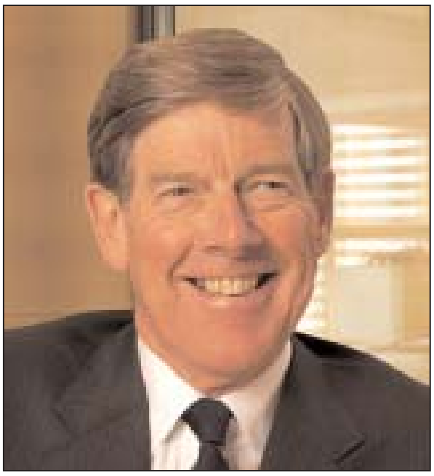
THE NUCLEAR ENERGY OPTION – WILL WE STILL NEED IT – AND IF SO – WHEN?

MEETING OF THE PARLIAMENTARY AND SCIENTIFIC COMMITTEE ON MONDAY 13TH JUNE 2005

Will nuclear energy still be an option if or when we realise the need to exercise it as an essential component of the plans to meet our ambitious climate change commitments and to ensure base-load supplies of electrical power for the UK? A satisfactory procedure for the disposal of radioactive waste is essential if progress is to be made – so why is there still just "a blank sheet of paper" in the UK after 40 years of planning while others move ahead? Renewables have a chance to demonstrate their environmental credentials and fill gaps in supply created by the escalating costs, increasing demand for and environmental impacts of fossil carbon-based fuels.

The Nuclear Energy Option – Will we still need it – and if so – When?



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In short my answer is yes – I see no alternative if we are to meet our obligation to protect the environment. At the same time we have to provide a secure supply, and avoid fuel poverty, so we will have to consider all of the alternatives, especially the renewables.

We have been fortunate in the UK because in our "dash for gas", we succeeded, almost by accident, in meeting our commitment under the UN Framework Convention on Climate Change – by 2000 we had already returned to 1990 levels of greenhouse gas emissions. Since February, however, the Kyoto Protocol commits the EU to a further 8% reduction between 2008-12. But again the UK has committed to do more. We have courageously agreed to a $12\frac{1}{2}$% reduction, and furthermore, the Government has committed to a domestic goal of 20% by 2010. These are laudable aims but provisional data for total UK emissions of carbon in 2004, whilst 4.2% lower than 1990, show a 1.5% increase over 2003.

Our electricity consumption between 1990 and 2004 increased by $25\frac{1}{2}$% but CO_2 emissions decreased by $15\frac{1}{2}$%, due to a combination of increased supply from nuclear generators, greater use of natural gas, and improved efficiency. The total electricity supplied by all generators in 2004 was 2% higher than in 2003 (some 7.5 TWh) but the fuel used was 0.9% lower.

It is worth noting that our gas production is declining as the UK Continental Shelf reserves deplete. The production of indigenous natural gas fell by 6.7% between 2003 and 2004. Most importantly, the UK became a net importer of gas in 2004, the first time since 1996, and it has been estimated that we have used just over half of our gas reserves, and with increased demand, it is expected that we will be importing 80% of our gas by 2020.

The 2003 Energy White Paper sets out the framework for our future energy policy. It identifies the challenges as: environment; decline of indigenous energy supplies; and energy infrastructure updating. It sets four goals: to cut CO_2 emissions by 60% by 2050; to maintain reliability of energy supplies; to promote competitive markets in the UK and beyond; and to ensure adequate and affordable home heating. The Government believes that these goals will be achieved by the market framework being reinforced by policy instruments. Targets were not set for the share of total energy or electricity supply to be met from different fuels, preference being for a market framework to give investors, business and consumers the incentives to determine the balance to meet the overall goals most effectively.

The White Paper continues by recognising that energy efficiency measures are thought likely to be the cheapest and safest way of meeting the four goals, but that renewable energy would play an important part in reducing carbon emissions. The target set by Government was that by 2010 some 10% of our electricity should be generated from renewable sources with a view to achieving 20% by 2020. The House of Lords Science and Technology Committee report "Renewable Energy: Practicalities" prepared under the chairmanship of Lord Oxburgh, was not optimistic about the possibility of meeting these aims. It states "We found almost no-one outside Government who believed that the White Paper targets were likely to be achieved. This was partly for practical reasons – planning consents, availability of labour and equipment and so on – and partly as a direct consequence of the Renewables Obligation method of support. We judge that by 2010 the United Kingdom may have achieved 6-7% renewable generation".

Our problems can potentially be solved in the long term by nuclear fusion, by replicating the thermonuclear reactions powering the Sun, but even the most optimistic of the experts say that this will take thirty years and the official timetable is closer to fifty. Progress with JET, the Joint European Torus, at Culham, has been significant. Within the doughnut shaped plasma chamber, called the Tokamak, fusion has been achieved and the strong magnetic fields of the Torus have been successful in keeping the plasma away from the walls of the containment vessel so that it does not melt.

The next stage in demonstrating that the process can be made practicable is to build ITER, the International Tokamak Experimental Reactor facility either in France or in Japan, both are seeking to host the facility. Then an International Materials Irradiation Facility is needed to show that the materials can withstand the intensive neutron irradiation. When all of this is complete DEMO, the demonstration power plant will be built and finally PROTO the prototype power station. The current timetable for all of this is fifty years but a fast track alternative where these tasks would be carried out in parallel might achieve the same in thirty years.

So we cannot rely on fusion to solve our near term needs in terms of greenhouse gas reduction. However, we do have nuclear fission. Our experience of generating electricity from nuclear fission extends back to 1956. The technological problems are well understood and manageable but there are well known issues, some sociological, some political, which will make it difficult to gain public and political acceptance for new build.

Other than for importing the uranium, the UK has been self-sufficient in employing nuclear fission, through plant design, operation, regulation, uranium enrichment, fuel fabrication, reprocessing and waste treatment. However, in 1995 the Government determined that nuclear power should be phased out and decommissioning undertaken as soon as reasonably practicable. Draft legislation was published in mid-2003 to set up and fund the Nuclear Decommissioning Authority. The NDA has now been established and is charged with dealing with the legacy of nuclear waste previously managed by BNFL and the UKAEA.

The disposal of nuclear waste is the issue which has created most public concern, but it will have to be dealt with whether or not we build new nuclear plants. If we were to build ten new nuclear stations and operate them for sixty years, there would only be an increase in the UK's existing waste stockpile of about ten per cent. It is also important to note that the wastes arising from a modern Pressurised Water Reactor are much less than those from the Magnox gas-cooled reactors. The costs of decommissioning a light water reactor will also be five times less than that for a Magnox reactor due to the smaller volume of material and graphite moderator.

It is crucial that the Government's Committee on Radioactive Waste Management (CoWRM) accelerates their deliberations and delivers their recommendations on the way ahead. Other countries are ahead of us. For example, a Parliamentary vote in Finland in May 2002 supported the building of a nuclear reactor on economic, energy security and environmental grounds. Finland is well advanced with provisions for the encapsulation and storage of spent fuel. They already operate underground repositories for intermediate level waste and an underground rock characterisation facility will verify the site selection for geological storage over the next few years.

The Nuclear Non-Proliferation Treaty is designed to minimise the danger that could arise from the "leakage of nuclear material, relevant technology or nuclear expertise". Verification of compliance is carried out by the International Atomic Energy Authority. There are broader questions on the possibility of terrorist groups acquiring nuclear, chemical or biological weapons.

The Health and Safety Executive, through its Nuclear Installations Inspectorate, regulates nuclear safety under site licences. There are well developed and tested arrangements in place for responding to any nuclear emergency at any UK civil nuclear site. To aid public understanding of the safety significance of events and their consequences an International Nuclear Event Scale has been developed by the International Atomic Energy Agency and the Nuclear Energy Agency of the OECD.

Finally , the application of nuclear technology demands a highly skilled workforce – not only for nuclear power but in the health sector, where it plays a key role in modern medicine, and in industry. The perceived shortage of people with the necessary skills is a serious concern.

Conclusions

- The demand for electricity is growing and emissions of Carbon Dioxide are increasing.
- Ageing nuclear plants are being decommissioned but replacing their generating capacity with that from renewable sources does not reduce Carbon Dioxide emissions.
- A balanced portfolio of energy sources is necessary to ensure adequate levels of security of supply.
- Nuclear energy is no longer regarded as uneconomic.
- The skills base in terms of nuclear engineers and technicians must be maintained.
- Government must take the difficult decisions concerning supporting nuclear fission whilst awaiting nuclear fusion technology and demonstrate leadership on the waste disposal issue.
- Finally, but most importantly, the public are partners and they must be brought on side to support the necessary actions, as exemplified by the intense debate and decisions taken in Finland.

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A Balanced Energy Policy

Sir Donald Miller FREng FRSE
Chairman, Scottish Power 1982-92

My first criterion for a robust electricity supply is a mix of fuels and sources. In the early 1960's, 90% of Scotland's electricity was from NCB coal at significantly higher prices than South of the Border and subject to the threat of interruption. The search for greater security led the Scottish Companies in 1964 to embrace nuclear generation with the commissioning of the Hunterston A 2x 300 MW Magnox reactors. These achieved the highest performance of any reactors world wide for most of their operating lifetime and in the light of this experience they were followed in 1972 by the Hunsterston B 2x 600 MW AGRs.

The more robust electricity supply system this provided allowed support to England and Wales of 2000MW on a regular basis during the miners' strike as well as profitable trading across the Border. Further diversity was provided by oil and gas fired generation as well as 700 MW of pumped storage. With growth in demand and to maintain our cost advantage, we turned again to nuclear in 1987 with the Torness 2x 650 MW AGRs so bringing Scotland's nuclear share to over 50%. Without subsidies of any kind and with full financial provision for the costs of decommissioning and waste disposal, tariffs were amongst the lowest in the UK.

The run down of UK nuclear capacity, losing 50% in 5 years and virtually all in a further 12 means not only the loss of 22% of the UK's electricity supplies but also a massive reduction in diversity.

We take the reliability of our electricity for granted but the role of diverse generation in achieving this is not recognised. Those who remember other times regard with disbelief a scenario in which we rely for 90% of our energy on unstable regions of the world, mainly Russia and its former Republics with smaller amounts from the Middle East. That is what is in prospect unless we do something about it – and do it soon.

At present the UK's only concession to maintaining diversity is renewables. In the quantities proposed these are proving neither economic nor environmentally friendly and their effect on reducing greenhouse gases is insignificant. Nor is it generally realised that the cost of their electricity to the consumer, including subsidies and support costs, is four times that of conventional generation. There are more effective and less costly means at our disposal, of which nuclear is one.

A recent report by The Royal Academy of Engineering shows new nuclear (including provision for decommissioning and waste disposal) at 2.3p/kwhr against 5.4p/kwhr for on-shore wind. This is without the subsidies and the high costs of transmission for renewables all of which additional costs are paid for by the electricity consumer. UK energy policy today requires a positive attitude to nuclear; without this we are not retaining the nuclear option, at least in any effective way.

Public sector R and D spend in the UK on nuclear power is virtually non-existent. The US Government on the other hand has stated its intention of increasing its budget to $240m with the objective, jointly with the private sector, of banking a portfolio of licensed sites ready for new construction.

Other assurances for potential developers are being created because of course a successful nuclear programme needs to bring together not only R and D but also design, licensing, manufacturing and construction skills, and not least, a competent customer.

This last is important; in the case of nuclear it is the owner who holds the licence and has to deal with the nuclear licensing authority. This is an ongoing and demanding activity throughout the station life and in today's industry few of our generators will have that particular competence.

Nevertheless we have a lot going for

us. Despite the discouraging climate of recent years the UK nuclear industry is in a position to provide us with an up-to-date and economic design of reactor which uses proven technology from earlier plant. This design has the important advantage of relying on natural effects for cooling in an emergency: gravity, natural water circulation and compressed gas. I refer to the passively cooled 1000MW PWR developed by Government-owned British Nuclear Fuels and their subsidiary American Westinghouse.

As an example of these passive features, the reactor steel containment doubles as the emergency heat exchanger with a high level static water supply displacing the multiple chains of pumps and other "engineered safety features", typical of Sizewell and the current French/German design. Not only does this offer improved inherent safety but also greatly reduced complexity and costs as well as shorter build time. This is all achieved with greatly reduced numbers of components.

Although a new design, the AP1000 is based on proven technology and should prove readily licensable. In the USA, following two years work by the Nuclear Regulatory Commission, it has now been granted a full licence. Regrettably, in the UK, not a single man-hour of the Nuclear Inspectorate's time has been devoted to this potentially world-beating British-owned design.

It is worth emphasising here the important advantages of concentrating all our resources from the outset on a single preferred design; we saw this clearly in the case of the Torness/Heysham B reactors, built simultaneously by Scottish Power and CEGB. Major components will in any case be bought in following competitive tender so there need be no concern that concentrating on a single preferred design from the outset will dilute commercial disciplines. No such loss of focus is allowed to impede the effectiveness of nuclear construction programmes across the Channel.

The next hurdle is the Planning Inquiry System. Repeated examinations of the same reactor design, one for each site need to be replaced by applications for any type of reactor licensable in the UK by the Licensing Authority. Consent on this basis was granted for the Torness site.

But we still need an owner/developer. It was recently claimed that no generating company in our market-led supply industry has yet applied to build a nuclear station. There are good reasons for this, so let us examine each in turn and identify solutions.

No generating company operating in a competitive market could be expected to build the first in a new series of nuclear construction, with the second and third units coming in at much lower costs – typically 80%. Then, just as oil companies form consortia to limit commercial risks in developing major fields, so the majority of nuclear plant, including that in Scotland, has been built by partnerships. This suggests a grouping of companies (three or four would be about right) for each project and secondly, a firm commitment in the initial series for not one station but at least three.

We need to ensure also that our competitive market caters for the very different cost structure of nuclear – the high initial capital, offset by low running costs. Other generators can respond by, for example, varying the operating regime or relying on commercial safeguards such as linking the largest element in their costs (fuel purchase) to the electricity market price. The nuclear operator is peculiarly exposed to Regulator induced instabilities in the market (British Energy found this to their cost) as he must secure a sale for his output at all times. I am not aware of any nuclear plant which has been built without a guaranteed market for its production. In short, when we are talking about investments which will continue for 40, maybe 60 years, we need to recognise the limitations of our essentially short term market for electricity.

But solutions are available. In the case of renewables, each distributor is required to purchase a fixed proportion of his energy from that source. If that is acceptable for wind power with all its limitations why not the same with nuclear – at one quarter of the price.

In the US the need for assurances for new nuclear construction has been recognised with the DOE's publication of a risk sharing scheme worth up to $450m for the first of a new design and up to $250m for each of three subsequent units. The DOE will reserve the right to select the reactor design. The aim is to have new build in place for 2010.

To make an impact on securing our future electricity supplies (not to mention greenhouse gas emissions) and at an economic cost, we need to deploy all the available technologies and that includes a start on new nuclear build now. My checklist for early action is as follows:

a A firm commitment from Government to the earliest construction of not less than three PWR stations. These should include a conditional decision, subject to licensing, in favour of the AP1000 design. The advantages of concentrating our resources on a single design from the start should not be lightly thrown away.

b Reinforce NII resources to allow an immediate start on the licensing of the AP1000.

c Consult with the Regulator and major generators to establish satisfactory market conditions for the output of the new reactors. This is essential to secure financing on acceptable terms.

d Reinforce those areas of R & D which cannot be funded from normal commercial recoveries. Specifically this should include building up a bank of suitable licensed sites.

The ball is squarely in the political arena; let us hope for all our sakes that we shall see an early try!

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Radioactive Waste – Is There a Solution?

Eur Ing Ann McCall, Head of Safety, Nirex

Introduction

Radioactive waste exists, it will remain hazardous for hundreds of thousands of years and it is crucial that appropriate measures are put in place for its long-term management.

Viable solutions exist for its long-term management. Many other countries have radioactive wastes to manage. Geological disposal is the preferred option for the majority of countries and most of those are now developing concepts that incorporate retrievability and a phased approach to implementation.

In the UK, Nirex has undertaken extensive development work on geological disposal of radioactive waste and more recently on its phased geological repository concept. Whilst technical solutions have been available for many years in the UK there has never been successful implementation of those solutions.

A technically viable concept in itself is not enough to solve the problem. There is a need to take account of lessons that have been learned from previous experience in the UK and overseas relating to:

- The structure of organisations involved in its implementation.
- The process by which a solution is selected and implemented.
- The behaviour of all parties involved.

Provided these lessons are acted upon we believe the UK's radioactive waste management problem can be solved without further delay.

Lessons and dialogue

Following the failure in 1997 to obtain planning permission for underground investigation of a potential repository site at Sellafield, Nirex set out to learn lessons from that experience. The aim was, through extensive dialogue, to gain an understanding of why previous attempts to solve this problem have failed. Those lessons could then be applied in the development of a new approach which could then lead to the successful implementation of a long-term radioactive waste management solution in the UK.

Structure

In terms of structure, one of the main lessons was the need for the organisation responsible for long-term waste management to be independent of the nuclear industry and for clear separation of long-term and short-term issues.

- Under nuclear industry ownership Nirex was seen by many as a front for the Industry.
- The independence of Nirex's overall objectives, including decisions on packaging standards and specifications, was questioned because of its ownership.
- The need for separation of the organisations looking at short-term and long-term is necessary to avoid long-term issues being "out-prioritised" due to short-term pressures, and so that tensions between short-term and long-term issues are resolved in an open and accountable manner.

In line with Government policy[1] Nirex has now been made independent of the nuclear industry and the Nuclear Decommissioning Agency (NDA). This has been achieved by placing the ownership of Nirex under a Defra/DTI holding Company Limited by Guarantee.

Process

A key lesson was that the process for selection and implementation of a long-term waste management solution must be open, transparent and accountable at all stages. Specific issues included:

- The adversarial nature of the planning process in particular where a planning application is rejected and referred to a public inquiry.
- Recognition of the need to address local issues in order to allow a national policy to be implemented at a given site.
- The need to develop and gain broad acceptance for each step in the implementation process ahead of its application, eg the approach and criteria to select suitable sites.

The Government has now established its Managing Radioactive Waste Safely (MRWS) process. As part of this process the Committee on Radioactive Waste Management (CoRWM) has been set up to recommend a long term management solution for the UK's intermediate-level waste.

Behaviour

Lessons learned relating to behaviour include the need to:

- Work at stakeholders' speed, be responsive and allow for involvement of a wide range of stakeholder groups
- Have a wide ranging transparency policy
- Reflect stakeholder views in our work programme eg retrievability.

Nirex is now seen as a very different organisation by the main stakeholders it interacts with and considerable progress has been made in transforming its reputation among the close watchers of UK radioactive waste management.

Phased Geological Repository Concept

The Phased Geological Repository Concept is a multi-barrier, phased approach, based on storing wastes deep underground, beyond disruption by man-made or natural events. The development of the concept takes full account of the lessons learned and feedback from continuing dialogue. An example that has fundamentally changed the concept is the incorporation of retrievability.

Before 1997 many stakeholders had asked Nirex to incorporate retrievability into its geological repository concept. These were resisted and we argued that if necessary the waste could be mined out of the facility. We were missing the point.

Following a programme that integrated dialogue with technical development it was established that retrievability could be provided and this is now at the heart of the phased geological repository concept. The incorporation of monitoring and retrievability means that choices on how, and if, to proceed towards closure of the facility are offered to future generations without placing an undue burden on them.

Work has been undertaken to review the status of the Phased Geological Repository Concept as a viable option for the management of the UK's radioactive waste. This has involved an extensive review of the concept including analysis of:

- Our own safety and environmental assessments of the concept.
- Regulators' scrutiny of our work and ongoing dialogue with a broad range of stakeholders including feedback on our programme under our Transparency Policy.
- Previous reviews of our work such as Sellafield Rock Characterisation Facility Inspector's report from the Public Inquiry, the Royal Society Study Group and other related information eg House of Lords, UKCEED

The report on this work and its underlying references have been reviewed by regulators and external specialists.

The results of the above "concept review" supports our view that sufficient work has been done to demonstrate viability of the Phased Geological Repository Concept as the basis for packaging standards and to provide the confidence to proceed with a process to select a suitable site in the UK for its implementation.

By having a viable concept, Nirex is able to derive standards and specifications for packaging of radioactive waste in the UK. Government policy is that ILW will continue to be packaged to Nirex standards and specifications during the MRWS process. These standards and specifications and Nirex's related assessment process are now embedded in UK regulatory arrangements and subject to regulatory scrutiny. Much of this waste is currently stored untreated in ageing facilities beyond their original design life. The standards and specifications allow the waste to be packaged now in a form that is suitable for its long-term management.

A viable concept is essential to identify what is required from a specific site for a phased geological repository. This will form a fundamental part of any site selection process in the UK. It will also form the basis for the characterisation and confirmation of the geological suitability of any potential site.

The Phased Geological Repository Concept has been developed for ILW and certain long-lived LLW. Recently Nirex has drawn upon the vast body of knowledge and experience internationally and has developed a geological repository concept for the UK's HLW and Spent Fuel. This work has been undertaken in collaboration with SKB of Sweden and other national waste management organisations.

Conclusions

Regardless of any decision on new nuclear build in the UK, radioactive waste exists now and something needs to be done for its long-term management. Most other countries are planning to store such wastes in a deep geological repository.

After many years of research both in the UK and internationally we believe that we can demonstrate the Phased Geological Repository Concept to be a viable technical option. However, we are well aware that there is a wide gulf between a technically workable option and a solution that has sufficient support to be implemented, in particular, with the support of people who will be most directly affected. Hence, we believe the implementation of a technically viable option must be done through a process that takes account of social and ethical issues in an open and transparent manner.

Any consideration of new nuclear build requires a full understanding of the wastes that would be created and arrangements need to be made for their long term management. Failure to do so could result in the generation of even more hazardous radioactive waste with consequent risks to man and the environment.

[1] Mrs Beckett's statements of July 2003 and July 2004.

Non-Nuclear Sustainable Energy Futures: What Can the UK Learn From Germany?

Godfrey Boyle, Director of the Energy & Environment Research Unit, Faculty of Technology, The Open University; editor and co-author of Renewable Energy: Power for a Sustainable Future, Oxford University Press, 2004

The debate on the nuclear energy option has been reopened in the UK by those who believe renewables and energy efficiency cannot hope to achieve the 60% cuts in fossil-fuel carbon emissions that will be needed by mid-century to avert catastrophic climate change.

Yet Germany, with higher electricity consumption, more nuclear power stations but poorer fossil and renewable energy resources, is on-course to phase-out nuclear energy by 2020, is phasing-in renewable energy many times faster than the UK and has detailed plans to cut its emissions by 80% by 2050.

In 2003-4, Britain's renewable energy sources contributed 1.3% of the country's primary energy and 3.5% of its electricity while in Germany renewables contributed some 3% of primary energy and 7.9% of electricity. So how do Germany's and Britain's plans for the rest of this decade and beyond compare?

The UK Government's 2003 White Paper on energy emphasised the role of renewables, combined heat and power and energy efficiency in enabling the UK to meet the Kyoto treaty commitment to cut greenhouse gas emissions (mainly carbon dioxide, but including other gases) by 12.5% by 2012. No new nuclear power stations would be built, though the option of doing so in future was left open. By the end of 2004, the UK had reached its Kyoto target. Through the Renewables Obligation the Government plans to increase renewable electricity to 10% by 2010 and to 20% by 2020. It has also pledged to cut 20% of the emissions of CO_2 the principal greenhouse gas by 2012.

Germany's renewable electricity targets are similar: 12.5% by 2010 and 20% by 2020. But by 2010 it also aims to achieve a 10% contribution of renewables to *primary* energy. Germany's Kyoto target is for a 21% cut in greenhouse gas emissions. By 2004, it had reached 19%. The rate of growth in Germany's renewable energy supplies has been astonishing: between 1998 and 2003 the contribution of biomass energy doubled, wind power capacity quadrupled and the number of solar photovoltaic roofs increased six-fold. By 2003-4, Germany's installed wind and solar photovoltaic capacities were respectively 19 and 70 times as great as those of the UK.

Premium prices are paid for renewable power under Germany's Renewable Energy Sources Act, but only €1 per month per household is added to electricity bills and no increase in taxes. Each year the price paid for electricity from new photovoltaic installations falls by 5%, giving solar manufacturers a strong incentive to reduce prices as the size of their market expands. But the premium prices are guaranteed for 20 years, giving confidence to investors.

TABLE

	GERMANY	UNITED KINGDOM
Gross Domestic Product (GDP) (2003)	$2,270 billion	$1,666 billion
GDP per person	$27,550	$27,630
Population	82.4 million	60.3 million
Land area	349,000 sq km	242,000 sq km
Population density (persons per hectare)	2.4	2.5
Annual electricity demand (TWh) (2003) (1 Terawatt-hour (TWh) = 1 billion kWh)	506 TWh	338 TWh
Annual electricity use per person, kWh (kilowatt-hours)	6140 kWh	5578 kWh
Percentage of Electricity from Nuclear (2003)	28.8%	22.7%
Percentage of Electricity from Renewables (2003)	7.9%	3.5%
Percentage of Primary Energy from Renewables (2003)	3%	1.3%
Capacity of wind power installed (2004)	16,600 megawatts	880 megawatts
Number of Photovoltaic Roofs & Capacity (2003)	>100,000 410 megawatts	<1000 5.9 megawatts

The renewable energy sector in Germany has a turnover of €10 billion with 120,000 employed in 2003. Investment is predicted to reach €18-20 billion per year with 400,000 employed by 2020. Germany has also been encouraging combined heat and power generation and stringent regulations on the energy performance of buildings.

Germany's plans for the rest of this century are described in the Environment Ministry's 2004 report *Ecologically-Optimised Extension of Renewable Energy Utilisation in Germany* which envisages primary energy use falling to around half the current level by 2050. By then, renewables should be supplying 65% of the nation's electricity, 45% of its heat and 30% of its transport fuel. Nuclear power will have been phased out three decades earlier and fossil fuel use reduced to around 20% of current levels enabling Germany to achieve an 80% cut in greenhouse gas emissions.

So why has renewable energy, and wind energy in particular, progressed so slowly in the UK? This has largely been due to misconceptions about wind power, its costs and its environmental effects and the electricity system.

The publication of *Wind Power in the UK* concluded that it is relatively cheap, with on-shore wind currently costing around 3.2p/kWh and offshore some 5.5p/kWh. These reduce to about 1.5-2.0p/kWh and 2.0-3.0p/kWh by 2020. By 2010, some 7.5% of UK electricity could come from roughly 4,000 MW of on-shore turbines and another 4,000 MW of off-shore capacity. Moreover, contrary to the 2004 report of the Royal Academy of Engineering, the additional reserve and balancing power requirements of wind power are not onerous. By 2020, some 20% of UK electricity could come from wind at a modest additional cost of 0.17p/kWh. These conclusions are similar to those of the German energy agency DENA, which reported in 2005 that it would be feasible for 20% of Germany's electricity to come from wind by 2020, that the requirement for additional reserve power and new power lines would be modest, and that the additional cost to householders would be 0.5 eurocents per kWh.

The development of wind power in the UK has been hindered under the Renewables Obligation by financial incentives to seek the windiest sites, which are often the most visually conspicuous and therefore most likely to be opposed by amenity groups. The value of the Renewables Obligation Certificates (ROCs) is determined by market forces and can go down as well as up. This is unlike the German approach where investors will be paid a fixed price for electricity over 20 years. However, the new guidelines issued to Local Authorities have resulted in a higher rate of planning approvals for on-shore wind farms.

Several UK offshore wind farms have been built, but progress has slowed as a result of mergers among the large Utilities and their reluctance to bear the risks, preferring to wait and learn from others' mistakes. The capital grants offered by the DTI to offshore wind projects are insufficient to compensate firms for the initial risks – though few doubt that offshore wind will be highly successful and profitable.

So how can the UK progress renewable energy and energy efficiency? More and "smarter" support is needed – with higher funding levels for technologies, earlier in their development, such as offshore wave, tidal and wind, biofuelled electricity and photovoltaics. The DTI has improved funding recently, with wave and tidal receiving capital grants and fixed price support, in addition to increases in value of ROCs.

Renewable electricity is important, however electricity provides less than 20% of UK delivered energy; incentives to increase the proportion of renewable energy used in heating and transport are urgently needed. Better community involvement in local renewable energy projects would improve acceptance.

Incentives for efficiency and penalties for inefficiency, backed up by stringent regulatory measures are needed for buildings, industry and transport. The UK should accept that energy is cheap, and that increased costs will encourage more efficient use with special protection for low-income consumers.

The Government's purchasing power could stimulate the market for low- and zero-carbon goods and services. There should be scope for low interest loans to assist investment in renewable and sustainable energy projects – perhaps through public-private partnerships, with Government funding some of the investment at low interest rates and the private sector funding the rest at higher rates of return.

Universities are aware of the need for education and training for the thousands of specialists who will be required to build and maintain the sustainable energy infrastructure of the 21st century. A major public education programme is also needed to better inform non-specialists on key issues.

Germany's track record and future policies demonstrate that it is quite possible to deploy renewables and energy efficiency *fast*. The scenario for 2050 shows how an 80% cut in CO_2 emissions by 2050 can be achieved without nuclear power. This is similar to the UK Royal Commission on Environmental Pollution's scenario number four for 2050, which entailed a 47% cut in primary energy use, with energy mainly supplied by renewables with a much-reduced fossil fuel contribution and no nuclear power.

A new nuclear programme for the UK is undesirable because it would starve renewables of investment and send the wrong signals to investors and to other countries.

The 2003 White Paper strategy remains broadly correct, but the UK Government needs to make a greater commitment to renewables and energy efficiency comparable to Germany, if its ambitious and laudable CO_2 reduction targets for 2050 are to be achieved.

In discussion the following points were made:

The finances and activities of the nuclear industry should be transparent in future although for historical reasons associated with the Cold War and military priorities, this was not always the case hitherto. Current Franco-German policies for power generation should be regarded as a combined and integrated system, with plans for future investment in nuclear facilities being made in France and for renewables in Germany, especially for geothermal power, their secret weapon. Hence an overview of future German plans for power generation should also take account of their investments to be made in France. Thermal generating power is an essential requirement as a back up to wind-power making it four times more costly than nuclear power. Future requirements for investment in power generation before 2030 are £30bn for Wind or £10bn for Nuclear. Progress is being made with fusion but the timescale before the delivery of commercial power from this source leaves a window that could filled by nuclear fission. Current stocks of Plutonium are sufficient to fuel two reactors for 25 years each. A coherent narrative is urgently needed to put together an integrated framework for nuclear waste disposal. A balanced energy system is needed and time is now very short. We must deliver something that is workable. The rotation of wind turbine tips is restricted by the speed of sound. Renewables are based on new technologies that are currently too risky to rely on when we already have the means to develop power and reduce CO_2 emissions. If we have a problem with climate why throw out the one method we have for reducing climate change? Don't look back, but be prepared for changing technologies in future.