Nuclear Power

Keeping the Option Open

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The Government announced in early 2003 that it would delay any decision to build new nuclear power stations for the time being. As current nuclear plants are gradually decommissioned over the next 20 years, it therefore seems likely that the UK will become increasingly dependent on a narrower range of fuels for electricity supplies, with a growing component of fossil fuels. The UK is, however, committed to reducing greenhouse gas emissions by 12.5 per cent by 2008-2012 under the Kyoto Protocol, and also has the more ambitious target of cutting carbon dioxide emissions by 20 per cent by 2020. It is thus important to retain the carbon-free nuclear option, and with it the technical skills needed to build, operate and decommission nuclear plants.

The Institute of Physics held a seminar in June 2003 to consider the potential role of nuclear power in maintaining adequate, stable and socially acceptable energy supplies in a future carbon-sensitive but competitive economy. The seminar was chaired by Sir Eric Ash, currently chairman of Hydroventuri Ltd, who also chaired a recent Royal Society review on the future of nuclear energy. Richard Mayson, Technology Director for Reactor Systems at BNFL, described the economic and environmental benefits of nuclear power made possible by current technological advances, and the importance of investing in nuclear energy research and development, while Gordon MacKerron of the economic consulting firm, NERA, considered the requirements that nuclear power has to meet to become socially and commercially acceptable. Nuclear waste management is a major issue for the public, and Ann McCall, Head of Safety and Strategy Development at Nirex, discussed the importance of raising public awareness of the problems and their technical solutions. Finally, Jane Nicholson of the Engineering and Physical Sciences Research Council (EPSRC) explained the background behind the Research Council's new £28 million initiative on energy, and its plans for supporting research relating to nuclear power.

Current Government energy policy

In February 2003, the Government published a White Paper laying down an energy policy for the UK over the next 20 years (and in outline for the next 50 years) aimed at addressing the threat of climate change within an updated infrastructure of efficient energy supply and usage, as well energy security and fuel poverty. The White Paper emphasised the importance of achieving a low-carbon economy while establishing new, environmentally sustainable energy sources to help replace dwindling indigenous supplies. The aim is to achieve a 60 per cent cut in carbon dioxide emissions by 2050.

The White Paper envisaged a diverse system of energy sources in place by 2020, including a significant percentage of renewables such as wind and wave power, as well as large-scale gas and some coal-fired energy production. These sources would be supplemented by distributed local and domestic generation based on, for example, biomass, photovoltaics and fuel cells.

It was recognised that as much as three-quarters of the UK's energy supplies would have to be imported by 2020, as the UK's coal, oil and gas resources become exhausted (by 2006 the UK will probably be a net importer of gas). Electricity generation would continue to operate within a liberalised European environment (that is, a competitive energy market not subject to centralised planning).

Despite the very ambitious nature of the strategy, the potential of nuclear power to help achieve these targets was largely overlooked within the 128-page document, which included a single paragraph tentatively saying that, because of its currently uneconomic status, no new nuclear build was proposed:

"While nuclear power is currently an important source of carbon-free energy, the current economics of nuclear power make it an unattractive option for new generating capacity and there are also important issues for nuclear waste to be resolved. This White Paper does not contain proposals for building new nuclear power stations. However, we do not rule out the possibility that at some point in the future new nuclear build might be

necessary if we are to meet our carbon targets. Before any decision to proceed with the building of new nuclear power stations, there would need to be the fullest public consultation and the publication of a White Paper setting out the Government's proposals."

However, the White Paper did acknowledge the potential of nuclear fusion for the more distant future.

The need for nuclear power

Nuclear power currently produces about a quarter of the UK's electricity. By 2023, all but one of the UK's nuclear reactors will be shut down.

Richard Mayson pointed out that if all the nuclear power lost were replaced by that from gas then carbon dioxide emissions would rise by 35 million tonnes a year; if replaced by coal it would increase by approximately double that. Five thousand of the largest windmills currently available would be needed to replace the reactor capacity that will be lost between 2010 and 2015 – equivalent to constructing 20 new windmills a week! (Indeed, energy expert Professor Ian Fells has noted that even if all the world's wind-generating plant were located in the UK it would only just meet the 10 per cent target for renewable energy exploitation – which shows the extent of the challenge).

Wind power is also intermittent and the energy shortfall will have to be met by conventional gas or coal-fired generation. The result is that many energy experts believe that without nuclear power, overall carbon emissions will not be reduced at all – as required by Government targets. In fact, in the annexes to the White Paper, the Government acknowledges that to meet the 2050 target for carbon emissions, nuclear power, together with carbon sequestration would have to play a substantial role in the post-2020 era if a massive cost penalty were to be avoided. "I believe that nuclear power will make a comeback," said Richard Mayson.

Problems to overcome

What are the problems that need to be addressed to keep the nuclear option open in the UK? According to Gordon MacKerron, nuclear power should not be treated by Government as a special case: it needs to become 'ordinary'. This means dealing with three main issues – costs, waste disposal and safety.

Economics

There have been major improvements in nuclear technology over the past 10 to 15 years. New reactor designs have been developed which are cheaper and more efficient. Costs such as waste disposal and decommissioning are now much better understood and treated more realistically.

The new Westinghouse Advanced Passive Reactor, the AP1000, which is ready for deployment now, is a much simplified design. It exploits passive safety systems based on gravity, natural circulation and compressed gas to shut down and cool the plant, considerably reducing operating costs. A South-African-led design, the Pebble Bed Modular Reactor (PBMR), is a liquid helium-cooled, high-temperature reactor and a demonstration reactor should be ready by 2010. Other so-called Generation IV designs should be ready between 2020 and 2030.

Richard Mayson mentioned a recent study carried out by BNFL and British Energy which showed that the costs of building and deploying the AP1000 would be competitive with other energy sources, especially when 'hidden' costs of electricity generation are taken into account. These include the environmental cost of carbon which will be quantified in the 'emissions market'. The European Emission Trading Scheme could add half a penny per kilowatt hour to the cost of fossil fuel generated electricity, making nuclear power economically attractive.

Attempts have also been made to quantify security of supply. Nuclear and wind power have a greater security of supply than imported gas. When the extra carbon costs resulting from the back-up capacity of fossil fuel plants needed to compensate for wind power outages are taken into account – plus the cost of new infrastructure requirements of wind power – then nuclear power looks more attractive. Another hidden advantage is that nuclear plant uses up very little land and natural resources.

One of the key issues, however, for new nuclear build is whether it can be financed in a liberalised market, whereby investors and energy suppliers can choose what technology to deploy and what projects to invest in. A full-scale commercial version of the AP1000 has not yet been built anywhere in the world. Nevertheless, the US is looking at ways of encouraging utilities to finance nuclear projects through loan guarantees.

Gordon MacKerron pointed out that designs need to be made more friendly to liberalised markets. Nuclear technology has to be able to operate on a smaller scale per individual unit (such as the PBMR) to make it easier for investors to commit money to new build. Nuclear programmes will have to offer investors the same kind of contractual guarantees that are now routinely available for established technologies like the combined-cycle gas turbine – in other words, fixed costs and performance guarantees. The problem of financing nuclear is very real – capital markets are

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suspicious of a technology that cannot offer the same level of performance and construction cost guarantees as gas-fired projects, and suffers from large risks, some political in origin, that are unique to nuclear power. This means that even if nuclear costs do seem to fall to those of fossil fuel generation, markets may still be reluctant to proceed because the financial risks are greater.

Waste disposal

Perhaps the biggest obstacle to nuclear power generation to overcome is developing a coherent and socially acceptable strategy for dealing with nuclear waste.

Ann McCall explained the current situation for the different types of nuclear waste – high-level, intermediate and low-level. Not all of it is produced by nuclear power – a certain proportion comes from defence and medical uses. High-level waste is produced in relatively small amounts from re-processing irradiated nuclear fuel, and is responsible for about *95 per cent* of the radioactivity in all wastes from nuclear power generation. It is vitrified and stored in a specially designed facility at BNFL's Sellafield site. Low-level waste which mostly consists of lightly contaminated rubbish is sent for near-surface disposal at BNFL's Drigg site in Cumbria.

About 200,000 cubic metres of intermediate-level waste has accumulated in the UK over the past 50 years, and most of it is still being stored at 33 surface locations around the country, awaiting long-term disposal. Nirex's solution is a stepwise (and retrievable) deep geological disposal. The waste is conditioned in cement in corrosion-resistant canisters, and placed in vaults between 300 and 1000 metres underground in carefully chosen geologically stable sites. Eventually, the repositories would be sealed with chemically conditioned backfill so as to avoid any possible leaching out of waste.

This form of nuclear waste management is now well understood, and could be used not just to remove the waste already created but also to deal with waste from future plant operation. New reactor designs like the AP1000 and the PBMR would produce only a tiny proportion of the waste generated by older plant. The main problem is not solving underlying scientific problems but instilling public confidence in the strategy. Ann McCall emphasised that Nirex was neutral on the issue of new or replacement build because, irrespective of the future of nuclear power in the UK, radioactive waste already exists and must be dealt with by the present generation. "There are three things we need to do that were not done before," she said: "First we have to raise public awareness that the waste is already there; secondly get acceptance that there is a problem to deal with; and thirdly that there is a safe and practicable solution that can be implemented."

So far, the Government has not instituted a policy for long-term nuclear waste disposal, and has put off making one. However, in Finland, Sweden and the US, considerable progress has been made in improving public perceptions and establishing a workable policy.

Safety

Closely allied with the problem of waste disposal is that of safety and security. The new generations of reactors are passively safe. (The Chernobyl disaster was a 'one-off' resulting from poor design and appallingly bad operating practice). There is even the possibility of building reactors underground to avoid possible terrorist attacks, although it is a popular misconception that a nuclear explosion would ensue; the effect would be more akin a to 'dirty bomb' produced by a chemical explosion. Similarly, placing waste deep underground would minimise any such security threat.

Another problem that has yet to be addressed at Government level is how to deal with the stockpile of separated plutonium generated by reprocessing spent fuel. There is currently about 60 tonnes of plutonium in the UK, which is set to rise to 100 tonnes by 2010. The UK has to decide if it should be made into fuel for future reactors as part of a coherent nuclear energy strategy. Plutonium oxide can be mixed with uranium oxide to produce mixed oxide fuel (MOX) which can be used in certain reactors (BNFL has a MOX reprocessing plant at Sellafield). However, reprocessing the spent fuel is expensive and there is public fear that stored, reprocessed plutonium could be stolen and used to make nuclear weapons. The alternative is deep geological disposal.

Maintaining the UK's skills

The delay in decisions on a nuclear waste strategy and the consequent deployment of the nuclear option could have serious consequences for the UK's future energy programme. The Government, through the Department for Environment Food and Rural Affairs (Defra), will not have concluded its deliberations on the management of radioactive waste until 2006, when legislation has been promised if required. Any future White Paper on nuclear build is therefore not likely until 2008 or 2009. A nuclear reactor takes typically 10 years to bring online, so that the UK would not have an operational plant until about 2020, by which time the UK would have lost most of its nuclear generating capacity.

A major concern expressed at the seminar was that with this time frame in place, the UK would be

unable to maintain an adequate skills base essential to deploy new nuclear technology. Today, most experienced nuclear engineers are in their fifties and thus likely to be retiring within the next decade. The White Paper admits that even without nuclear build, the industry requires around 19,000 graduates and skilled people. However, bright young scientists and engineers are not likely to join a shrinking industry.

One of the key actions to maintain the UK's competence would be to carry out preparatory work on new nuclear technology, for example, selecting and licensing new reactor designs, such as the AP1000, so as to shorten the timescale to future new build. Government regulators could review designs without a direct commitment to new build. Nuclear development programmes are being carried out around the world. The UK therefore needs to invest in research that keeps it abreast of international developments so that informed choices can be made on the best technology currently available.

Participating in internationally developed designs for long-term deployment, such as the PBMR and the other Generation IV designs, are vital for the future. Japan and the US are already working on systems that efficiently integrate these designs into the hoped for clean energy production based on hydrogen generation. Such systems could have a key role to play in attaining the kind of carbon emission cuts needed to achieve the 2050 target.

The delivery of energy via nuclear fusion is a long-term goal but it is unlikely that a commercial reactor would be ready before 2050. Fusion R&D receives about £40 million per annum of public support while Government funding of fission research is less £1 million. Most of this goes on waste management rather than reactor development. BNFL says it fully supports recommendations to spend between £5 and 10 million a year into new reactor systems.

Research and development

The Government has, in fact, recognised the importance of investing in technological innovation. Jane Nicholson elaborated on the new £28 million initiative on energy to be administered across three research Councils – EPSRC, the Natural Environment Research Council (NERC) and the Economic and Social Research Council (ESRC). A key component is the establishment of a UK Energy Research Centre, which will act as a hub for a national energy research network involving researchers in a wide range of disciplines. The aim will be to link the technology research to issues such as market economics, and environmental and social constraints. EPSRC has also taken over responsibility from the Department of Trade and Industry (DTI) for the UK's domestic fusion programme at the Culham Laboratory in Oxfordshire.

Until now, the research councils have supported very little fission R&D, so no natural research community working in this area exists. However, there is a broad skills base that can be drawn on, and EPSRC will collaborate with the other research councils in bringing together a community to work on nuclear fission projects. The EPSRC is planning to establish a research consortium funded by about £5 million spread over four years. Potential priority areas include:

- novel reactor concepts;
- fuel cycles and fuel management;
- waste management and storage;
- decommissioning technologies;
- fission materials;
- energy markets and regulation; and
- social issues and public acceptability.

Conclusions

So what are the main actions needed to keep the nuclear option open – which may be essential in the post 2020 era?

1. The Government should make a small financial commitment to keep the UK involved in international R&D programmes on new reactor systems such as the ones already mentioned. Some research groups are also working on speculative systems based on novel physical processes, as well new methods of waste disposal, and the UK should also keep a watching brief on these.

2. The regulators should be given resources to review the candidate's designs. The review could be completed without any commitment to new build.

3. The Government needs urgently to implement and complete an objective appraisal of the waste issue and establish a coherent policy and strategy to deal with nuclear waste. Until this is done the nuclear option is closed.

4. The mechanism of financing nuclear programmes needs to be addressed by both industry and Government, in light of the nuclear contribution to carbon savings, security of energy supply and low infrastructure costs.

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5. Academic research into the science, and social and economic issues regarding the exploitation of nuclear power needs to continue and expand in order to prepare the UK for a carbon-reduced future.

Further reading

1. *Our energy future - creating a low carbon economy*, (Cm 5761), Government (DTI) White Paper, 25 February 2003.

2. *Towards a Non-Carbon Fuel Economy: Research, Development and Demonstration*, (HC 55-I), The House of Commons Science and Technology Committee, 3 April 2003.

3. *Why the UK should build more nuclear power stations*, The Engineer, 24 January-6 February 2003.

4. *Nuclear power in the twenty-first century*, Interdisciplinary Science Reviews, 2001, 26, pp. 233-312.

5. *An Essential Programme to Underpin Government Policy on Nuclear Power*, Nuclear Task Force, July 2003.

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