Parliamentary Office of Science and Technology

postnote

December 2003 Number 208

THE NUCLEAR ENERGY OPTION IN THE UK

The government's recent White Paper on energy policy did not endorse a programme of new nuclear power stations at this time, but declared that *"at some point in the future new nuclear build might be necessary if we are to meet our carbon targets."* Thus, its policy on nuclear energy is *"to keep the option open"*.[1] Parliamentary interest in this topic is high. This briefing analyses some of the issues associated with keeping the option open that the government and industry might need to resolve. It does not examine whether there is a need to keep the option open nor indeed the precise means for doing this. Rather, it focuses on options for new reactors, the economics of nuclear energy, the knowledge base for nuclear technology, and issues related to waste management, licensing and security.

Background

Nuclear energy in the UK

The UK operates three types of civil nuclear reactors:

- 'Magnox' reactors were the first generation of commercial nuclear reactors. They are operated by Magnox Electric (part of British Nuclear Fuels Ltd, BNFL). Some have already closed, and the remaining five are due to close by 2010.
- Advanced gas-cooled reactors (AGRs) evolved from the Magnox design. British Energy (BE) operates seven AGRs; all of which are scheduled to close between 2008 and 2023.
- Pressurised-water reactors (PWR), a US design. BE operates one PWR, Sizewell B in Suffolk. This will close around 2035.

Together, nuclear power stations in the UK meet 23% of current electricity demand: 5% from Magnox, 16% from the AGRs and 2% from the PWR. By 2020, total nuclear capacity will have reduced by around three-quarters.

When built, nuclear reactors are designed to last for a specified lifetime but, in principle, it is possible to extend this. Magnox reactors have already run longer than originally expected, but further extensions of their lifetime are not economic. In 1994, BE increased the lifetime of some of its AGRs by five years. However, BE currently has no plans to extend the lifetime of its AGRs further, nor is it planning to extend the lifetime of Sizewell B.

Options for new reactors

Magnox and AGRs are no longer built anywhere and the PWR is now the most common reactor type. Should there be new nuclear build in the UK, there are three designs which are the likeliest contenders in the short-term. The first is based on a unique Canadian design while the latter two are based on PWR technology:

- **ACR 700** – the 'advanced Canadian Deuterium-Uranium (CANDU) reactor 700MWe',[2] designed by Atomic Energy of Canada Ltd. (AECL)
- **AP1000** – the advanced-passive 1000MWe reactor, designed by BNFL-Westinghouse
- **EPR** – the European Pressurized Water Reactor 1600 MWe, designed by Framatome ANP.

None has yet been built anywhere. Each of the above reactors has been designed to operate for 60 years. They are also designed to use fuel more efficiently than previous reactors, reducing fuel use and waste arisings. For safety, a nuclear power plant must be robust to protect the reactor core. Each of the above designs employs containment structures that include a concrete outer shield. Similarly, the reactor core needs to be cooled to prevent overheating, which could otherwise lead to releases of radiological material. The ACR 700 and AP1000 use 'passive' safety features which do not require the active intervention of, say, a plant operator to initiate them. These are also replicated and each can perform the safety function on its own should another fail (this is called 'redundancy'). The EPR, on the other hand, does not have passive safety features but builds on the idea of containment and redundancy. Here, possible releases of radioactivity would be trapped inside the containment and safety devices are replicated four times.

To familiarise itself with new reactor technology, the safety regulator, the Nuclear Installations Inspectorate (NII), normally conducts pre-licensing reviews prior to the formal licensing process. The NII would then scrutinize preliminary safety and pre-construction reports to ensure general compliance with UK safety regulation. This would form the basis of a license to construct a nuclear power plant. Finally, before operations can begin, a nuclear generator would have to obtain a license to operate.

Economics of nuclear power

Costs for nuclear power plants are commonly quoted in the form of the costs of producing one kilowatt-hour (kWh) of electricity (in pence per kWh). There are a number of conflicting studies on this issue. Cost estimates produced by AECL for the ACR 700 project costs of 1.6-2.5p/kWh, while Framatome estimated costs of 2.1p/kWh for an EPR built under the German regulatory regime. BNFL projects costs between 2 and 2.5p/kWh for the AP1000. BNFL and BE have indicated that the costs of building 5 new power stations, each with two reactors, would be around £10bn.

These numbers have been subject to some criticism especially with regard to assumptions over discount rates, lifetime plant performance and availability, construction time and costs. The discount rate is arguably the most important factor affecting the sensitivity of the cost projections (see box opposite).

The Massachusetts Institute of Technology (MIT) estimated that costs for new nuclear construction in the USA would be 3.9-4.5p/kWh. Nuclear power projects in the past have often turned out more expensive than assumed. For example, cost estimates for the Sizewell B reactor were revised upwards by 40% and generation costs were higher (~6p/kWh). However, Sizewell B was a one-off project and the nuclear industry has changed considerably since privatisation, and so past experience does not necessarily apply to future projects. Recent constructions in China and South Korea have been completed on budget and time although this experience is not necessarily transferable to the UK. The 2002 Cabinet Office Energy Review noted that its own cost estimate (which was 2.5-4p/kWh) *"still represents a major decrease in costs compared to all previous nuclear construction in the UK, including Sizewell B."* [3]

The basic problem in all these comparisons is that the situation is a classic catch-22. Only the construction of a new reactor could verify the cost assumptions made by the nuclear industry. Currently, private investors, aware of the risks, would need more certainty before they invested. Nuclear energy will ultimately have to compete in the electricity market with other technologies and the nuclear industry recognises that it will have to make its case to potential investors. The circumstances within which all energy sources will develop are constantly evolving. Future cost estimates will depend on a number of factors, including technological progress, fossil fuel prices and UK and European energy policy. Consequently, it is not possible at this time to provide accurate projections of the future costs of electricity from any generating source.

Discount rates and nuclear power economics

In previous nuclear power station projects, 60-70% of total lifetime plant costs are upfront capital costs. Although, for example, BNFL outlines that the AP1000 would be cheaper and quicker to build, this figure would still be in the region of 50-60%. In this context, the discount rate chosen to cost a nuclear power plant over its lifetime is probably the most sensitive parameter to overall costs. It reflects the value put on time preferences – for a nuclear power plant project, high up-front capital costs have to be valued against a stream of future income. For example, a benefit of £100 occurring in 10 years' time is worth ~£60 now at a discount rate of 5% and ~£38 if discounted at 10%.

Taking a real example, the Sizewell B project appeared to be economically viable at a 5% public sector discount rate and was approved on that basis in 1987. By 1989, the official rate had risen to 8% and the next PWR, Hinkley Point C, was close to being viable, though with lower expected construction costs than Sizewell B. Following privatization, the nuclear industry was advised that the lowest possible commercial discount rate for a nuclear project would be 11%. At this rate, the proposed Sizewell C power station would have made a large loss, though the construction costs were even lower than those expected at Hinkley Point C.[4]

Should the government pursue the nuclear option, the question arises over how policy could make the economics of nuclear power more attractive to the market. The government has not made any statements on this, other than to say that it is up to the market to make the decision at the time. However, some in the industry have suggested a number of measures to improve the market prospects for nuclear energy. First, market mechanisms, such as carbon taxes, which would benefit the low carbon status of nuclear power, or exemption of nuclear power from the existing Climate Change Levy, could be introduced. It is, however, unclear what level of tax would be sufficient to make nuclear power competitive. The forthcoming EU emissions trading scheme will benefit nuclear energy although it is doubtful whether this would be sufficient to stimulate new build. Another option is making direct support available, possibly as loan guarantees on construction costs. This was discussed in the USA, but it is unclear whether this would be legal under EU state aid rules.

The knowledge base for nuclear technology

Nuclear education and training

A recent report from the Department of Trade and Industry (DTI) highlighted a potential future shortage of skilled employees in the nuclear sector.[5] It stated that, not only are engineering and physical sciences currently unattractive fields of study, but nuclear technology courses are unpopular choices in this unpopular field.

There is no undergraduate course focusing exclusively on nuclear technology, but 20 universities offer courses with nuclear components. 13 were engaged in postgraduate teaching. In 2001, and ~1500 students had some nuclear component in their undergraduate courses. A further 500 attended special diploma courses in nuclear technology. Furthermore, 320 students finished post-graduate courses with nuclear content, 72 of which had exclusive nuclear content. These figures compare with a projected annual recruitment need for people with nuclear skills (in the power, fuel, defence and clean up sectors) of ~1000 students.[9]

A recent survey by the Health and Safety Executive (HSE), found that overall nuclear education was in a state of 'fragile stability'. While some universities ceased nuclear education and training, others had extended their programmes, often in partnership with the nuclear industry. In particular, BNFL has set up four 'university research alliances' (at a total cost of £40m over five years) to support the UK nuclear research base. This funding also provides facilities and capacity for nuclear research and training at universities. Furthermore, a sector skills-council combining industry, government agencies and training providers will shortly be set up to enhance the skill base in the nuclear sector.

Research and development

In the longer term, designs currently being examined by an international 'Generation IV' nuclear research programme could become an option.[6] It is important to note that neither any of the near-term reactor options (see page 1) nor those being examined under generation IV are being developed in the UK. Hence, any new reactor technology would have to be imported. Thus, the industry and regulator argue that being informed of and involved in international research would be an important aspect of keeping the nuclear option open in the UK.

Most UK nuclear reactor research is sponsored by the industry and research councils. BNFL funds UK involvement in the Generation IV project, although the exact sum is undisclosed. The research programme 'Towards a Sustainable Energy Economy', operated jointly by three research councils, will spend approximately £5m on general nuclear technology research over the next four years. It is unclear at present what proportion of this would be dedicated to novel reactor research. The DTI does not directly fund research into nuclear fission reactor developments, but focuses more on nuclear fusion. The Minister of State for Energy recently announced that this is under review and may change.[7]

The Government plans to establish a Nuclear Decommissioning Agency (NDA) to decommission and clean-up nuclear facilities in the UK. The Energy Bill presented in the recent Queen's Speech will require the NDA to ensure that an adequate skill base is available in the UK to carry out its task. In its pre-legislative scrutiny of the draft bill to establish the NDA, the House of Commons Trade and Industry Committee noted that there could be overlap between research for clean-up and research that may be relevant to the wider development of the nuclear skill base. The Committee recommended further investigation before the bill is debated.

Changes in the UK nuclear industry

The UK nuclear industry is undergoing structural change, particularly on reactor operations and the associated fuel cycle, and on nuclear clean-up and decommissioning. The latter will soon operate in a market that is statutorily guaranteed by the NDA, and expected to be worth at least £50 billion in this century. However, reactor and fuel operations face a declining future as existing power stations close (Magnox by 2010 and AGRs by 2023).

BNFL has responded by reorganising its company into two main subdivisions. The 'Government Services Group' focuses on the developing nuclear clean-up market while the 'Utilities Service Group' is involved in reactor design, operation and the fuel cycle. In the absence of a UK decision on nuclear power, BNFL is involved in a number of overseas nuclear power plant projects, for example in South Korea. BE is currently restructuring its finance following emergency loans from the government. This still awaits approval from EU competition authorities. The long-term future of BE remains uncertain.

The Nuclear Installations Inspectorate

In 2001, BE and BNFL asked the NII to start a pre-licensing review for the AP1000 (see page 2). The NII declined because of a lack of adequate staffing. The NII recruits staff from a range of industries with a strong safety culture (such as chemicals) who can bring skills with them relevant to the nuclear industry – such as preparing and assessing safety cases. Thus, it does not see an impending shortfall in staff that would inhibit its ability to fulfil its current duties. The NII has stated that, until the government signals its intention to seek new nuclear build, it will make no bids for additional resources for pre-licensing of new reactor designs.

Moreover, many existing NII staff with experience of previous licensing exercises (such as for Sizewell B) are nearing retirement in the next few years. Also, the NII has had limited exposure to the development and assessment of new reactor designs to date, and so in-house knowledge of these may be constrained. Together, these issues may create knowledge gaps in the medium-term that would take time to fill and so limit the pace at which new nuclear build could be developed in the UK.

Waste management

Nuclear power stations produce four categories of radioactive waste (RW): very-low-level, low-level, intermediate-level and high-level. There is as yet no long-term management option for the last two categories. Much RW remains radioactive for hundreds to many thousands of years and must be isolated for long time-periods to prevent harm to people and the environment.

One issue is the likely contribution to the existing waste stockpile arising from any new reactors. BNFL argues that the contribution would be small. It has suggested that ten AP1000 reactors (each operating for 60 years) would add no more than 10% to the volume of high- and intermediate-level waste (and 3% of low-level waste) likely to arise from existing nuclear reactors. Others (such as environmental NGOs) argue that this is still unacceptable, as no further waste should be generated until a solution is found for existing wastes. Some go further and suggest that a solution for RW can never be found while there is still a commitment to nuclear energy which would continue to produce radioactive waste.

Moreover, research has shown that the public expresses high levels of concern over RW and often inextricably links the issues of new nuclear power and RW management in terms similar to those expressed by NGOs.[8,9] The feasibility and timetable for finding a publicly acceptable RW management strategy is likely to have a significant bearing on any government decision to support or abandon the idea of new nuclear build. After achieving public consensus on a long-term option for managing RW, Finland has recently announced that it would begin construction of a new nuclear power station.

In 2001, the UK government (and devolved administrations) launched a process to find a publicly acceptable approach to RW management in the UK. This is currently scheduled to run until 2006/2007. A new Committee on Radioactive Waste Management (CoRWM) was established to recommend a preferred option (or options) for managing RW. Its members include natural and social scientists. It will operate on the principles of openness, transparency and public dialogue, and will consult widely with the public.

Planning and licensing issues

When Sizewell B was planned, the ensuing public inquiry took almost four years. The nuclear industry argues that the public inquiry process should be streamlined, as it presents an additional risk for private investors. Clause 150 of the Energy Bill introduced in the Queen's Speech, provides for a re-organisation of public inquiry procedures for new power station proposals. Here, lead inspectors for inquiries would be assisted by further inspectors to share the work and allow issues to be considered concurrently rather than sequentially as at present. Forthcoming law on public access to environmental justice requires 'meaningful' public participation in environmental decisions. Some are concerned that Government's proposals to streamline planning may reduce the public's rights for participation.

Another approach may be to revise the regulatory process so that it is more akin to US certification, where industry can obtain general design certification for new reactor types, leaving more localised design and construction issues to a public inquiry. However, the NII points out that the UK regulatory process is already relatively flexible and that the safety approval of Sizewell B was significantly shorter than the subsequent public inquiry. Revising the regulatory system would do little to streamline the overall consents process.

Security

Following the September 11 attacks in the US, terrorist attacks against nuclear power plants became a focus for attention. Currently, there is little information available in the public domain on this issue due to security considerations. POST is shortly to publish a detailed report on this, based on public domain information.

The heightened security situation might lead to a conflict between the openness and transparency of the industry and requirements for confidentiality. Creating and maintaining public confidence in current and future nuclear power projects would largely rely on the public being able to trust the institutions designing and implementing safety and security measures. Recent research has shown that UK citizens are concerned about nuclear safety, and that their trust in the nuclear industry to be open and transparent was low.[11,10]

Overview

The Energy White Paper announced that the government will review the current strategy in 2005/2006. The current consultation process on radioactive waste management is also expected to conclude around this time. Any explicit support for new nuclear build would be set out in a specific White Paper, and licensing, siting and public scrutiny could then begin. There is no certainty on the timetable for this process, but some commentators have argued that the first of any new generation of nuclear power stations is unlikely to come on stream much earlier than 2020. Regardless of the precise timescale, a renaissance of nuclear power in the UK would need the government and industry to address:

- market acceptability of the balance between the risks and rewards of investment in nuclear power
- adequacy of industry and regulators' skills and knowledge to enable new power stations to be planned, developed, operated and regulated
- public acceptability of a long-term strategy to manage radioactive waste.

Endnotes

1 *The Energy White Paper – Our Energy Future, Creating a Low-Carbon Economy,* Cm 5761, 2003.
2 MWe is the maximum capacity of a reactor in Mega Watt (MW)
3 The *Energy Review*, PIU, Cabinet Office, 2002
4 MacKerron, G. (2000), Financial considerations of exploiting fuel cell technology, *Journal of Power Sources,* 86:1-2, 28-33
5 *Nuclear and Radiological Skills Study*, DTI, 2002.
6 See http://gen-iv.ne.doe.gov/
7 Stephen Timms, speech at the *'energy choices 2003'* conference
8 *Eurobarometer – Europeans and Radioactive Waste*, EC, 2002.
9 *Public Perceptions of Risk, Science and Governance*, Poortinga, W. and Pidgeon, N. University of East Anglia: Norwich, 2003.
10 *Eurobarometer – Energy: Issues, Options and Technologies*, EC, 2003.

POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of public policy issues that have a basis in science and technology. POST is grateful to Till Stenzel and Imperial College for assisting in the preparation of this briefing note. A longer report on the nuclear option in the UK is available on the POST web site.

The Parliamentary Office of Science and Technology, 7 Millbank, London SW1P 3JA Tel 020 7219 2840

www.parliament.uk/post