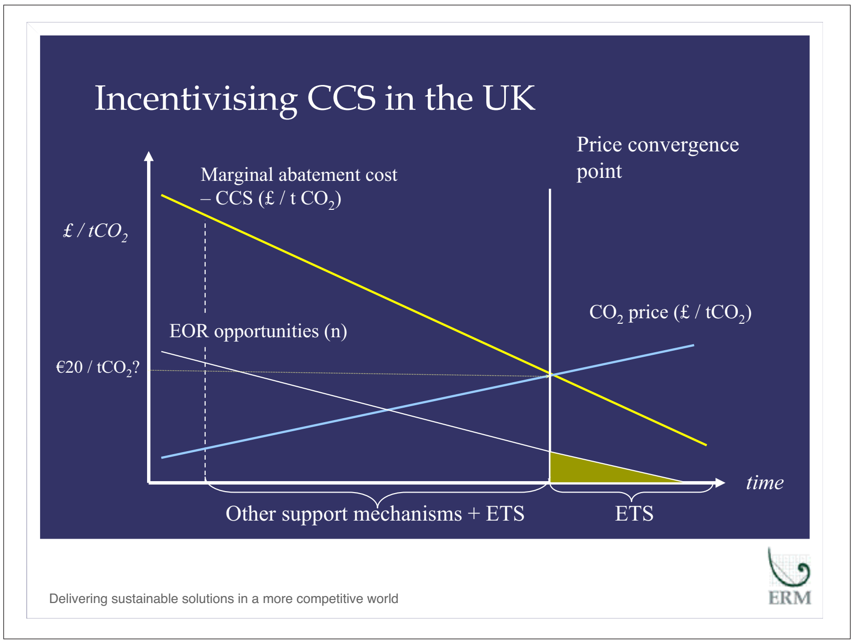

Figure 6.4: Incentivising CCS in the UK

Norway has a €40 per tonne CO_2 tax, which has stimulated investments in Sleipner field to re-inject CO_2 . This poses the question of whether there is a role for taxation in the UK, and is there a need for other mechanisms in addition to CO_2 trading? The cost of capture and storage is decreasing as the technologies are advancing. The carbon value is likely to increase under a tighter carbon cap, so there must be a convergence point somewhere, where the cost of carbon is equal to the abatement cost of deploying a CCS system. The question is when will that be ?

These are some of the key issues for why such incentives are needed now. There is only a narrow window of opportunity for EOR in the North Sea.

The EU ETS works on a five-year period basis, with the allocations only given out every five years. There is no long-term price certainty in the system over what the value of carbon might be. No one knows what period 2 of the EU ETS might look like, nor what the cap will be, and what kind of liquidity that will put into the emissions trading market. It has been agreed in principle about the need to cut CO_2 emissions in the EU by 15% to 30% by the year 2020 – this is the post-Kyoto period. Clearly, to make those kinds of cuts, CCS will play a key role in meeting those policy objectives.

The presentation ended with conclusions and challenges in regulatory terms: the ongoing work required to clarify the legal uncertainties; regulatory systems need further clarification; and incentive mechanisms beyond the emissions trading scheme need to be considered, in order to bridge the existing price gap.

Other challenges for CCS in the future will be public acceptance of CCS as a climate change mitigation technology, the need to develop some kind of storage site risk assessment and a licensing and permitting regime.

6.6 Concluding Remarks

In the Discussion that followed these talks the following points were emphasised:

- Fossil fuels will make a major contribution to power generation in the UK for many years. There have been considerable developments in gas turbine technology with improvements in performance. Gas-fired CHP is not economically attractive at present mainly due to regulatory issues, despite the efficiency and emission benefits.
- Major clean coal programmes are taking place in many other countries for both R&D and the construction of new plant. Whilst there are considerable R&D programmes in other countries the UK programme is relatively small and needs to be expanded.
- CO_2 capture and storage are essential and the technologies are in place. For the UK the estimates are that after 2010, 25Mt/year of capture and storage are required.
- There is a strategic link between CO_2 and H_2 technologies. This research is supported by the EU.
- The legal background and regulatory issues of the storage of CO_2 are important as is public perception. The safety and security of the CO_2 storage technologies is also paramount. If it is going into the trading scheme then it has to be verifiable and environmentally acceptable.
- Incentive methods for the capture and storage of CO_2 are important.

7 Infrastructure

Chairman:	*Dr Malcolm Kennedy, CBE FREng FRSE*
Speakers:	*Nick Wheeler, National Grid Transco*
	Dr Phil Jones, CE Electric UK
	Prof Robin McLaren, Formerly ScottishPower
	John Scott, Ofgem

7.1 Introduction and Background

The fixed infrastructure necessary for the supply of natural gas and electricity in the UK has remained largely unchanged in terms of both extent and technical characteristics for some 30 years. Such changes as have occurred have been incremental as a result of slowly growing demand and in the case of electricity, the introduction of a number of new large combined cycle gas fired generating stations which have otherwise required only modest extensions to the high voltage national grid system. The driver for change and innovation in the nation's local electricity distribution network has been even weaker.

Two unconnected events are now set to accelerate change in the gas and electricity infrastructures in a way that has not been seen for many decades.

Firstly, the recent but accelerating trend of sharply reducing gas supplies from the UK continental shelf means that the future demand for gas in the UK will have to be made up increasingly from sources outside the UK with new pipelines from the near continent and deepwater ports receiving liquefied natural gas from a wider market. The impact during the next few years on flows within the gas transmission network will be profound and reinforcements required will cost many hundreds of millions of pounds.

The second driver comes directly from the Government's decision to promote progressively increasing amounts of renewable electricity generation with a target of 10% of electricity supplied coming from such sources by 2010 rising to 15% by 2015. Most of this renewable generation will, in the short and medium term, come from onshore wind farms which by their nature will be much more distributed than has been the case with conventional thermal forms of generation. Moreover, the wind farms will generally be located in remote areas, distant from load centres, with a tendency to take advantage of windier locations resulting in concentrations of generation in coastal and northern areas.

7.2 Gas and Electricity Transmission, the Changes Ahead

Nick Winser, Group Director UK and US Transmission, National Grid Transco

In regard to the future supply of gas to the UK only about half of our demand will be delivered from the UK continental shelf by 2010 moving from a position of self sufficiency in the recent past. Significant imports will arrive from Norway and Holland over new sub sea interconnectors whilst new liquefied natural gas facilities will be completed at Isle of Grain and Milford Haven over the next two years. This will enable gas to be supplied from a much greater diversity of supply points than before.

The increasing diversity of gas supplies and points of supply will also mean that the flows on the gas transmission system onshore within the UK will change quite dramatically. It is also expected that there will be increased variability in the short term flows themselves (see Figure 7.1).

The level of investment required to meet this new pattern of supply will be of the order of £700 - £800 million thus enhancing the gas transmission network over the next few years and enabling it to accommodate both the new sources of supply and the fundamental changed flows within the UK itself.

Turning now to electricity, it is expected that there will be significant nuclear, coal and oil generating plant which will be closed over the next 10 years or so on account of age. This could amount to the removal of a total of some 11GW of this type of plant over the next decade. These retirements of plant would reduce the margin of generating capacity to less than 5% if no new plans were commissioned before the middle of the next decade.

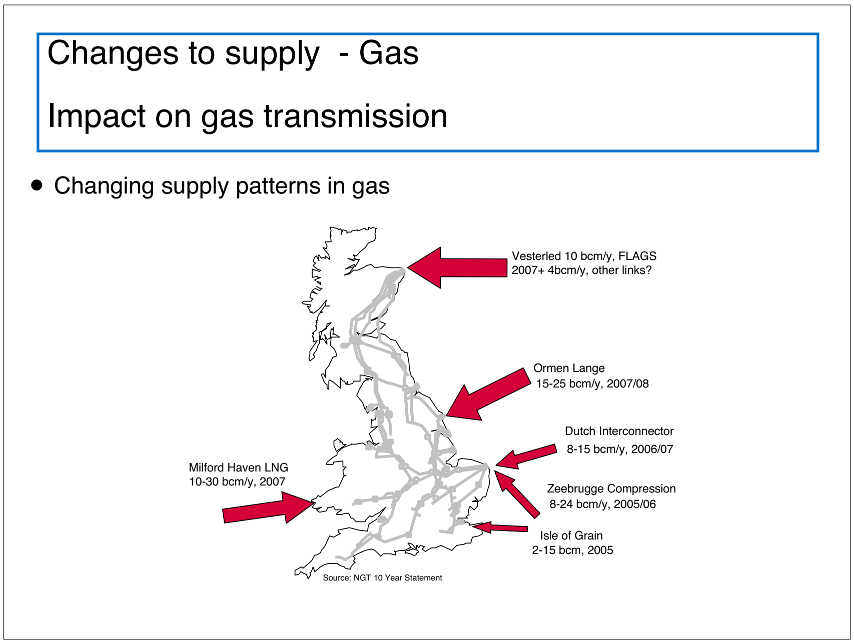

Fig 7.1: Changes to the Supply - Gas

One of the ways in which this gap in generating capacity will be filled will be through much greater development of wind power. Most of the additional wind power will be in coastal and northern regions and will bring about the need for significant new investment in the transmission infrastructure to deliver this energy to the demand centres.

In addition to wind power there are still many applications to build and connect new CCGT plants. The pattern of plant margin changes over the next 10 years is illustrated by Figure 7.2.

The possibility of building new nuclear generation, although unlikely to come onstream before the middle of the next decade, would also significantly alter power flows within the existing system, requiring future reinforcement to that system.

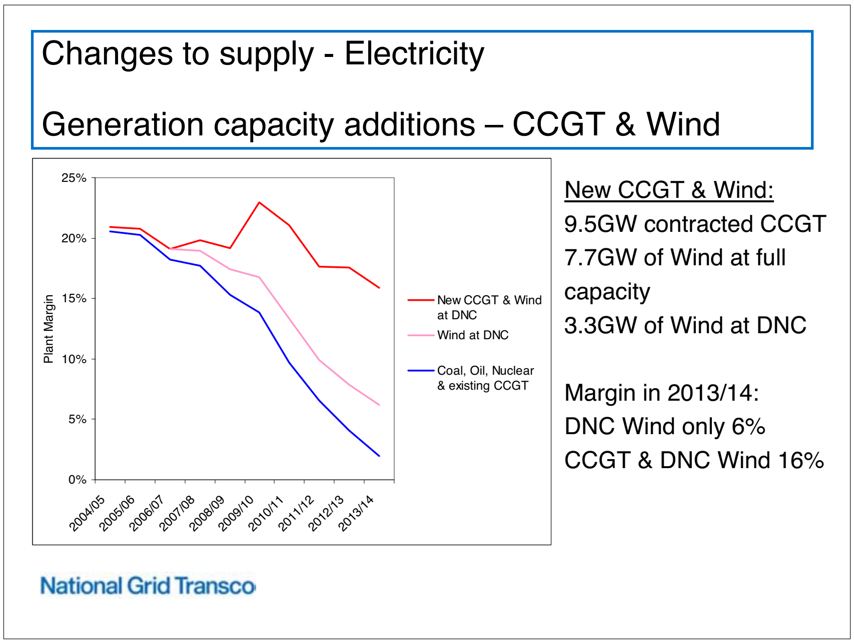

Fig 7.2: Changes to Supply - Electricity

Besides the fundamentally changing pattern of electricity flows that is foreseen in the future there is also a need for asset replacement within the system as it stands. Whilst the nominal lifetime of transmission plant and equipment may be assumed to be 40 - 50 years it is clear that the peak of activity of the 400kV grid between 1965 and 1970 cannot be precisely replicated in the future. Asset replacement must be carried out economically but at the same time in a way that does not compromise security of supply (see Figure 7.3).

When considering the expansion and asset replacement of both the gas and electricity networks, one of the main challenges in achieving the required results will be the availability of the people needed to design and deliver the required investments. The numbers needed will far exceed those that have been required in the recent past and new skills may also be required.

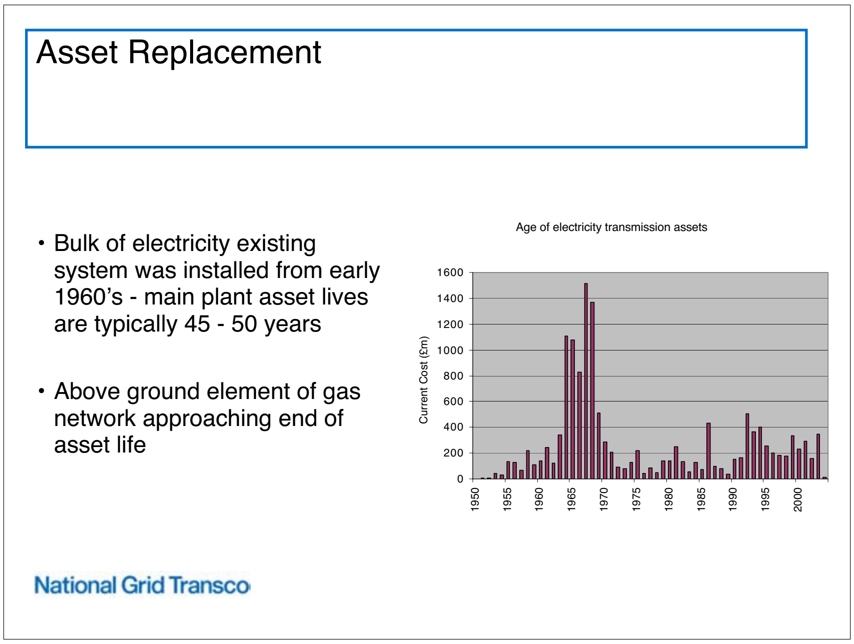

Fig 7.3: Asset Replacement

7.3 The Dinosaur's Destiny, the Outlook for DNOs in a Low Carbon Economy

Dr Phil Jones, CE Electric UK

Few would dispute that electricity distribution networks, their owners and employees have experienced little change since the early 1990s when the electricity supply industry as a whole was deregulated and privatised.

With this situation unlikely to continue much longer however, it may be wise to first decide what you would be (see Figure 7.4) and then do what you have to do (see Figure 7.5). The competences now required and those needed in the future have not been drilled into the organisations concerned. In other words, our history has not prepared us well for the future.

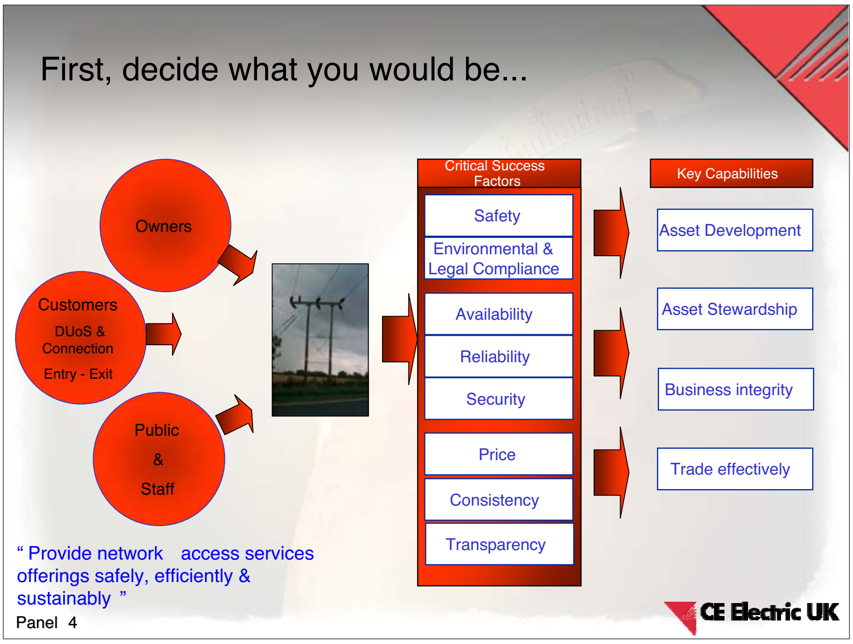

Fig 7.4 : Electricity Distribution Network - Aspirations

As with the transmission system described by Nick Winser, one of the major challenges facing Distribution Network Operators (DNOs) is the management of peaks and troughs of investment in the replacement assets. It is not enough to look at the age of different groups and types of plant and equipment but to find out what lasts and what doesn't and to discover as a result how patient different types of equipment are. This, in the new world of the future, means doing asset replacement better than before.

Superimposed on the need to replace ageing assets lies the huge level of investment required to accommodate foreseen distributed generation, forcing DNOs to forecast and guess the future with levels of uncertainty not apparent for many decades. Figure 7.6 summarises the challenge that lies ahead.

An additional feature of today's distribution network is their resilience and need to provide security of supply during emergencies and extreme weather. One way is to hope these emergencies never turn out to be as bad as they could. Another is to accept that they often will, coupled with the certainty that the public's tolerance of supply failure has also significantly diminished in recent years.

In common with other areas it is important to draw attention to the skills and manpower required in the future bearing in mind that perhaps 50% of the workforce in a typical distribution system organisation still has more experience of working in a nationalised environment than they have of the private era which has now lasted some 15 years. The DNOs must be ready for the future and all concerned must contribute to the need for change and excitement in the future.

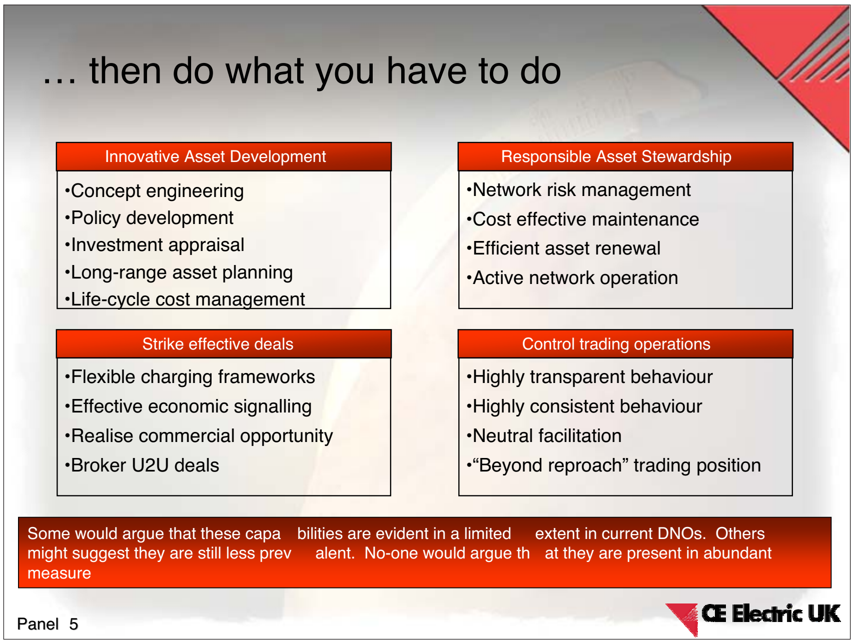

Fig 7.5: Electricity Distribution Network - Requirements

7.4 Sustainable Generation in the Wrong Place? Where Will the New Infrastructure be Needed?

Prof Robin McLaren, formerly ScottishPower

This presentation began with a few simple facts:

- 6.3GW peak load in Scotland.
- 2.2 GW of Interconnection to England.
- 9.7GW of existing generation.
- 1GW of wind under construction/connected.
- 15GW of wind applications.

This leaves 17.2GW with nowhere to go (and that doesn't include wave power).

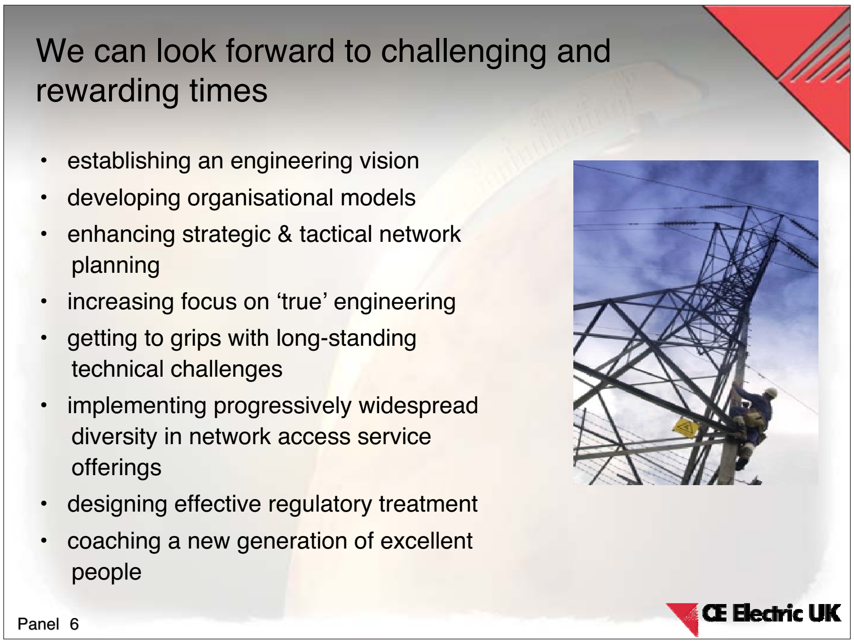

Fig 7.6: Distribution Network Operators – Future Challenges

There is some progress being made in the building of new transmission infrastructure, eg, the Beulie-Denny line upgrade in Scotland but the process of building major new infrastructure is hindered by regulatory and planning considerations and as a result is extremely slow. What needs to be done now is:

- Infrastructure needs to be built to anticipate demand with appropriate risk/reward for investments by regulated businesses.
- Major infrastructure changes needed to support renewable energy.
- We still need to move much faster in terms of regulation and planning.

Progress has been made but there is still a long way to go.

Figure 7.7 shows what has been achieved on the ScottishPower network. To allow new renewable generation to be connected the gap between what is needed and what has been achieved is growing.

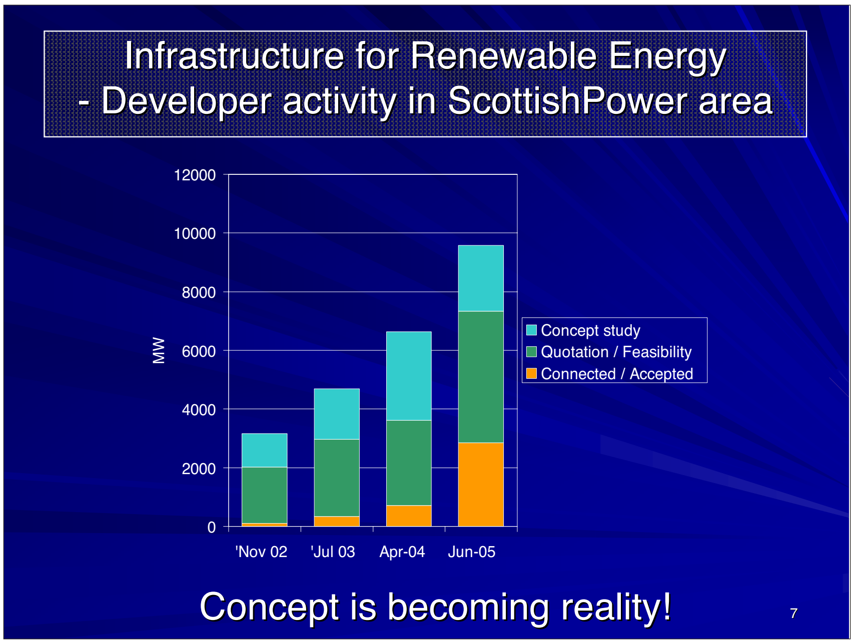

Fig 7.7: Infrastructure for Renewable Energy

With a high level of uncertainty surrounding the development of all renewables the way forward to provide the necessary supporting transmission infrastructure can be summarised as follows:.

- Regulator and government policy implementation need to be aligned.
- Conflicting criteria for investment need to be resolved, especially:
  - Urgency in decision making
  - Finding the economic optimum solution
  - Market timescales and planning timescales differ
  - Deciding who pays
  - Planning processes need streamlined within democratic framework

To remove the growing log jam of the transmission infrastructure four questions are relevant. These, along with Professor McLaren's answers are given below:

- Should large scale strategic infrastructure investment be left to markets? – NO
- Should we build the motorways before the traffic jams up? – YES
- Should we accept current timescales for decision making? – NO
- Should we change planning processes for national infrastructure projects? –YES

7.5 Regulated Networks – Fit for Tomorrow

John Scott, Technical Director, Ofgem

To meet the capacity and standards of supply required to deliver the future distribution of electricity the latest five year price control review outcome for the distribution companies is summarised in Figure 7.8 which shows a 48% capital expenditure increase over the previous period together with a 4.8% cost of capital, ie, the upper end of the range that was heavily debated. Both of these are seen as necessary to allow investment in the changing requirements of transmission and distribution networks

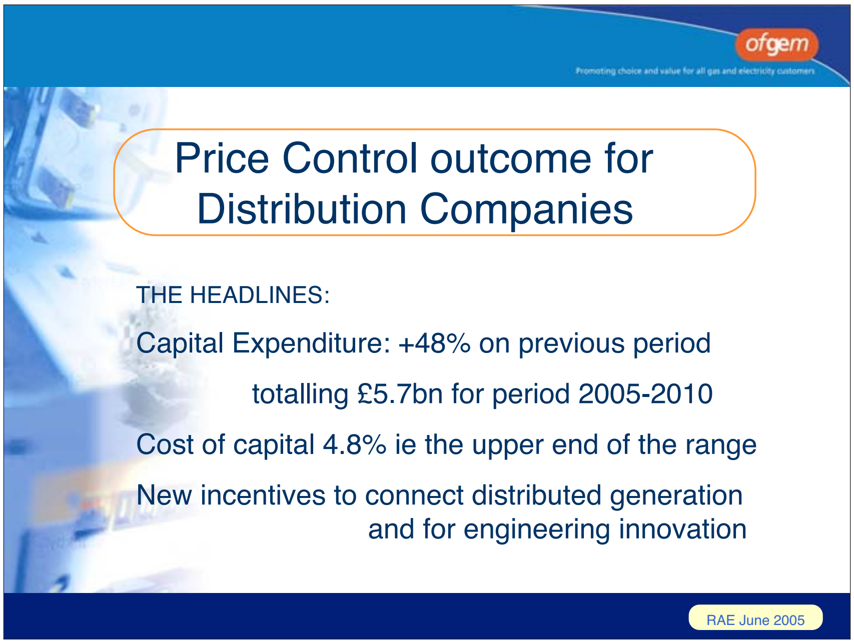

Fig 7.8: Price Control Outcome for Distribution Companies

The cost of connecting distributed generation has also been heavily debated and recent work shows that some 50% of the expected distributed generation can be connected at nil additional cost using up the 'headroom' provided by the presenters. A further 40% could probably be connected at less than £100 per kW but the last 10% will be of the order of £1000 per kW. In other words there is 'headroom' in the networks for connected distributed generation at present but it is clear that as this is used up cost of connection of distributed generation rises dramatically.

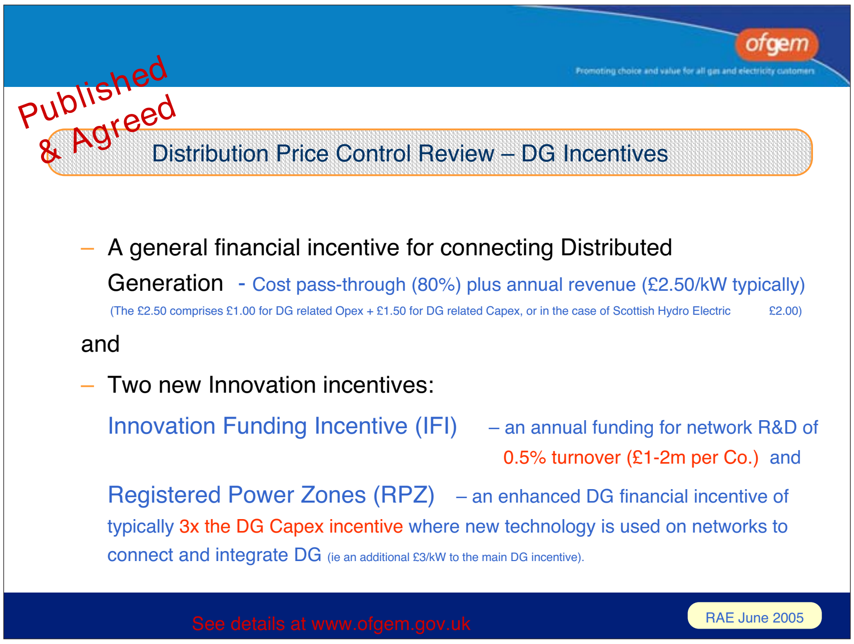

Fig 7.9: Distribution Price Control Review

The Regulator, Ofgem, has also introduced three new and significant incentives for the connection of distributed generation to distribution networks. These are described in Figure 7.9 and underline the need for and encouragement of innovation in the distribution networks as the level of distributed generation rises.

A full price review for the high voltage electricity transmission and gas transmission systems will take place, both for implementation in 2007.

All the speakers so far had indicated the need for increased levels and volume of skill. Perhaps one of the most important elements in this debate is the absence of what can be described as professional engagement. The activity of sharing ideas in a disaggregated industry in which competition between companies is characteristic has diminished. For the necessary innovation to flourish in the future it is essential that professional engagement must be redeveloped for the common good of the electricity supply industry. The principles underlying this important issue are described in Figure 7.10.

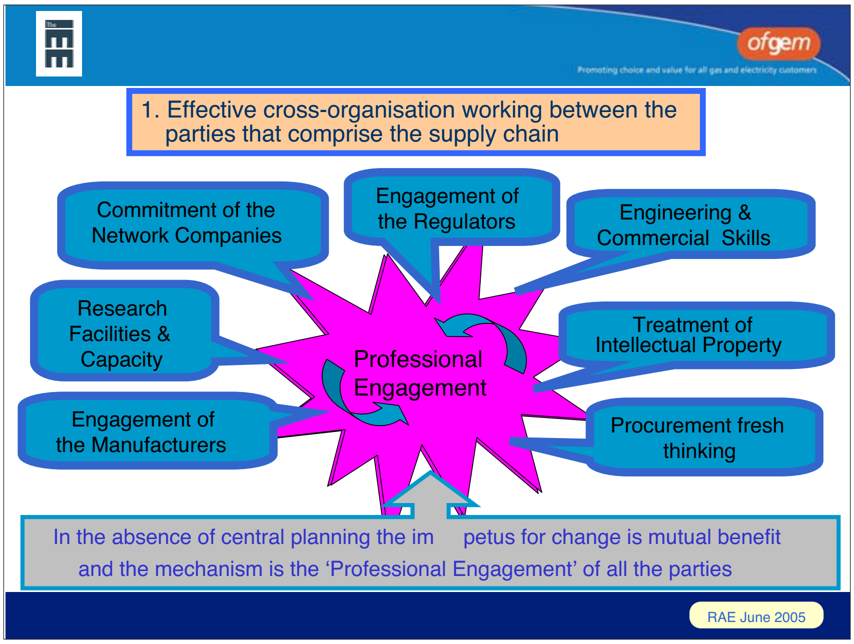

Fig 7.10: Principles of Professional Engagement

The key messages for the future may be summarised as follows:

- The path ahead reverses the trend of 50 years. Engineering innovation can be deployed to contain costs and find solutions.
- Ofgem has introduced new financial incentives for distribution companies to encourage R&D and network innovation for distributed generation.
- The whole 'technology chain' will need to participate actively if successful innovation is to underpin business growth.
- Lack of professional engagement is a threat to effectiveness – a wider conversation is needed if this is to be addressed.

7.6 Main Issues and Conclusions

The gas grid in the UK has been systematically developed over recent decades on the basis of imports from the UK continental shelf principally at St Fergus. Gas supplies from this source have started to diminish and the demand will be made good by supplies from Holland, Norway and the importation of liquefied natural gas from a variety of sources further afield. The combined result of the fundamental changes in points of supply and resultant flows in the onshore gas network will lead to significantly increased investment in the gas infrastructure over the next two or three years. This investment will help secure the UK's supply of gas by diversifying its sources of supply so as to maintain the security of supply of gas upon which, as a nation, we depend.

Whilst the seminar was interested to note the significant changes required in the gas infrastructure the vast majority of debate and unanswered questions surrounded electricity supply where far more uncertainties exist despite significant interventions in the past, and potentially in the future, by the Government.

The Government's policy of requiring increasing levels of renewable generating capacity, which in practice in the foreseeable future will be in the form of onshore wind, will require extensions to the national grid of an unprecedented kind. The grid has in the past connected to give sources of conventional generation based upon high levels of concentration. As much of the existing coal, nuclear and oil-fired plant is retired the number of points of concentrated generation will reduce. This will in part be replaced by much more dispersed sources, namely onshore wind, but also located in many cases where the grid is not readily available. The need to build new high voltage lines and substations to connect the new renewable generation faces significant regulatory and planning hurdles which are creating serious delays in the construction of these facilities. There is a growing feeling, taking an analogy with motorway construction, that the motorways should be built before the traffic develops rather than at present where the traffic is appearing in the distance without any significant motorway extensions to cope with the foreseen changes. The feeling persists that what is needed is a network capable of accommodating changes in government policy in terms of generation mix and one where investors in new plant have confidence that they can be connected. National Grid plc for its part must be sure that all generation must be properly connected but they too face the uncertainties of the amount, type and location of new generation plant as they seek to fulfil their obligations of securing supply to all consumers.

In terms of the nation's distribution networks where again much distributed generation is expected to be connected, fundamental changes in the way these networks will be designed and operated are becoming apparent. For the first time since privatisation of the energy supply industries (ESI) the distribution network operators must ask themselves what kind of networks they wish to own in the future. Technical issues of stability, power flow, and fault levels are being addressed but it is imperative that the business opportunities which underlie the whole movement towards more distributed generation must be both understood and grasped. The distribution systems have undergone little in the way of change in recent decades unlike most of the rest of the ESI but this period of business as usual is coming to an end.

In common with the national grid system the distributors are facing and will continue to face, extensive programmes of asset replacement. No longer is it sufficient to think only in terms of nominal age of plant. A smarter approach is needed to determine the patience and longevity of plant and then to replace accordingly so as to retain security of supply without exceeding expenditure which would be borne by customers.

The recent distribution price review has recognised the need, over the next five years, for significant increases in investment in the distribution network. Perhaps, more importantly, it also has provided, for the first time, new incentives for investment in new ideas. This is a welcome and necessary move from the Regulator.

A common thread running through all presentations and the ensuing debate is the need to provide the necessary people to conceive, design, provide and operate the new infrastructure networks into the future. Some of the old tried and tested skills and competences will be required as long as networks are needed but new skills and attitudes and an increasing number of those involved will be required to meet the challenges of the future. Most of these will contain uncertainties, some never faced before. This in itself may well attract the next generation who will serve the ESI.

One of the elements so important in the people side of the business is the urgent need for professional engagement which has been in decline since the end of the nationalised and centralised era of electricity supply. It is advised that if innovation is to prosper in the new paradigm, those who hope to share in its innovation and resultant prosperity must be prepared to share in the ideas that can only come from improved professional engagement and dialogue.

8 Oil and transport

Chairman: *John Baxter, FREng*
Speakers: *Wim Thomas, Shell International*
Graham McNeillie, BP Exploration
Prof Tony May, OBE FREng, The University of Leeds
Philip Maguire, Ford Motor Company
Rupert Furness, Department of Trade and Industry

8.1 Introduction

This seminar assessed future prospects for oil supply in the coming decades and the implications for the transport sector, particularly automobiles. It explored some of the technological breakthroughs that will be required to access oil reserves in the more challenging environments around the world and also considered alternative transport technologies. The speakers from the oil industry set the scene for liquid hydrocarbon availability in the future and how access to that will be maintained. The transport and regulatory speakers responded in the context of oil supply challenges overlaid with the restrictions being proposed through concerns about global warming.

8.2 Oil Supply and Demand to 2020 and Beyond

Historically, per capita energy use and GDP have been closely correlated: as economies become more wealthy, their energy use increases and, conversely, increased energy use is necessary for economic growth. Over the last third of the 20th century, however, this correlation broke down. Energy use became decoupled from GDP in advanced economies, which were able to continue economic growth without corresponding increases in energy consumption. But different economies reached a plateau at different levels of the energy/GDP relationship: in the US, energy use per capita stabilised at broadly twice the level at which the EU and Japan settled.

With this in mind, Wim Thomas, Head of Energy Analysis in Shell's Scenario Group, explored how oil supply and demand might develop over the next 20-25 years. His significant starting point was that over the last 10 years, energy intensiveness and GDP growth have become recoupled, and demand for energy is once again being driven by economic growth, principally in the rapidly industrialising economies of China and India. Absolute growth in energy demand in the developing world will dwarf that in the developed world over the next 20 years. Within this overall picture, growth in energy demand for power generation will outstrip that for transport or heat three times over. The key uncertainty in forecasting longer-term energy demand is whether the developing countries will reach a plateau at EU/Japanese levels of consumption, or at US levels.

Against this background, demand for oil is expected to increase by 20-50% over the next 20 years. At the same time, the rate at which new oil resources are being discovered is decreasing, and there is clear evidence that the peak phase of oil discoveries was passed 25 years ago. The top 100 biggest oil fields known hold 53% of all known resources, and all but two of these were discovered before 1970.

Non-conventional fossil fuel sources could potentially dwarf those of conventional oil resources. These include oil shales, heavy oils and bitumen. In addition, coal remains a major source of fossil energy, equivalent to twice the total volume of oil and gas. But by far the largest potential source of fossil energy is gas hydrates – particularly methane hydrate – which in total are larger than all other fossil sources combined. However, there are major technical, economic and environmental obstacles to the exploitation of all these non-conventional sources.

The next 25 years, therefore, are likely to see a continued tightening of the oil demand-supply balance. Coal will continue to play a major role, supplemented by a growing but unpredictable contribution from unconventional hydrocarbon resources and renewables. The increasing concern about, and the impact of, CO_2 emissions and global warming associated with all fossil fuel use will impose growing constraints. More effective carbon management will be the key to continued reliance on fossil fuels.

8.3 Technology Challenges to Accessing Hydrocarbon Reserves in Increasingly Hostile Environments

As the rate of discovery of new oil resources declines, those discoveries which are being made are increasingly in smaller, more complex reservoirs, found in ever more difficult environments: deeper water offshore, harsher climates, more remote locations. Exploitation of these resources poses much greater technological and engineering challenges. Graham McNeillie, Head of Engineering BP Exploration & Production outlined some of the main engineering challenges and implications.

Exploration and imaging technology has made great strides in recent decades. The use of massive computing power combined with leading mathematical talent has transformed the industry's ability to see into the reservoir, for example beneath salt formations, and has even begun to allow prediction of fluid type. Twenty five years ago, exploration had a success rate of maybe 1 in 10; now the aim is to do better than 2 out of 3. With deepwater and Arctic exploration wells costing $125 million each, this is obviously important.

Fifth Generation rigs now allow drilling in water 10,000ft deep. Extended Reach Drilling permits deviation up to 10 km from position. Steered drill bits allow manoeuvring through the geology to relatively tiny targets that may be several kilometres down and several kilometres away. Multi-lateral drilling enables several targets to be hit from one well. But the engineering challenges are formidable.

Operating in water 6,000ft deep requires extraordinary feats of engineering. Sub sea equipment has to be accessed remotely. This requires the capability to monitor, inspect and maintain very complex equipment on the sea bed. Fluids are increasingly arriving at the well head at higher pressures – 2,000psi – and higher temperatures – 400°C – and containing more and more sand as well as oil, gas and water.

Operating in remote locations requires the building of huge pipeline projects. For example, Bechtel has just completed the In Salah project for BP and Sonatrach, deep in the Sahara. BP is also just completing the Baku-Tbilisi-Ceyhan pipeline, crossing Azerbaijan, Georgia and Turkey. It is also planning projects in Kovitka, Eastern Siberia, and Alaska which, at about $15-20 billion each, will be two of the biggest projects ever undertaken. Such engineering requires the development of new materials, new welding techniques, new trenching methods; and new techniques for standards, testing and quality assurance. The next big challenge is to transfer these technologies to the Arctic, operating offshore in relatively deep water with rapidly moving ice.

There is still plenty of oil, but it will be ever more difficult to develop. And it will be an incredible challenge to find, develop and produce oil economically while maintaining safety and minimising damage to the environment.

8.4 Transport Challenges

Congestion costs the UK around £15 billion per annum, 15% more per capita than France and 40% more per capita than Germany. There are approximately 3,400 fatalities and 300,000 casualties each year on the UK's roads. Although this is one of the lowest casualty rates, time spent on road travel is still eight times as dangerous as the rest of everyday life.

Pollution levels have fallen, but transport is still a major contributor of many pollutants, and early deaths from traffic pollution may exceed 10,000 per annum. Transport contributes 21% of the global warming gases emitted in the UK, and up to 28% of the CO_2. Over a quarter of households still do not have cars, yet UK public transport fares are the highest in Europe, and bus services (outside London) are the least coordinated. Forty per cent of job seekers cite poor transport as a barrier to securing employment.

Some, at least, of these problems are likely to get worse. Road traffic may increase by 50% over the next 50 years, equivalent to all the traffic in 1977, with much of the growth coming from longer journeys. The EC predicts that congestion costs may double in the next decade, and CO_2 emissions could increase by 12% by 2015 and 30% by 2050.

Against this background, Tony May, Professor of Transport Engineering at the University of Leeds, drew on the Academy's recent report *Transport 2050: the route to sustainable wealth creation* to set out a vision of a land, sea and air transport system that would:

- underpin the continuing prosperity of the UK
- support wealth creation
- enhance quality of life
- respect the environment
- meet social needs
- contribute to long term sustainability

There is no single solution to the current challenges. Transport performs as an integrated system: poor public transport encourages car use; infrastructure investment stimulates longer journeys; growth in passenger travel disrupts freight; and inadequate ports and airports discourage international business. Accordingly, transport needs to be planned and operated as a system. A holistic approach is necessary, embracing pricing, infrastructure, management, technology and land use.

In a pricing approach based on true cost charging, all users would pay the true cost of their journeys, including those involved in providing, maintaining and enhancing the system, and the indirect costs of congestion, pollution and accidents. For road users, most charges would be distance-based, with higher rates in congested, sensitive areas and for less fuel-efficient vehicles, and with charges replacing vehicle and fuel taxes. Similar principles would apply to public transport and air travel, with simplified fare structures for bus and rail.

New infrastructure would still be needed, but it should reflect the changes in demand arising from true cost charges:

- new roads to relieve congestion, protect the environment, access ports
- rail investment to relieve bottlenecks
- guided bus and light rail
- port and airport enhancements

Better use of low cost traffic management would increase capacity on the national road network and in urban areas, and would be the most cost-effective route to reducing casualty rates. Regulated competition for buses outside London would provide greater control over service levels, fares and performance.

This vision depends on technological progress in a number of areas. New information technology will be necessary to operate true cost charging, to provide better information to operators and users, and to enhance safety. Continued development of vehicle and engine technologies is needed to reduce pollution and CO_2 emissions and to achieve greater fuel efficiency. Improving environmental protection also requires better infrastructure design and maintenance.

Land use policies on their own will not significantly reduce travel, but the right policies can make transport policies more effective. Land use policies should promote:

- higher density development
- development in association with public transport
- limited private parking provision in new developments

Major developments should not be countenanced where transport cannot meet their needs.

Achieving these objectives requires more effective government action. The Department for Transport should develop a national strategy covering all modes and policies, looking ahead at least 30 years, which would ideally attract all-party support. Regional and local strategies should be developed within that context, with implementation delegated to effective agencies operating at arm's length from the Government:

- a National Roads Corporation
- a National Rail Corporation
- regional, conurbation and local authorities
- private sector contributing within the context of the strategy

Government action is needed now, particularly on pricing and infrastructure, and commitments need to be long term and consistent.

Such a vision would have some implications for future oil demand. These would follow a reduction in the demand for travel, a substantial transfer to more fuel efficient modes, and reduced congestion and energy inefficiency. However, these will be secondary benefits from adopting a genuinely holistic strategy to meet the UK's current transport challenges.

8.5 Alternative Automobile Transport Technologies

Although some level of increase in atmospheric CO_2 concentrations (eg, a doubling to 550ppm) might be manageable, it is clear that current trends would produce concentrations of 1000ppm and above, with unacceptable impacts on global warming and sea levels. Man-made emissions of greenhouse gases will have to be reduced dramatically to avoid catastrophic impacts. But even reducing the *growth* in CO_2 emissions to ~20% by 2030 will be a huge challenge. Hence 'business as usual' is not a viable strategy.

Philip Maguire, Director of Powertrain International Operations for the Ford Motor Company, discussed vehicle and propulsion technologies in the 2005 to 2020 period from a fuel economy perspective, and examined the impact of tightening emissions standards, the development of competing technologies and market place drivers.

New vehicle technologies can make a significant impact through weight reduction, optimisation of aerodynamic performance and reduced rolling resistance. For example, the new Ford Mondeo uses a high-strength steel body structure to help reduce weight by 30%; the aluminium-bodied Jaguar XJ achieves a weight reduction of 40%. Over time, such technologies can contribute significant benefits. New powertrain technologies (hybrid engines, bio-fuelled engines and hydrogen fuel cells powered by renewable generation) are capable of reducing overall 'well-to-wheel' CO_2 emissions by up to 80% compared with conventional gasoline. A CO_2-neutral hydrogen fuel cell powertrain could be achievable within 30 years.

However, such technological advances carry economic costs and there is evidence that the costs and benefits are converging, weakening the economic incentive for continued development. An integrated approach is required, with responsibility shared between the automotive and oil/chemical industries, public policy and customers to achieve targets agreed by the whole community, feasibly and cost effectively.

Despite the fact that large-scale societal trends are driving towards zero emissions – of both CO_2 and noxious gases - consumer demands for increased safety, features and performance often conflict with this. No single solution can reconcile these conflicts. Multiple technology options exist, generally at different states of readiness and offering a spread of cost/benefits, and each needs to be evaluated on a 'well-to-wheel' basis, reflecting total greenhouse gas emissions across the complete fuel chain.

8.6 Government Policy and Associated Regulatory Issues

Transport is central to the performance of the UK economy, and to personal freedom, but it is at the same time a major contributor to climate change and air pollution. Transport currently accounts for ~25% of total UK CO_2 emissions – road transport alone contributing ~20%. Emissions of CO_2 from the transport sector continue to rise, by 10% from 1990-2000, and are likely to rise by another 10% or so between 2000 and 2010. Road transport is responsible for the majority of air pollution problems in UK city centres, and has other adverse environmental and social impacts.

The Government's policy, set out in *The Future of Transport: a network for 2030* (July 2004), sets out "to balance the increasing demand for travel against our goal of protecting the environment". Rupert Furness, Department of Transport, explored some implications of the Government's perspective on the low carbon transport agenda, and considered how the Government could best encourage the development of clean, low carbon vehicles and fuels. Key policy initiatives are aimed at:

- Improving the environmental performance of vehicles – and encouraging people to buy them.
- Promoting the use of clean, low carbon fuels.
- Complementary objectives, including reducing the need to travel, encouraging people to use alternatives to the car.

In pursuit of these aims, the Government has introduced supportive vehicle tax and company car tax regimes which encourage reduction in CO_2 emissions, with reduced rates for alternative fuels including LPG, CNG and biofuels. The Government is also supporting research, development and demonstration programmes. Longer term targets have been set, for instance that by 2012, 10% of all new cars sold will have CO_2 emissions of less than 100g/km, and that by the end of 2005 0.3% of total road transport fuel sales will be from biofuels.

Other initiatives include improving consumer information, for example through new car labelling; grants to support the take-up of new low-carbon vehicles; and Government's own procurement of clean, low carbon vehicles and fuels.

As a consequence of such initiatives, good progress is being made on emissions of air pollutants from road transport: total emissions of NOx and particulates have fallen by more than 50% since 1990, despite the increase in traffic volumes, and are likely to reduce by a further 20% or so by 2010. Progressively tighter European standards will deliver further reductions.

Some progress has been made on average new car CO_2 emissions, largely as a result of the Voluntary Agreements between the EU and the automotive industry: the average new car fuel efficiency has improved by about 10% since 1995, delivering significant carbon savings. However, progress has slowed somewhat in recent years as a result of people's tendency to choose larger vehicles.

There have been huge improvements in petrol and diesel specifications – low sulphur fuels have been mainstream in the UK for several years, ahead of EU deadlines. The Government has also supported clean, alternative fuels: the UK is currently well on track to meet a biofuels sales target of 0.3% of total fuel sales by the end of 2005.

In the longer term, reducing total CO_2 emissions from transport to very low levels will require a move to low carbon fuels. Advanced biofuels and renewably-produced hydrogen look the most promising options here, although there are real uncertainties over economics and technology. As part of its evaluation of options for a road pricing system, the Government intends to ensure that incentives for cleaner vehicles are safeguarded in order to contribute to meeting its environmental targets.

9 Nuclear Fission

Chairman: *Brian Eyre, CBE FREng FRS*
Speakers: *Dr Robert Hawley CBE FREng FRSE*
Dr Regis Matzie, Westinghouse
Keith Parker, Nuclear Industry Association
Veijo Ryhänen, TVO Finland

9.1 Background

The UK pioneered the introduction of civil nuclear power in the 1950s in an era of enthusiasm for new technology but also driven by the need to ensure future security of supply. Over the next 40 years some 14GWe of capacity was built largely based on UK developed technology and this provided up to some 30% of demand by the mid 1990s on the introduction of Sizewell B.

However, the development of North Sea oil and gas together with our long standing extensive coal resources meant that by the end of the 1980s the UK was perceived as being energy rich reflected by our role as a net energy resource exporter. This together with a decline in confidence in the economic and technical viability of nuclear technology meant that plans to order further additions to our nuclear generation capacity were abandoned by the early 1990s. Over the period following privatisation of the CEGB in 1989 the market was price driven and investment in new nuclear plant with its high capital cost and high perceived risks was unattractive. The result is that on the basis of present commitments the nuclear contribution to electricity demand is expected to decline to about 5% in 2020 when only Sizewell B of the present stations will remain in operation.

In the 1990s we entered a period of intense investment in the much less capitally intensive combined cycle gas turbine generation plant supported by an apparently abundant and cheap supply of fuel. This had been accompanied by a dramatic fall in electricity prices. Nuclear power (along with coal and the emerging renewable technologies) was unable to compete in such a market. But as we have moved to the 21st century the market drivers have undergone a further shift. The need to reduce carbon emissions to combat the threat of global warming together with growing concerns about the price and supply security of oil and gas have become more dominant factors.

Over the last decade the Government has introduced measures including substantial financial inducements to stimulate development and investment in renewable generation plant. As a result, on-shore wind generation currently provides about 3.5% of demand and current policy is for renewable capacity to increase to 10% by 2010 and 20% by 2020 largely from a combination of on-shore and off-shore wind. But these are challenging targets and in the face of growing concerns over gas price stability together with possible threats to supply from distant overseas sources, there is a recognition that the present renewable generation programme alone may not meet our strategic goals particularly regarding reductions in carbon emissions.

The 2003 Energy White Paper, while keeping open the possibility of future investment in nuclear technology, was distinctly unenthusiastic stating, the current economics of nuclear power make it an unattractive option for new generating capacity and there are important issues for nuclear waste to be resolved. This position was based on past UK experience, including the accumulation of a large nuclear waste legacy. But developments since the White Paper and particularly sharply rising oil and gas prices, plus increasing CO_2 emissions have changed the strategic and market drivers, with the question of investment in new nuclear stations again being raised. Moreover, decisions on investment in the technology should take account of best modern practice and of international experience.

This forms the background to the Royal Academy of Engineering seminar on Nuclear Fission which was aimed at an objective consideration of the parameters impacting on the exploitation of nuclear power particularly from an engineering viewpoint. This chapter summarises the main points made in the opening talks and in the ensuing discussion.

Since the seminar, concerns over rising carbon emissions levels and volatility in the fossil fuel markets, particularly oil and gas, has received increasing attention in the media and elsewhere. The Government's recent review of energy policy concluded that nuclear energy would make a significant contribution to addressing these concerns and it is in the process of drawing up a policy framework for any proposed new nuclear build which will be detailed in a forthcoming Energy White Paper.

9.2 Nuclear Power in the UK – Past and Present

The seminar opened with Bob Hawley's paper summarising the UK experience with its nuclear programme. This emphasised the uniqueness of the technology based on gas cooled and graphite moderated Magnox and Advanced Gas-cooled Reactors (AGRs) compared to the dominant water cooled and moderated technology adopted by the rest of the world. The programme of 11 Magnox stations encompassing 44 reactors, of varying design, commissioned over the period 1962 to 1973 encountered some technical problems as expected on introduction of a new technology. But this phase of the programme was reasonably successful and eight of the stations remain in operation today, with planned closure over the next four years. The decision to follow the Magnox programme with the AGR system flew in the face of the international position in which most countries were basing there nuclear power programmes on water cooled and moderated reactor designs (with the notable exception of the former Soviet Union who also adopted the disastrous RBMK design).This meant that the UK programme was dependant on national technical capability. The programme was beset with difficulties: with a diverse industry structure, different designs and a stop go ordering strategy particularly after the first tranche of three stations had been ordered. This reflected uncertainties in national policy, for example the question of preferred reactor type was revisited a number of times between the mid 1960s and the end of 1970s. While seven AGR stations were ordered over a 15 year period from 1965 their performance has been mixed and most recently they have suffered from a lack of investment in care and maintenance so that today their performance falls well short of best international experience with Light Water Reactor (LWR) systems. It is worth noting that the UK belatedly decided to move to the Pressurised Water Reactor (PWR) system with the ordering of the Sizewell B system and after a protracted planning and licensing process this came on stream in 1995 and has since performed to international standards. However, only one reactor to this design was built, the plans for a further four being abandoned on privatisation of the generating industry. Thus, while being technically successful Sizewell B has proved expensive carrying all the first of a kind costs.

As Dr Hawley emphasised, this UK nuclear experience should not be the determining factor in a decision on whether to build new nuclear stations, although it is clearly essential to learn the lessons from our past. These include series ordering of plants to a consistent design from an internationally respected vendor, clarity in licensing, planning and nuclear waste management policy, simplicity and consistency in the market drivers particularly with regard to stimulating carbon free technologies and technically competent management in the construction and operation of nuclear plants. Many of these key messages were made by the other speakers and in the discussion.

9.3 Building New Nuclear Plants to Cost and Schedule – An International Perspective

Regis Matzie summarised international experience in building new nuclear plants and outlined the essential requirements for success. Considerable progress has been made since Sizewell B in LWR design with the new simplified systems incorporating passive safety features as exemplified by the Westinghouse AP1000 PWR. As demonstrated by the French in the 1980s the requirement to reduce

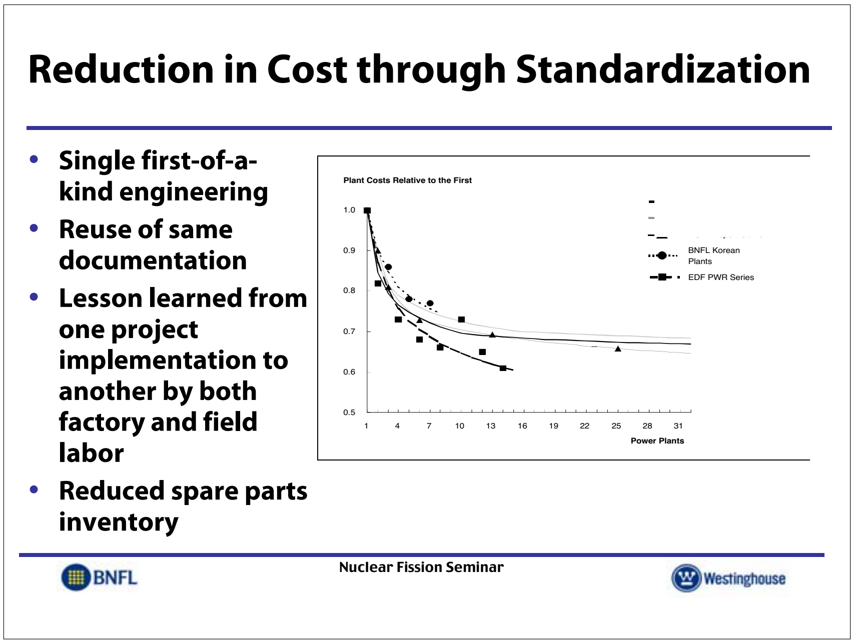

Figure 9.1: Reduction of Cost through Standardization.

capital and construction costs is to series order and experience shows that a series of at least 4 to 5 of constant design can reduce total project costs by about 30% as shown in Figure 9.1. The UK civil nuclear programme has never met this simple criterion.

International experience, particularly in South Korea with its standardised national PWR, shows that construction times of four years and a specific capital cost of about £1600 per kWe can be achieved, see Figure 9.2. China is set to follow the South Korean example with its planned programme of 30 new reactors standardising on an advanced PWR design, the location and type of these reactors is illustrated in Figure 9.3. On the other hand, the performance of Japan, also strongly committed to nuclear power, has not been so impressive due to a combination of industry and political issues, resulting in high construction costs and long build times. Nevertheless, more recently, substantial improvements have been made with the new Advanced Boiling Water Reactors (BWRs) installed by Tokyo Electric Power.

Worldwide, 25 nuclear stations are under construction in 9 countries predominantly of the LWR type and this is set to increase substantially with the Chinese programme. In addition, in the USA, Government and industry are working together to resume their civil nuclear construction after a gap of some 25 years. France is also laying plans to start building new PWRs to the European Pressurised Water Reactor (EPR) design to replace its ageing stock of PWRs. Looking ahead there is international cooperation in developing so-called Generation IV with High Temperature Gas Cooled Reactors being a front runner. Designs such as the South African Pebble Bed Modular Reactor (PBMR) are modularised which can offer greater flexibility in both construction and operation that can offset the well established economies of scale, see Figure 9.4. Dr Matzie suggested that with our long experience of gas cooled reactor systems the PBMR could be a candidate for a new reactor build programme in the UK depending on timing.

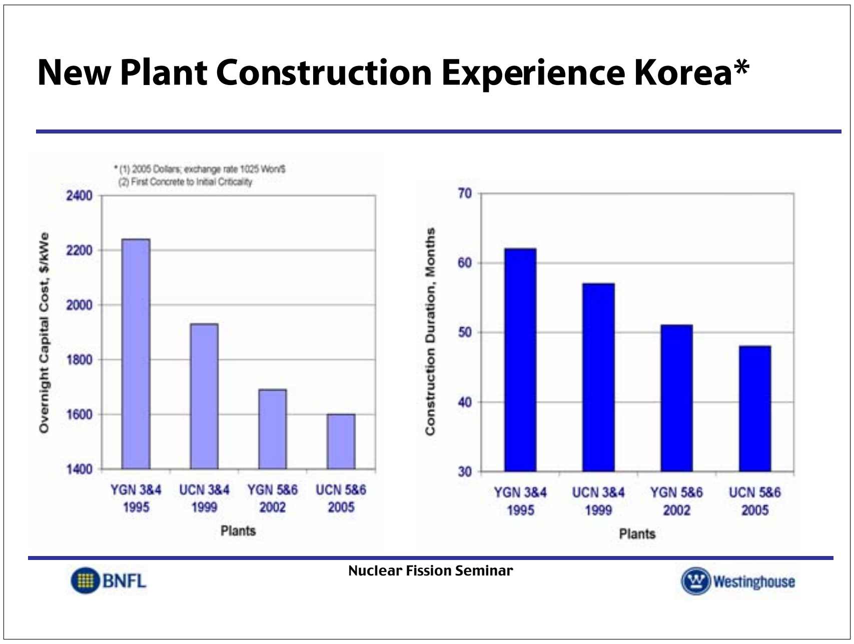

Figure 9.2: New Plant Construction Experience Korea.

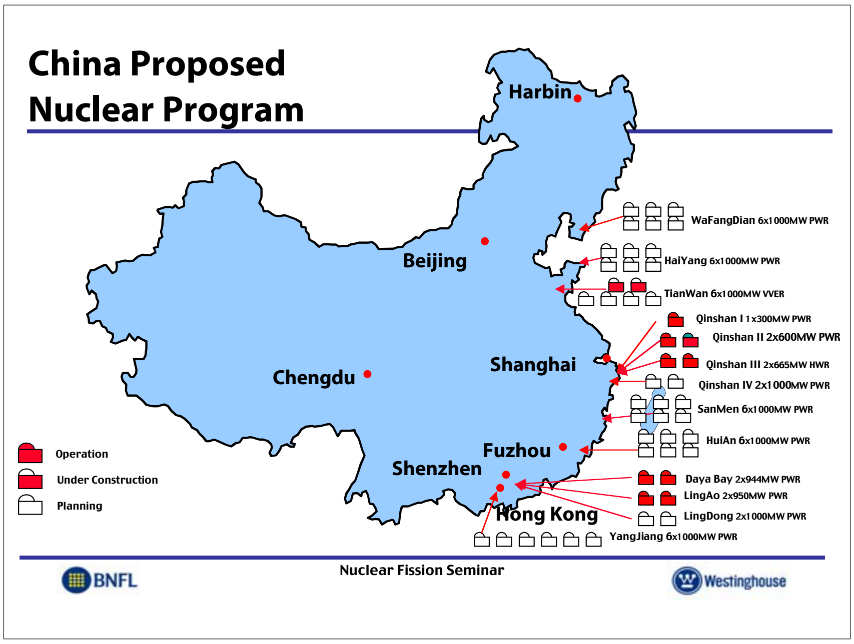

Figure 9.3: China Proposed Nuclear Program.

The overall conclusion from Dr Matzie's talk is that by adopting best international practice together with the advanced simplified reactor designs the UK could overcome the problems typified by its past experience and construct new nuclear stations economically in terms of time and cost.

9.4 Energy Supply in the UK and the Need for New Nuclear Build

Keith Parker outlined the UK industry position regarding new nuclear build. Key factors include the change in market drivers due to threats from global warming and security of supply, as indicated in the Prime Ministers speech to the Labour Party Conference in September 2005, and the risks of depending entirely on renewable energy production and increased energy efficiency to meet these threats. Nuclear power is an established technology that can meet our base load requirement with zero carbon emissions. Looking specifically at the UK's requirements there are a number of reactor designs that could potentially be economically competitive and contribute to meeting our goals of reduced carbon emissions and energy security.

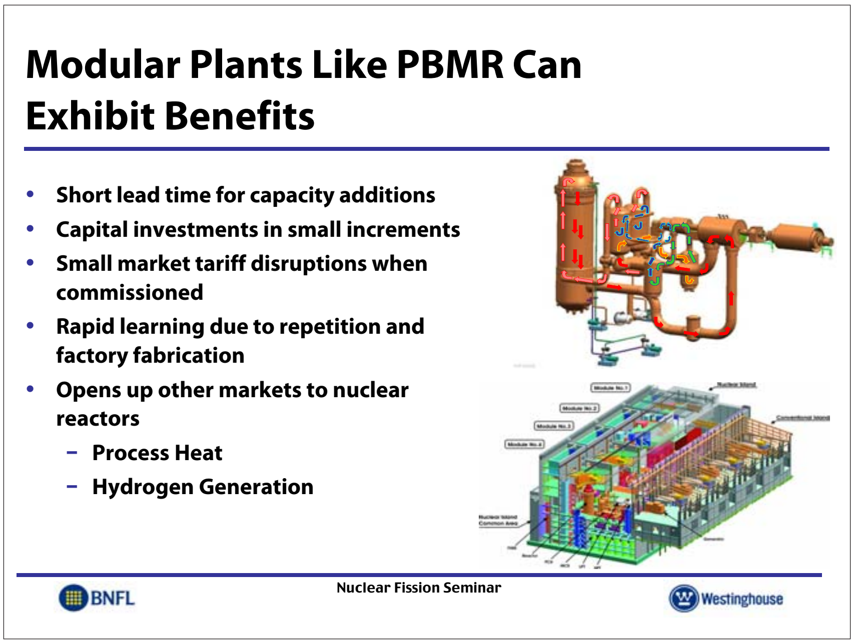

Figure 9.4: Modular Plants Like PBMR can Exhibit Benefits

In considering investment in new nuclear plant in the private sector the generating industry require assurance on a number of issues relating to political framework and market structure. These include a stable regulatory and planning framework, a long term strategy for nuclear waste management, consistency in market measures to support climate change and security requirements and the need for longer term supply contracts (a necessity for any capital intensive technology). It is vital that the forthcoming energy White Paper considers these issues with the aim of arriving at solutions that are consistent with a competitive framework but that at the same time provides the necessary incentives for investment in any new technologies that can contribute to the UK's strategic energy objectives.

9.5 Nuclear Waste Management – The Finnish Approach

A major issue for nuclear power world wide is to have a secure waste management strategy in place and to win public support for the strategy. A number of countries have made progress in resolving this issue and Finland is a particularly successful example which was a key factor in its recent decision to order a new PWR station to the Franco-German EPR design. Veijo Ryhnen outlined the essential elements of the Finnish approach to nuclear waste management.

Finland's Government has played a central role in defining policy on nuclear waste management starting in the 1980s and in winning public support for the policy. Implementation is simplified by having a single nuclear utility, TVO, who have led the programme to develop the necessary facilities for the long term safe storage and disposal of the waste.

The decision of where to store and dispose the waste was simplified by the uniformity of the underlying geology in Finland which is crystalline bedrock. Thus it has been possible to construct two underground repositories for low and medium level waste at the Finnish nuclear power sites. These two categories account for a large proportion of the operational (and decommissioning) waste and having the repositories at the power station sites eliminates the need for transport of the waste with its associated risks. The repositories are designed to allow extension to accommodate the decommissioning waste.

This leaves the issue of spent fuel management. In common with international practice interim storage is in water tanks at the power stations. But Finland has been planning for final disposal of the spent fuel since the early 1980s with good collaboration being maintained with neighbouring Sweden who are following a similar strategy. The Government took the lead in arriving at decisions regarding the strategy for final disposal in 2000 and ratified by Parliament in 2001. The endorsed process is deep disposal in crystalline bedrock and a site has been selected for the repository at Olkiluoto.

Construction of an underground rock characterisation facility at this site is underway and the plan is for this to be further developed into the repository for spent fuel following preparation of the preliminary safety analysis report, submission of the construction license application will be made to Government in 2012. It is intended that disposal of spent fuel in the repository will start in 2020.

Thus the lessons from the Finnish approach to nuclear waste management is long term planning underpinned by a consistently supportive political framework that played a key role in gaining public confidence.

9.6 Key Points raised in Discussion

There was extensive discussion following both the talks and in the final part of the seminar. This was constructive and mainly focussed on the key factors in the UK relating to starting a new nuclear build program. The following summarises the main points covered in the discussion.

Industrial Capability and Skill Base: Doubts were raised about whether the UK now had the capability to play a significant part in the construction of new nuclear stations. The point was also made that if we depended on overseas suppliers for the majority of the hardware there could be supply bottlenecks for key components such as steel forgings for the reactor pressure vessel due to a scarcity of facilities and existing orders for plants elsewhere in the world. However an NIA survey of its industrial members has concluded that UK industry has the capability to play a substantial role in a new build program. Nevertheless the general message was that if the UK decided to embark on construction of new nuclear stations an early commitment to procurement of key major components would be important. On the related point of skill base and renewal via the introduction of young nuclear engineers there was agreement that there has been a serious loss of key skills over many years. This is widely recognised by Government and industry and some steps have been taken to raise the profile of nuclear science and engineering in universities. But it was agreed that this is inadequate and there is an urgent need for radical steps backed by resources to attract young people to engineering and particularly nuclear engineering. While industry clearly has a role, for example through the provision of student bursaries and graduate apprenticeships, Government must also act in its role as custodian of our education system.

Engineering Factors: It was agreed that for a new build program to succeed it will be essential for there to be a series ordering of reactors to a consistent design and specification. Regarding choice of systems that are available today, realistically this is restricted to LWRs with three or four possible vendors. If a decision on new build were to be delayed for five or so years so-called Generation IV designs might be considered with the South African PBMR currently in a lead position in terms of technology readiness. The modern designs incorporate passive safety features and as well as being of lower capital cost, they are also easier to decommission with less associated waste than older designs. Project management performance has significantly improved and this has been facilitated by the use of computers to optimise plant layouts and construction schedules. It was agreed that decisions on choice of new reactor types would rest with the ordering utility and that it would be commercially driven requiring the raising of finance in the private sector. Nevertheless it was recognised that Government could influence the decision as custodian of the regulatory and planning processes.

Market Conditions: There was extensive discussion about the conditions in the UK electricity market and the requirements for new nuclear build to be viable. It was agreed that direct government subsidies would not be available and a wholesale revision of the present liberalised market structure was also not possible. But there was a demand for a level playing field to be applied to carbon free generation technologies. In particular, the application of the climate change levy to nuclear power was considered to be illogical. In addition, as advocated in a recent Royal Society report, there was strong support for greater simplicity and it was suggested that this could be accomplished most straightforwardly by the application of a carbon tax to all carbon emitting technologies including transport and other users of fossil fuels. Such a tax would directly stimulate investment in carbon free technologies including nuclear power in the generation sector. The alternative being pursued is the EU emission trading system which may have a similar outcome once the carbon price level has settled down. While market related economic measures could meet the level playing field requirement, there is also a need for assurances on consistency in regulation, planning requirements and a long term waste management policy. It was noted that as things stand the Nuclear Installations Inspectorate do not have the resources to conduct advance licensing of plants before a specific application is made by a utility. This also raised the question of moving to an international licensing framework (such as applies to civil airliners). However this is unlikely to be on a timescale to impact on new nuclear build decisions in the UK in the short to medium term. Reference was made to the position in the US where advance licensing and planning approval for sites is in place and the recent Energy Bill provides for tax advantages in the early stage of a new build program and Federal insurance against the political risk associated with regulatory delays. US public opinion has been moving in favour of nuclear power in recent years and currently a number of utilities are making plans to order new nuclear plants. Thus while it was agreed that direct government subsidies for new nuclear build are not realistic, Government would have to initiate some changes to enable commercial decisions on new build. It is hoped these issues will be addressed in the forthcoming Energy White Paper.

Nuclear Waste Management: The advantages of the position in Finland in having an agreed long term strategy for waste management which has been developed alongside the ordering of new nuclear plants were recognised. This has been a key factor in establishing the basis of confidence for investment in nuclear power and in winning public support. It was also agreed that having a waste fund created through an appropriate levy on nuclear electricity prices had the merits of transparency and simplicity. This process is adopted in a number of countries and in the US the nuclear waste fund currently stands at $23 billion. It was pointed out that Nuclear Electric and British Energy (BE) had also built such a fund through a levy on its electricity tariff that had reached some hundreds of millions of pounds at the time of the recent restructuring of BE. But it was reported that the waste management fund was not refinanced when the recovery package was put in place. More generally it was commented that large though the present UK legacy waste liabilities (at around £50 billion) are, if nuclear power had been replaced by coal fired stations the environmental costs would have been around £60 billion (quoted from a European ExternE Report). An important lesson from the Finnish experience is that an agreed waste management strategy is in place in a liberalised electricity market that is supported by all of the stakeholders: Government, public, utility and consumer. For the UK it is essential that similar agreement is reached between Government and nuclear industry on a long term nuclear waste management strategy.

Reprocessing: Although not covered in the presentations or discussion at the seminar, the question of the fuel cycle and reprocessing is an important issue impacting on the future of nuclear power. There is disagreement internationally on the role for reprocessing particularly between the US which is opposed on the grounds that it increases the risk of proliferation and a number of countries having substantial civil nuclear programs. France and Russia are committed to reprocessing civil reactor fuel in order to recycle the separated uranium (U) and plutonium (Pu) thereby gaining additional benefit from the uranium resource. The UK also operates reprocessing plants at Sellafield. This is partly driven by the need to reprocess fuel from the Magnox reactors, a requirement that will end following closure of the civil Magnox reactors by around 2010. But BNFL also operates THORP to reprocess fuel from the AGRs without any plans to recycle the separated uranium and plutonium. In addition the THORP plant is used to sell reprocessing services (along with France) to other European countries and Japan. Japan is in the final stages of building its own reprocessing plant and a central part of its civil nuclear strategy is to recycle separated U and Pu first in its LWRs and then in fast reactors. India is also aiming to close the fuel cycle ultimately using fast reactors and has a significant development program supporting this objective. In addition, South Korea has stated a wish to follow a fuel recycle strategy but has not constructed a reprocessing plant to date.

Thus, the position internationally regarding reprocessing is complicated. The case for reprocessing rests on two main arguments. First, to recycle fuel particularly in fast reactors substantially increases the energy obtainable from the natural uranium resource by a factor of some hundreds and closing the fuel cycle with the objective of burning the actinide elements that are an inevitable result of nuclear fission. This is seen as being consistent with sustainability. But the strength of this argument has been weakened by the slow expansion of nuclear power internationally and the present abundance of natural uranium. Thus we have seen a marked decline in programs to develop fast reactor technology, the main remaining players being Japan, Russia, India and France. The UK, along with Germany and the US stopped their programmes some 10 -15 years ago. The second leg of the argument for reprocessing is that it reduces high level waste volumes by recycling the separated actinides rather than leaving them in spent thermal reactor fuel for disposal as waste. The actinide elements are the longest lived isotopes in spent fuel and there is an international program having as its prime objective the separation and burning of these elements in fast reactors. The achievement of this objective would require relatively few fast reactors. However this does have to be balanced against the disadvantage of producing larger volumes of intermediate level waste that would have to be disposed of most probably in underground repositories.

In the context of the present debate on whether the UK restarts its civil nuclear program, the question of whether this includes reprocessing and fuel recycling does not have to be addressed in the short to medium term. The question may have to be revisited if there is a major expansion of nuclear power internationally and uranium supplies become potentially limiting or the advantages in reducing high level waste volumes becomes established. The UK's investment in developing reprocessing technology could then prove valuable. Keeping this option open does have a bearing on our nuclear waste management strategy in the shorter term in that spent fuel should not be treated simply as waste but be placed in repositories from which retrieval is possible.

10 Security of Supply

Chairman: *Professor Nigel Lucas, FREng*
Speakers: *Professor Robert Mabro, CBE, Oxford Institute of Energy Studies*
Ms Sylvie Cornot-Gandolphe, International Energy Agency
Professor Michael Laughton, FREng, Emeritus Professor, University of London
Mr Tahir Majid, Centrica
Dr Boaz Moselle, Brattle Group

10.1 Background

Security of energy supply means different things in different contexts. For the purpose of the seminar it was taken to have three main attributes:

- Reliability
- Security
- Sustainability

Reliability is the question of whether the systems we build can provide predefined levels of service in the context of familiar stresses for which we can provide reliable statistical descriptions such as climate or plant performance and increasingly rather more complex issues to do with the generation from intermittent sources. Physical failures in energy supply may arise from failures in production, transmission or distribution. Generation and transmission failures are rare, but when they occur then they affect many people. Failures of distribution are common but affect few people. It is relatively easy to know what improvement in reliability can be obtained by an incremental investment in generation or transmission, but the relationship between investment and improved reliability in distribution is much less clear.

There is another important distinction between generation and network failures. In the modern liberalised industry model generation is a competitive business but the network businesses are regulated. In the network businesses the assurance of reliability depends on proper regulation and in this respect there is little difference between administered and liberalised systems although the unbundling of the network businesses in the liberalised system may help make regulation more precise and lends more credibility to penalties.

The mechanisms for ensuring generation reliability are radically altered. A crucial issue to be explored in the seminar is whether the market will deliver the level of reliability required.

Security is the robustness of the system to low probability events that we can easily describe, but for which there is no guidance on probability. These might include war in the Middle East, terrorist attack on pipelines in Russia or a supply embargo for political reasons. This is evidently of concern with respect to the growing importance of natural gas in Europe, declining domestic production and a declining tendency to invest in long-term storage of gas.

These low probability events could happen to liberalised and non-liberalised markets and the question is not whether liberalised markets are secure but whether they can be made secure more or less easily than non-liberalised markets. The actions that could mitigate the consequences of such events are:

- Diversity of technology, fuels and sources of imports.
- Long-term storage of gas.
- Emergency procedures for sharing available supplies and reducing demand.

Sustainability is the question of whether we can keep going down the path we choose or whether it will lead eventually to a complete breakdown. The answer to this question involves taking a view on the viability of long-term technological options such as carbon capture and storage, nuclear power, renewables and hydrogen. It is also requires a judgement on timing: how much oil is there and how near are we to peak extraction?

The seminar was designed first to review the global issues then to move on to consider the implications of changes in the supply of gas to Western Europe. The focus then turned inwards to the UK to examine the reliability and security of the generation system, the adequacy of incentives to network businesses and the nature and effectiveness of government policy in the area.

10.2 Security of Supply – the International Dimension

Professor Mabro introduced his presentation with a caution that the topic attracts people with a neurotic or paranoid predisposition that may confuse the debate. Security is an issue across the energy sector. Concern for oil is long-standing but there are now issues over gas and even more recently electricity. The security problem is different for these different industries. In 1973 the countries that suffered most were the oil-importing, developing countries. The production cuts and the embargo in 1973 were lifted after about four months. Sanctions imposed by the international community and by the West, in particular on Libya, Iraq and Iran, in the past lasted 15 to 20 years which indicates the balance of power between the two sides.

In all cases where there have been interruptions in the market the shortfall in oil supplies was made up within a maximum of three months by other oil-producing countries which had surplus capacity. In the past 25 years, every crisis was compensated for by increased production by some countries. This may not happen in the future because surplus capacity in the production of crude oil may no longer be there. That is a serious issue because the system cannot work smoothly without surplus capacity.

Oil security has recently been linked not only to geopolitical factors but to geology, expressed in the peak oil theory. The question, however, is not whether oil production will eventually fall but when. Insufficient consideration is given in these analyses to non-conventional oil and other substitutes. The need is not for oil, but for liquid fuels. The reason for worrying about an oil shortage is not because production will reach a peak for geological reasons, but because people have not thought ahead and have not invested either in oil or in unconventional oil or in substitutes in time. It is a problem about the timeliness of investment, because the lead times are long, and because the private sector will require an incredibly high rate of return at 20-25% – that cannot realistically be achieved.

We can assess the geo-political difficulty as well as the geological difficulty but the third problem is a case of market failure. You must have some surplus capacity. You need four per cent surplus capacity in the upstream which means 3 to 3.5 million barrels a day and we do not have that. You must also have between seven and nine per cent in the downstream, because the maintenance times are longer, but we do not have that. The issue is who will pay for this redundancy. Private companies do not want to pay for it so they work their refineries hard and when there are unforeseen failures there are shortages.

Professor Mabro concluded that carbon capture and storages was a key technology to extend mechanisms for fossil fuels and that the contribution from renewable energy had been dramatically overemphasised. He criticised major oil companies for lack of focus on their core businesses of finding and refining oil. He reiterated that the real problem was not peak production, but inadequate investment.

10.3 Security of Gas Supply to Europe

The presentation on security of gas supply by Sylvie Cornot-Gandolphe distinguished three aspects of security: short and long-term timeframes; an internal European dimension and an external one; and economic and physical security. It established that the power sector is the driver of economic growth, forecasts for other consumer classes up to 2030 being rather stable; see Figure 10.1.

The point was also made that European gas supply is more and more dependent on imports that will reach about 80% by 2030 as shown in Figure 10.2.

It follows that the power sector will be increasingly dependent on natural gas (34% by 2030) as shown in Figure 10.3. This is potentially a cause for concern. The point was made again that the issue is not fundamentally one of reserves which are plentiful but of access and investment. There is a need for financial incentives to producers to develop reserves and export infrastructure and there is a need for financing and risk mitigation. Long-term contracts have underpinned the development of the gas market in the past and this form of risk-management needs to be adapted to the context of a liberalised market. The concentration of transit is as much a concern as the concentration of production. 90% of Russian gas passes through the Yamal-Nenets corridor and 80% of exports to Europe pass through the Ukraine.

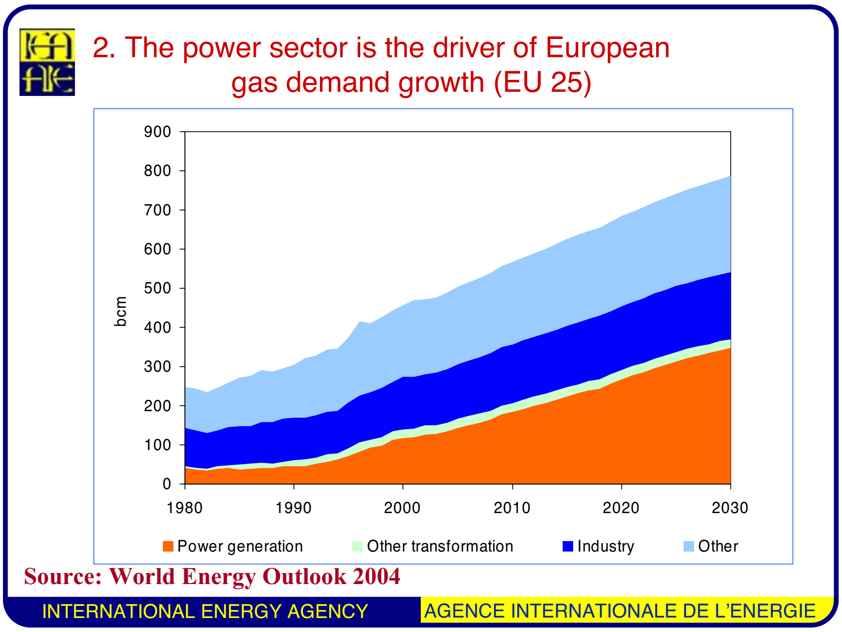

Figure 10.1: Origins of European Natural Gas Demand to 2030.

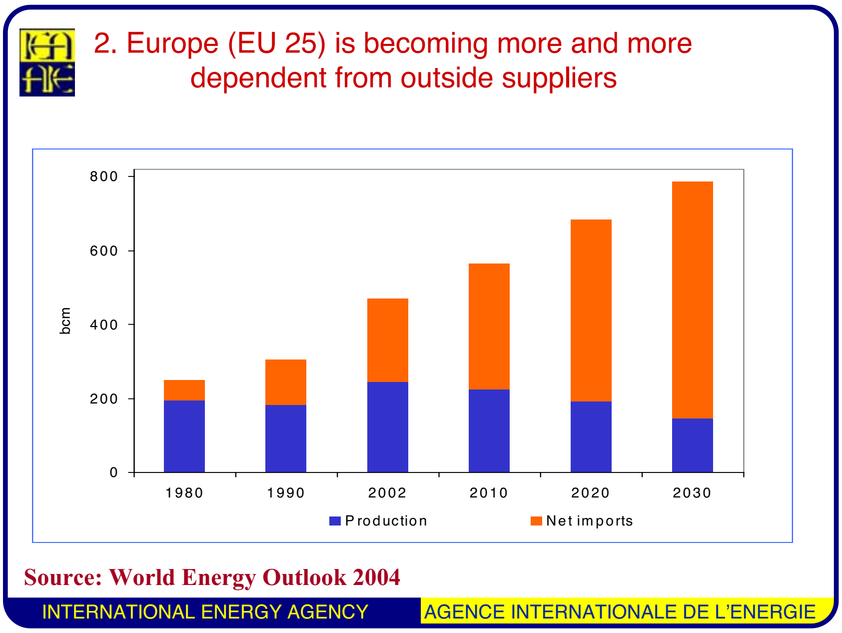

Figure 10.2: Dependence of Europe on Imports of Natural Gas

Large investments will be needed to produce and transport the gas. The IEA estimates that $110 -120 billion per year is necessary from 2010 to 2030: more than $2 trillion over the period. Most of this investment will need to be made by or in non-OECD countries. It is a major challenge to provide the framework for inward investment that will give acceptable risks and returns, especially with the changing market structure in the EU.

The second issue addressed was whether liberalized markets can guarantee the timely investment internally and externally to ensure security of supply. The UK provides an interesting case study. The price of gas for forward delivery has risen sharply in recent months as shown in Figure 10.4 and in principle this should signal new investment.

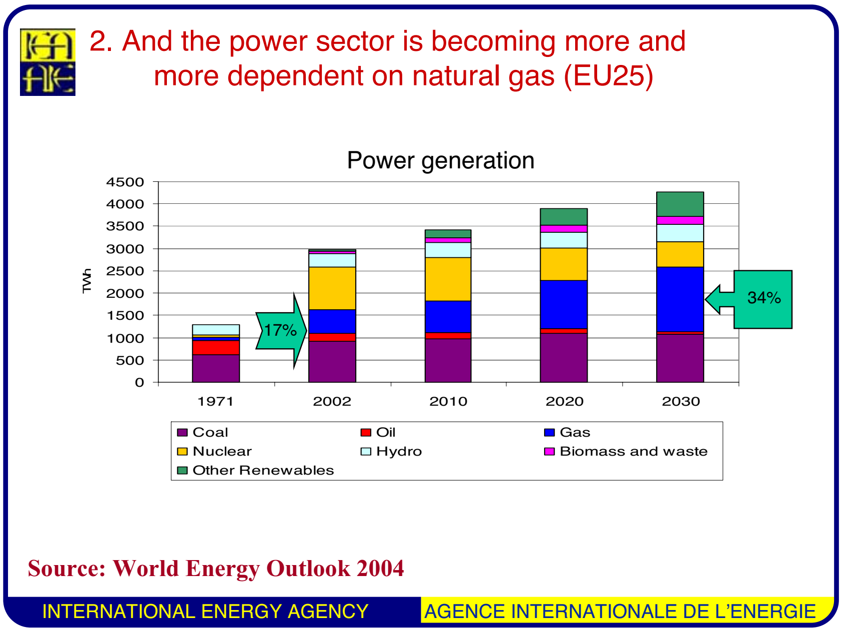

Figure 10.3: Estimated Origin of Electricity by 2030

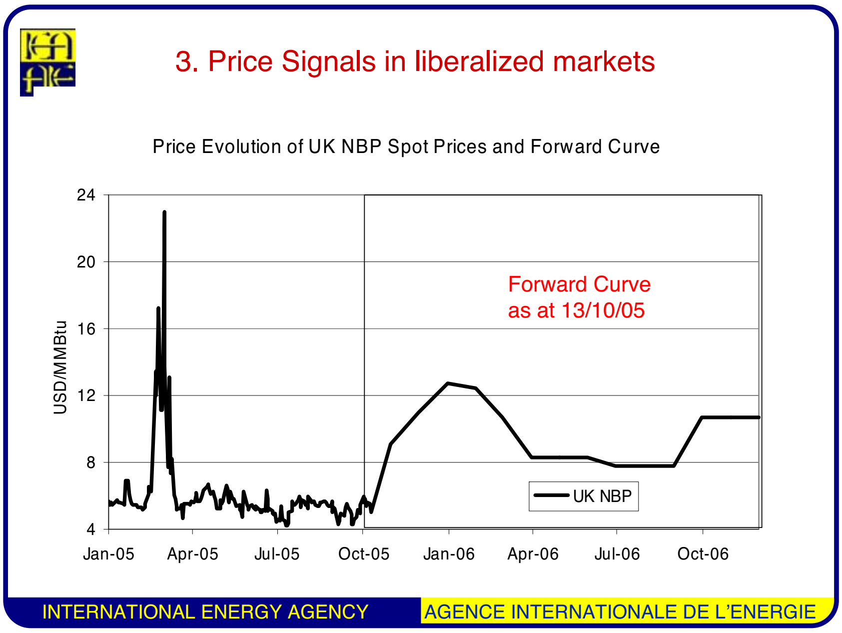

Figure 10.4: Forward Prices in the UK

Indeed many projects for gas supply are to be commissioned in the UK between end 2005 and 2008. A list is given in Table 10.1. It is not certain whether these projects will avoid shortages in the intervening years.

Table 10.1 Planned Additions to UK Gas import Capacity

Mode	Project	Capacity bcm/year	Start-up date
Pipe	Langeled	25	2007/08
Pipe	Statfjord Late Life	5	2007/08
Pipe	Interconnector	+8 and +7	End 2005/06
Pipe	BBL	17	2006/07
Pipe	NEGP	> 5-10*	?
LNG	Isle of Grain	4.4-14	July 2005-2008
LNG	Dragon (Petroplus)	6	End 2007
LNG	South Hook (ExxonMobil/QP)	10 (first phase)	2007/08

The conclusion is that the market will deliver the necessary investments, but possibly not in time.

An interesting development is the globalisation of the market for LNG and signs of convergence between prices on the US and European markets suggesting that, at the margin, the price of gas to Europe and the US will be linked, possibly to the detriment of Europe. Figure 10.5 shows the arbitrage between US and European prices.

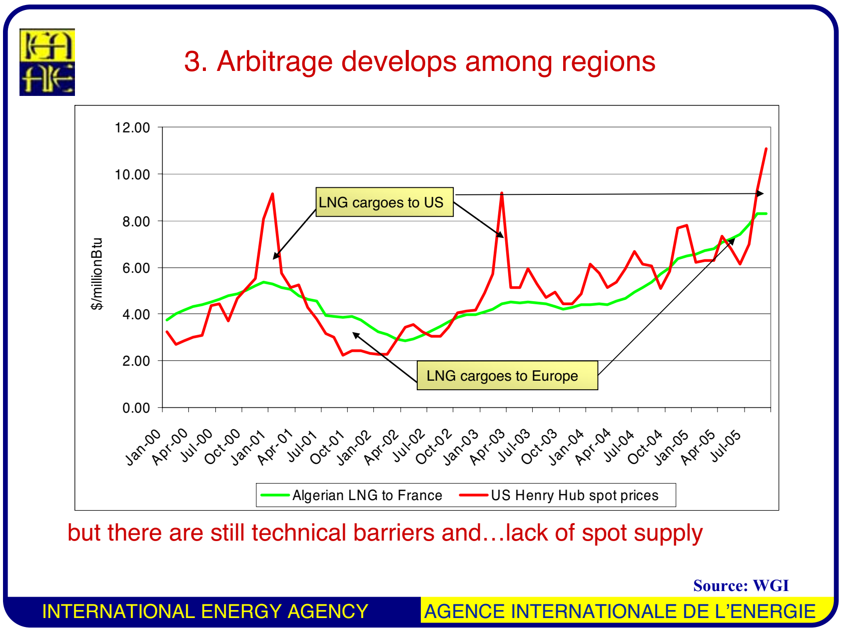

Figure 10.5: Arbitrage between US and European Prices

The conclusion of the presentation was that the European (and global) supply and demand balance for natural gas is at a turning point. It is a joint responsibility of governments and corporate sectors to ensure secure supplies. Markets have a role to play but cannot play it alone. Governments have an important role based in the following functions:

- To define clear security of supply policy objectives and criteria (for both supplies and infrastructure).
- To define clear responsibilities for the various stakeholders.
- To ensure consistency of the regulatory framework with policy objectives.
- To ensure markets can work properly.
- To leave operational issues to the market players.
- To ensure a mix of supply-side instruments, storage, demand-side response, spot and trading instruments.

10.4 Security of Electricity Generation in the UK

The presentation on electricity supply by Professor Michael Laughton drew attention to the radical changes that are inevitable in the UK electricity sector which depend on two basic changes:

- More than 30% of electricity generating plant in the UK will need replacing by 2025
- The Government aspires to a target of 20% of electricity from renewable sources by 2020

The apparent fossil fuel of choice over the period is natural gas and the updated government paper EP68 shows a markedly increased dependence, as shown in Figure 10.6.

Putting together the available indications on the evolution of maximum demand and installed capacity suggests that by 2020 the margin of conventional supply over simultaneous maximum demand will have fallen to a few percent and that system security will be dependent on some contribution to reliability from renewable plant. Historic experience shows that wind turbines in practice generate for a long time at low capacity. Figure 10.7 shows essentially a probability distribution of output for wind power. The mean output from approximately 7,300MW of installed capacity is around 2,270MW and much of the time it is a great deal less than this.

It is also the case that their relative contribution to system reliability is low and falls with increased penetration. Work commissioned by the DTI is reproduced in Table 10.2. It shows for various levels of installed capacity of wind energy as a percentage of peak demand the conventional capacity that would still be required to maintain a reliable supply. It can be seen that, in the extreme, the construction of 38,000MW of wind power, were it feasible, would displace only 7,500MW of conventional capacity.

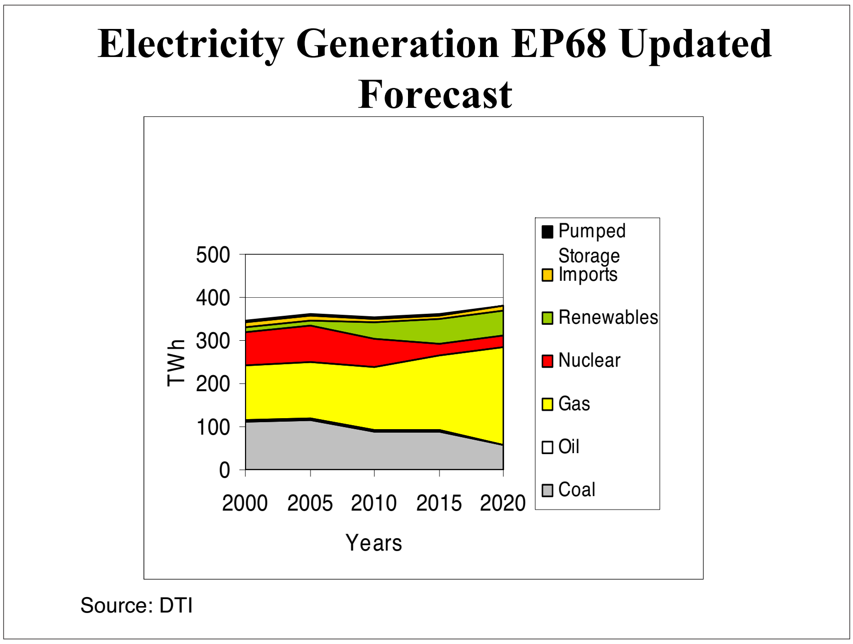

Figure 10.6: Forecasts of Origin of Electricity Generation in the UK

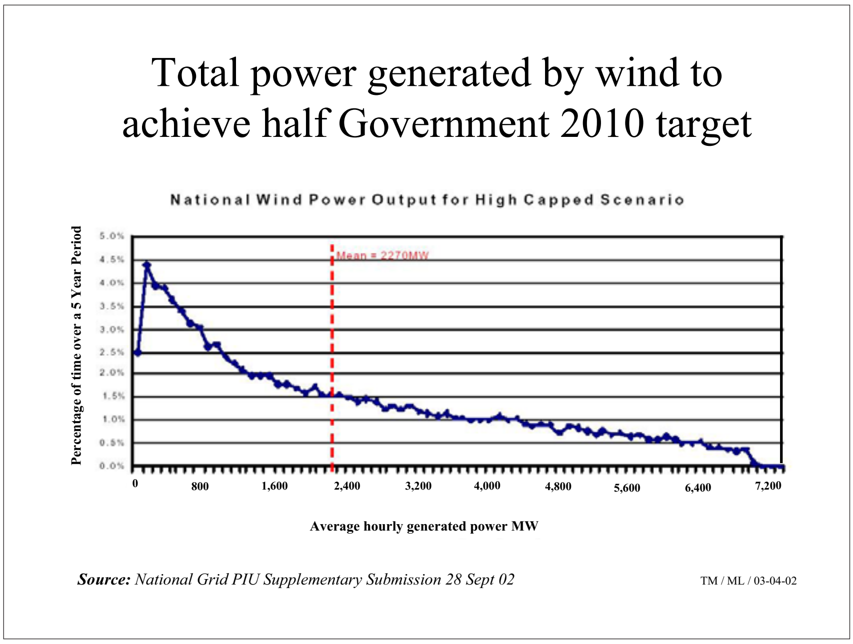

Figure 10.7: Probability distribution for wind power

Table 10.2 Impacts of Various Volumes of Wind Capacity by 2020

Total wind energy %	Installed wind capacity MW	Conventional capacity required MW	Conventional capacity margin %	Spare capacity margin MW	Spare capacity margin %
0	0	90,083	19	15,983	21
10	9,900	86,800	15	22,600	30
20	24,000	84,000	11	33,900	45
30	38,000	82,500	9	46,400	61

Source "Quantifying the System Costs of Additional Renewables in 2020", ILEX Energy Consulting Report to the DTI, October 2002

The paper then explored the practical possibilities of meeting the Government's actual renewable target. The proposition in the DTI scenario is to generate 13 to 14% of electrical energy from 19GW Wind by 2015-20. This would represent some 28% of peak demand by 2015. The experience of Denmark with a similar percentage of installed wind capacity demonstrates that it is not possible to operate their system without exporting a large proportion of power to neighbours, as needed, to preserve security of supply.

The implication was drawn that 19GW of installed wind capacity by 2015-20 would be too much for the domestic electricity supply system for technical reasons and that other forms of renewable energy with greater predictability must be developed if the renewable target is to be met.

The presentation concluded that:

- Energy demand is likely to rise by almost 60% between now and 2030.
- Therefore the predicted long-term (to 2050) trends in the availability of supplies and costs of fuel and the transition from oil to gas to coal should have a significant influence on today's investment decisions for security of energy supply.
- Security of UK electricity supply is jeopardized by large contributions from renewables unless a greater diversity of technologies with more predictability is adopted along with nuclear power, improved system interconnections, better energy efficiency and demand side management.
- Security of electricity supply will be increasingly at risk from legally binding targets for emissions and renewable energy contributions set without adequate knowledge of the technical and scientific constraints governing electrical power systems.

10.5 Incentives to Distribution Networks

In normal years most loss-of-load events are the consequence of failures in distribution networks. Failures in generation and transmission are rare, but when they do occur they affect large areas and many people. Failures in distribution are frequent, but generally do not affect many people at any time. The presentation on energy distribution by Tahir Majid of Centrica examined first the implications and consequences of traditional RPI-X regulation for security of supply. The essential features of this approach are that the regulator defines, in discussion with the companies, allowances for operating and capital expenditure (opex and capex). The framework of allowances is determined for a five year period and if the companies can deliver the necessary services at lower costs than forecast in the allowances then they can keep the savings made within the period.

The arrangement provides strong incentives to reduce costs, and indeed may be criticized as leading to the lowest cost rather than the most efficient solution. In terms of security of supply the more important of the allowances is the capex allowance. The capex allowance is established by reference to industry benchmarks and recently, in response to concerns about quality and continuity of supply, has been increased by around 50%. It is actually rather difficult to know what impact the marginal investment has on quality of supply. In the light of this uncertainty the justification for the increase is debatable. The discontinuous change also introduces uncertainty about how the regulator may set allowances at the next regulatory review.

Traditional RPI-X regulation has been complimented by a system of performance incentives. These are based on targets for quality of supply measured by customer interruptions and customer minutes lost, excluding events beyond the control of the operator such as storms. The operator is then subject to penalties and rewards as a function of achieved performance relative to the targets. The range of penalties and rewards is +/- 2% of turnover

The presentation came to the following conclusions:

- Incentives to improve performance need to be better integrated with incentives to reduce costs.
- Under investment today may lead to problems many years later, therefore the incentives should be paid over an extended period.
- Effort is still needed to determine the real marginal costs of improved reliability.

10.6 Policies for Security of Supply

The last presentation, by Dr Boaz Moselle of the Brattle Group, addressed the question of what policies for security of supply were appropriate in the UK. It reviewed the arrangements in place. Namely that:

- Government sets energy policy framework.
- Ofgem then: provides funds for network investment through price controls; sets the framework for wholesale markets; and monitors market behaviour.
- The National Grid ensures network capacity and is responsible for residual balancing.
- Emergency arrangements are implemented by the network companies and Government.

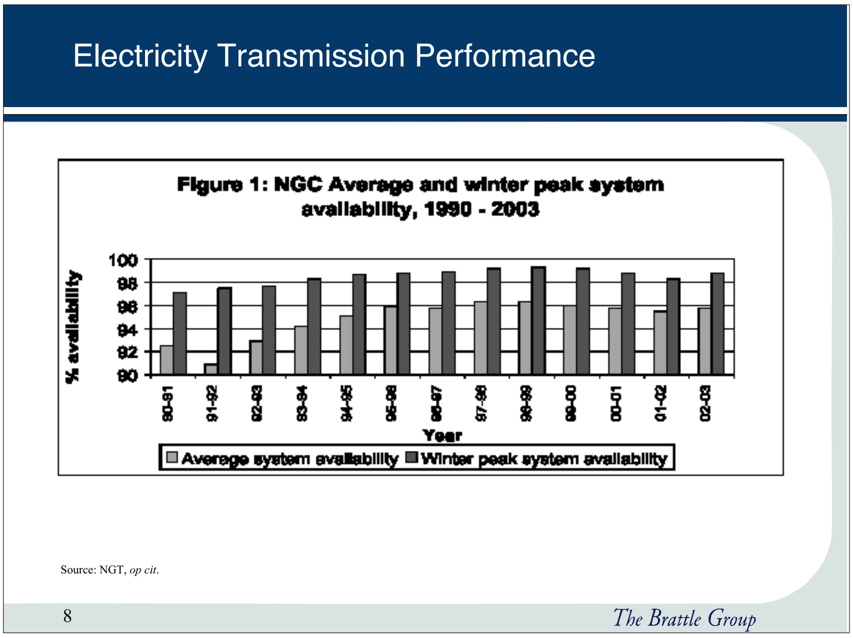

Figure 10.8: Average and Winter Peak System Availability 1990 – 2003

The lights have stayed on but there may be some fortuitous aspects: the inherited overcapacity from the nationalized industry; a regulatory bias toward excessive new generation; and the gas bubble that encouraged new investment in gas fired plant. Past performance does not necessarily ensure future security. Again the relationship was drawn between security and investment. Security of supply depends upon adequate transmission investment, adequate investment in new sources of gas supply and adequate investment in new generation. Performance in the UK has been good by international standards. It is better than most countries of mainland Europe and much better than in the US, which has larger territories to cover. The availability of plant since liberalisation has improved significantly, reaching a peak in the late 90s since when it has fallen slightly. Figure 10.8 shows average and winter peak system availability since 1980. Investment in the transmission system has also increased substantially, the average in the period 1990-2000 being almost double that in 1980-1990, as shown in Figure 10.9.

There are some signs of an improved quality of service, but the historical record is not adequate to permit a close scrutiny. As mentioned earlier, new price control targets aim at significant improvements (4% in Customer Iterruptions and 3% in Customer Minutes Lost by 2010); new price control funds will fund 50% higher investment.

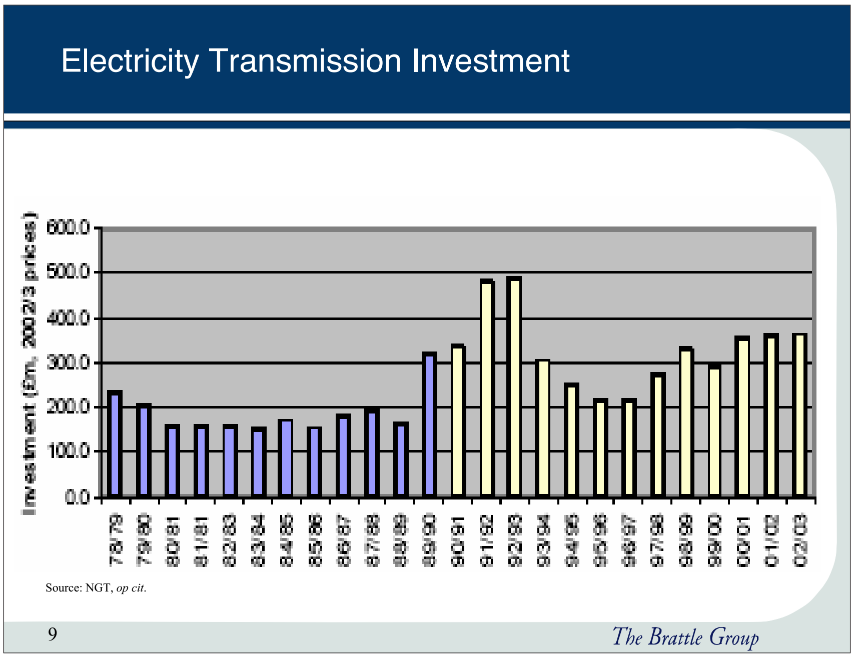

Figure 10.9: Investment in electricity transmission since 1980

The NGT Winter Outlook Report 2005/06 asserts that "even in 1 in 50 cold weather, there will be sufficient gas to maintain supplies to domestic and other non-daily metered customers." Tightness in supply up to 2005 and 2006 should be rapidly alleviated thereafter. The same source forecasts a 21% reserve margin in generating capacity for the winter of 2005/06. New investment in generation is adequate with CCGTs being built by a range of investors, eg, at Langage 1,010MW (Centrica), Pembroke 2,000MW (RWE) and Marchwood 800MW (ESB).

The need for considerable new investment in generation in the medium-term was again recognized and the link confirmed with the rate of retirements of existing plant and renewals for environmental and security of supply concerns. The presentation also acknowledged the impact of the high perceived degree of "regulatory" uncertainty, but suggested it was more in the political determination than in the regulatory implementation.

The presentation concluded that:

- Regulation works to finance needed transmission and distribution infrastructure.
- The market has produced huge investments in gas supply infrastructure, albeit apparently with one or two years delay.
- So far the market is working to produce new generation capacity, but there is a challenge from the high level of political/regulatory risk.
- UK government shows a remarkable commitment to markets and with the right commitment the market can deliver.

10.7 Key Points Raised in Discussion

There was extensive discussion after the presentations and in the closing round table. The main factors addressed were: what degree of credence can be paid to the theory of peak oil; how to develop mechanisms to encourage investment in producing and transit countries; and whether the liberalised market would deliver timely investment at home.

Peak oil

Alternative views about falling future oil production were expressed. It was reported that in a recent international meeting of senior oil executives there was some consensus on a plateau for oil production of 100 million barrels a day, and that it would occur between 2012 and 2017. This contrasts with the IEA position of 120 million barrels a day by about 2015.

Incentives for investment in producing and transit countries

The need to find a framework for investment in producing and transit countries was addressed in several different ways. It was pointed out that producing countries may not wish to develop resources at the same pace that the industrialised countries would prefer. The possibilities for worthwhile investment in development might not materialise at the same rate as the oil was produced. This syndrome is exacerbated by high oil prices. In the gas sector the huge investments that are necessary can only realistically come from the developed countries, not primarily the producers and transit countries. Despite considerable diplomatic effort the legal and institutional framework to provide a fair return to transit countries and to manage the risks perceived by both sides is not in place.

Will the liberalised market deliver timely domestic investment?

This topic engendered much debate and exposed a variety of positions, but little consensus. There was a view that markets certainly can deliver timely investment. This position is based on the premise that investors naturally respond to price incentives and people will provide capacity because they know that there are times when they will be able to sell it. If it happens occasionally then either they will be able to get a very high price or people will pay an insurance policy to use it occasionally. The alternative view is that you need to get what is good from markets but to intervene when markets fail. If you want a system that is reliable and which will carry the surplus capacity that is needed for that system to operate smoothly, then you need an intervention. It was proposed that oil companies should be compelled by law to have a defined proportion of surplus capacity at all points in the chain. The analogy was drawn with stockholding obligations of the EU and IEA. Some similar sentiment was expressed in the case of gas: government should set objectives. This could be in terms of extreme events or of interruption of supplies by a large supplier. It could be different from one country to another because, indeed in Europe, each gas market has its own characteristic at the moment and the share of gas is different from one country to another. The share of domestically produced gas is also different and so these objectives should certainly be different from one country to another. The experience of the UK in this regard is ambiguous – investment is coming, but it may be too late. The point was also made that it may take a very long time to know whether the market can react adequately. There is a question as to whether involuntary interruptions necessarily mean that the market has failed. It may not be so because the market and the arrangements will evolve and actors will learn from those mistakes. Until there has been long experience of the liberalised market and it has been given a chance to bed down then you cannot say with any certainty whether it can deliver or not. It was also agreed that there was a spectrum of views across Europe with the UK at one extreme. This could be a confusing factor in the design and implementation of policies for security of supply.

10.8 Conclusions

External dimensions of security

The availability and affordability of primary supplies from producer countries is not fundamentally constrained by resources but by access that is in turn a function of investment. Investment is needed not only to supply expected needs but to provide a surplus to deal with unexpected events. For the investments to occur there must be adequate incentives for the producer and transit countries and the risks on both sides must be managed. Long-term contracts have underpinned the development of the gas market to date but they need to be adapted to the context of a liberalised market. There is some sign that the margins of reserve that have ensured stable supplies in the past are being eroded, eg, the margin of crude oil production in the Middle East is falling. We are consuming oil faster than it is being found and perhaps the volume of long-term gas storage in Europe is decoupling from demand growth. There is an ever clearer separation of countries into producers and consumers that implies a sharp difference of interests that has not yet been adequately reconciled.

Internal dimensions of security

Internal security is again essentially a question of investment and especially investment in an adequate reserve margin, both of the competitive generating plant businesses and the regulated transmission and distribution system, which will deliver energy reliably.

The transmission and distribution is regulated through price controls and these have evolved in the UK to include incentives and penalties for good and bad performance. Possible weaknesses in this framework have been noted and in particular the difficulty of knowing exactly what increase in reliability is achieved by incremental investment. Despite this the process is fundamentally sound and incremental improvements can be expected in the future.

In the competitive sector the paradigm is that market forces will deliver the necessary investments. The extent of belief in the proposition varies among countries. The UK has a strong and sustained belief in markets and the view is that markets will deliver. The logic is that generators will invest in marginal plant in the expectation of achieving high prices in the balancing markets if there are shortages. This has never really been fully tested in practice and there seems to be no clear relationship between the social costs of outage, the process for ensuring the necessary marginal investment and the volume and timing of the investments made. The issue needs further exploration. It is compounded by the emergence of some technologies that make little contribution to reliability, eg wind power. Mention is often made of the new investments planned by the market in gas supply to the UK but this needs to be qualified by the fact that they may not be commissioned in time to avoid shortages in 2005-07 and also that the LNG terminals required derogations from the gas market Directive to be financed.

Regulatory uncertainty

Uncertainty and the associated risks are a natural part of investment. A new risk in the liberalised system is regulatory risk or policy risk that arises from uncertainty about future actions of the regulator or implementation of other policy decisions. Of considerable concern at present are the set of risks that arise from uncertainties over the implementation of environmental policy decisions pertaining to the Large Combustion Plant Directive and the European Trading System for carbon. There are still significant uncertainties as to how these will be implemented in the future that have a great impact on the retirement of older plant and therefore on the need for new investments.

Recommendations

- **A Financial framework for external investment.** There is an urgent need to align the interests of producing and consuming countries into a financial framework that provides acceptable rewards for producers and affordable and reliable supplies for consumers.

- **Coherent analysis and policies for security of supply.** Within the UK and Europe there is a compelling need to develop a clear and coherent approach to the measurement and provision of security of supply and to reconcile it more effectively with the practice of regulation and the implementation of other policies, especially for the environment. The approach of targeting incentives to selected technologies that are perceived to be either environmentally friendly or secure (eg renewables and not nuclear) needs to be replaced by explicit reward for the attribute that is sought, eg security or being carbon-free.

- **Monitoring of the competitive market.** There is a need to carefully study the extent to which the market does provide timely investment. There needs to be a convincing theoretical case and documented empirical evidence. The possibilities and costs of combining market forces and policy intervention to provide security need to be fully assessed.

Glossary

AGR	Advanced Gas-cooled Reactor
APGTF	Advanced Power Generation Technology Forum
billion	One thousand millions (10^9)
BNFL	British Nuclear Fuels plc
BWR	Boiling Water Reactor
CCGT	Combined Cycle Gas Turbine
CCT	Clean Coal Technology
CCS	Carbon Capture and Storage
CDM	Clean Development Mechanism
CEGB	Central Electricity Generation Board
CHP	Combined Heat and Power
CNG	Compressed Natural Gas
CO_2	Carbon dioxide
CoRWM	Committee on Radioactive Waste Management
Defra	Department of Food and Rural Affairs
DNO	Distribution Network Operator
DTI	Department of Trade and Industry
EC	European Commission
EOR	Enhanced Oil Recovery
EP68	Energy Paper 68, DTI energy forecast
EPR	European Pressurised Reactor
ESI	Energy Supply Industries
EU	European Union
ETS	Emissions Trading Scheme
ExternE	Externalities of Energy. A research project of the European Commission
FGD	Flue Gas Desulphurisation
FREng	Fellow of the Royal Academy of Engineering
GDP	Gross Domestic Product
GNP	Gross National Product
IEA	International Energy Agency
IGCC	Integrated Gasification Combined Cycle
IPPC	Integrated Pollution Prevention and Control (EU Directive, established in 1996, to minimise pollution from industrial sources)
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LWR	Light Water Reactor
Magnox	Nuclear power reactor type which uses magnesium non-oxidising alloy to clad the fuel rods
MtC	Million tonnes of carbon
MoD	Ministry of Defence
NETA	New Electricity Trading Arrangements
NGT	National Grid Transco plc (became National Grid plc in July 2005)
NGC	National Grid Company plc (became National Grid Electricity Transmission plc in July 2005)
NII	Nuclear Installations Inspectorate
NOx	Oxides of nitrogen
Ofgem	Office of Gas and Electricity Markets
O & M	Operations & Maintenance
OECD	Organisation for Economic Co-operation and Development
OSPAR	Oslo/Paris convention for the protection of the marine environment of the North East Atlantic
PBMR	Pebble Bed Modular Reactor
ppm	Parts per million (by volume)
PV	Photovoltaics
PV-TRAC	Photovoltaic Tecnology Research Advisory Council
PWR	Pressurised Water Reactor
R&D	Research and Development
RBMK	Reactor Bolshoi Moschnosti Kanalynyi (water cooled, graphite moderated nuclear reactor built in the former Soviet Union)
RPI-X	Price-cap regulation (Retail Price Index minus expected efficiency savings)
RTD	Research and Technological Development
SOx	Oxides of sulphur
THORP	Thermal oxide reprocessing plant
trillion	One million millions (10^{12})
UN	United Nations
UNDP	United Nations Development Programme
UNFCCC	UN Framework Convention on Climate Change
US	United States of America

Note: Throughout the text we have used standard units for power and energy.

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The Royal Academy of Engineering
29 Great Peter Street, London, SW1P 3LW
Tel: 020 7227 0500 Fax: 020 7233 0054
www.raeng.org.uk