ELSEVIER

Energy Policy 32 (2004) 1957–1965

ENERGY POLICY

www.elsevier.com/locate/enpol

Nuclear power and the characteristics of 'ordinariness'—the case of UK energy policy

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Abstract

This paper first considers why nuclear power has become unattractive to private investors in liberalised electricity markets. It then outlines some of the thinking behind current UK energy policy, which emphasises the centrality of developing a low carbon economy. It sets out the arguments, mostly based on the market failures of environmental externalities and inadequate private investment in R&D, for giving greater public support for nuclear power, using the UK as a case-study. The conclusions are: (i) Government implicitly regards nuclear power as suffering from non-climate change externalities that balance its climate change advantages, and thus does not give nuclear the same advantages as renewables; (ii) there is a case for limited public R&D support for long-term, radical nuclear technology; (iii) nuclear power will only become a serious choice for new private investment if it can become an 'ordinary' technology, and the conditions for ordinariness are set out.

Keywords: Nuclear; Market failure; UK energy policy

1. Introduction

As a new investment option, nuclear power has been doing badly for a decade. There are a few niche exceptions, such as China and possibly Finland, but the general picture is poor. Even where there has been investment activity over this period, as in Japan, the prospects do not seem promising. The explanation for this downturn is in essence relatively simple—the economics of nuclear power have been poor in increasingly liberalised electricity markets.

Market liberalisation is likely to progress further in the electricity systems of industrialised countries. Some recent events (especially power blackouts in the US, UK and Italy in 2003 and the serious problems of the California power system in 2001) have caused some re-evaluation of liberalisation, especially in the developing world. However, the momentum behind liberalisation in the EU and wider OECD world remains powerful. While Governments still set regulatory and policy frameworks, increasing liberalisation means that investment decision-making for electricity generation will ultimately depend on the decisions of private investors. For nuclear power to perform better as a new investment option in these circumstances, one or both of two conditions will then need to be met:

- On the basis of market prices, the economics of nuclear power will need to become significantly more attractive relative to its competitors;
- Governments will need to introduce policies, either nuclear-specific or generically in favour of low carbon options, to improve the relative attractiveness of nuclear power to the private investment community.

In practice, significant resumption of nuclear investment will probably depend on both of the above conditions being fulfilled.

Within a mainly UK setting, the first major part of this paper explains the state of nuclear economics in current market conditions and explains why the option of nuclear investment remains unattractive to the private investment community.

The second main part of the paper introduces the framework of justification for Government intervention in energy markets, in terms of both sustainable

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0301-4215/$ - see front matter
doi:10.1016/j.enpol.2004.03.011

development and 'market failure'. It looks at arguments for interventions specifically in favour of nuclear power (analogous to those often currently made in favour of renewable energy) as well as impacts on nuclear power of more generically low-carbon support policies. It concludes by defining the economic characteristics that nuclear technology might need in order to play a significant role in a long-term low-carbon energy system.

2. Context: nuclear power and sustainable energy policy

Sustainable development involves the idea that public policy should try simultaneously to promote economic, social and environmental progress, where the idea of environmental progress includes resource efficiency as well as minimising environmental damage. In relation to energy policy, the environmental part of this agenda has been especially prominent, and—as in current UK energy policy—the specific issue of mitigating climate change has become increasingly a touchstone of the sustainability of energy policy. The 'low carbon' economy is therefore a major focus of energy policy debate.

In relation to the objective of the low carbon economy and resource efficiency, nuclear power performs extremely well. Nuclear power:

- is, in currently commercial forms, well-established technology;
- produces no carbon or other climate-relevant emissions in operation;
- can provide large amounts of power using limited land area;
- and uses a plentiful natural resource (uranium) in very small quantities.

All else equal, this makes nuclear power a very attractive option in moving towards a radically lower carbon economy at a high level of resource efficiency.

However, nuclear power raises other issues that are problematic in relation to the sustainable development agenda. In terms of other environmental impacts than climate change, nuclear waste poses a substantial problem, and is some way from consensual solution in most countries including the UK. There are also potentially important issues in social terms (indeed the problem of nuclear waste may be seen primarily as a social and trust-based issue) including the overall public acceptability of nuclear generating and fuel cycle technology, whether in relation to nuclear waste, to safety or to wider issues like non-proliferation.

These other problems of nuclear power might be resolved and they may not, in any case, provide a binding constraint on further nuclear investment even if they are not fully resolved. In such circumstances, the advantages of nuclear power are so substantial in relation to climate change objectives that nuclear power could, in the medium to long term, become an important and large-scale investment choice again.

3. UK energy policy

The current context in the UK is a large review of energy policy, starting with the process leading to PIU (2002b) and culminating in the publication of an energy policy paper ('White Paper') in early 2003 (DTI, 2003). The impetus for this review process was the Government's desire to review the implications for energy of perceptions of greater energy supply insecurity and the climate change agenda. Both of these issues implied a need to take a much longer term view of policy than has been characteristic in the UK since liberalisation and economic efficiency became the centre of energy policy during the 1990s.

Government has made quite different responses to the issues of security and climate change. Its White Paper has left the energy supply security issue largely to markets to resolve, but in relation to climate change, the result has been startling: a Government commitment to get the UK on a path towards 60% carbon emission reductions (compared to recent levels) by mid-century (DTI, 2003, p. 25). This is a radical break with past energy policy in the UK, both in its emphasis on the importance of the very long term, and in elevating climate change to a central driving role in energy policy decision-making.

Commitments to the long term and to climate change mitigation suggest that there might be good news in the White Paper for nuclear power. There is none. Not only does Government reject nuclear power at present, apparently on economic grounds, it also argues that any resumption of nuclear investment would need to be preceded by extensive public consultation as well as a further White Paper on new-build nuclear power (DTI, 2003, pp. 61–62).

The Government's statements mean that delivery of power from new nuclear sources will be postponed by many years. The next nuclear White Paper will almost certainly be on the subject of nuclear waste, concluding a separate Government review of waste that is due to finish in 2006 or more likely 2007 (DEFRA, 2001, p. 8). So the earliest that a White Paper on new-build could appear would be 2008 or 2009, followed by siting, licensing and local public inquiry processes that would probably take until around 2013. With a 5-year period for construction, the earliest commissioning date would probably be 2018 or so, if everything in the whole process had gone well. In practice, everything rarely goes well and the earliest realistic date for delivery of power from a new UK reactor is around 2020. This timetable has important implications for nuclear technology choices in the run-up to 2020.

The overall approach of the UK Government to nuclear power is instructive. A cornerstone of public policy in the liberalised electricity system is to allow markets to make their own investment decisions about electricity generation. It is therefore surprising to find that the relevant sub-heading in the White Paper is 'We do not propose new nuclear build'; then to read that 'new nuclear build might be necessary'; and finally to discover that any new White Paper on the subject would be 'setting out the Government's proposals' (DTI, 2003, pp. 61–62). The implications are that new nuclear power would, as in pre-privatisation days, still be defined in terms of a Government 'programme' subject to a degree of central planning. Note that even in renewable energy, which Government is compelling consumers to subsidise heavily, there is no central planning of this sort. An explicit virtue of the main policy instrument to support renewable energy in the UK (the Renewables Obligation: see the paper in this issue by Mitchell) is that it precisely *avoids* the need for central planning—including any prescription of precise technology to be used.

The fact that such central planning appears still to be necessary for nuclear investment to succeed is a symptom of the political difficulties associated with nuclear investment. Putting it another way, and to foreshadow a main theme of this paper, nuclear power will only become a viable option again if or when Government *can* treat it as just another investment option, and not need to plan and control it centrally. If nuclear power is to become a serious option again, it will need to acquire the characteristics of ordinariness.

4. The private market economics of nuclear power and competitors

The UK Government's stated primary reason for rejecting nuclear power at present is economic. This reflects the fact that at current and foreseeable market prices and market structures, private investors do not find nuclear power an attractive option. In the circumstances of a private market place, such a 'rejection' by Government of nuclear power is of course redundant. What it really signals is Government's current unwillingness to 'tilt the playing field' towards nuclear power by offering it any specific incentives of the kind it offers to renewable energy. Whether or not this difference amounts to discrimination against nuclear power is the subject of a later section.

This part of the paper examines the costs per kilowatt hour at the power station of the various options for investing in new power generation sources under current market conditions. Such single-station economics is intuitively appealing and adequate for the present purpose: for more precise and sophisticated analysis, system issues also need to be taken into account. The comparison here is between the costs of combined-cycle gas turbines (CCGTs, far and away the market leader in recent years in the UK), and the costs of nuclear power. Limited attention is also given in a later section to the economics of renewable energy. There are large differences in the quality and accuracy of data available for such comparisons. For CCGTs there is a great deal of recent market experience and the data for construction costs, for example, is therefore reliable, though future gas prices are of course much more uncertain. There are also fairly reliable data on the economics of some kinds of renewables (especially wind power). For nuclear power, there is no market experience at all of the designs advocated, and while there are many engineering-based studies of potential construction cost, these must all be treated with care until real-world construction experience emerges.

Since 1990, CCGTs have been the only technology in which private investors have taken a serious interest on commercial grounds. There has been some commercially-inspired investment in combined heat and power (CHP), but this has almost always used gas and has often also involved CCGT technology. Investment in renewables has also been significant, but only because of various public support mechanisms. Consequently, out of a total investment volume of some 25 GW since 1990, some 22 GW has been CCGT (National Grid Company, 2003, Table 3.6a).

5. The predominance of CCGTs

Why have CCGTs become so pre-eminent? At an immediate level, they have clearly been the cheapest option, offering power at between 2.0 p/kWh at low gas prices and 2.5 p/kWh at high gas prices (British Energy, 2001, p. 15). But the appeal of the CCGT is only partly expressed in these headline figures. CCGTs were also (apparently) a low risk option, well-suited to the new market conditions of liberalisation. In these new conditions, wholesale power prices were in principle outside the control of generators, so that unexpected cost increases could no longer be automatically passed through to consumers. CCGTs had the following advantages over traditionally favoured technologies like nuclear power:

- They could be planned and built, without opposition, in about 2 years, allowing investors to start recouping their capital relatively early.
- They were modular and could be built at any size from around 300 MW upwards, with no major economies of scale to dictate large plant size.

- They are not capital-intensive (their principal costs were fuel and only 25–30% of generating cost is capital-related) and this, together with potentially smaller unit sizes, meant that the total capital needed was limited relative to output.
- Competition between manufacturers grew rapidly and investors could get fixed construction cost terms and guarantees of operating performance.
- The combination of these characteristics meant that the required rate of return (cost of capital) was low, and so financing costs were also minimised.

6. The economics of new nuclear power

Nuclear power, according to current industry estimates, might generate at between 2.2 and 3 p/kWh (British Energy, 2001, p. 15; BNFL, 2001, p. 3), seemingly overlapping the costs of CCGTS and therefore, apparently, potentially competitive even without any support mechanism. But in practice, and whatever Government thinks, the investment community is nowhere near regarding nuclear power as a close competitor with CCGTs. Why is nuclear power treated so sceptically?

- The total planning and construction time is lengthy. Even if Government gave full support through the planning and regulatory approval system, it would take at least 2 years to start on site and a further 5 years to construct. A 7 year minimum lead time is 5 years longer than for a CCGT, postponing returns to investors. And there is substantial political risk—especially ahead of any resolution of the nuclear waste issue—which means the lead times could in reality be substantially longer. Note, for instance, that British Energy reckons that the planning/licensing/construction lead time for a new nuclear unit would be 10 years (British Energy, 2001, p. 8).
- The cost figures for CCGTs are well-established in the market place, while those for nuclear power are radically uncertain. No nuclear power plant has started construction in the UK for 15 years and this has costs, in today's money, of around 6 p/kWh (PIU, 2002a, Table 1). No nuclear plants have been started elsewhere in OECD Europe or North America for 10 years. Not only is there a history of serious appraisal optimism in the nuclear industry, the designs (Canadian CANDU or Westinghouse/BNFL AP1000) that the nuclear industry expects to deliver power at 2.2 p/kWh to 3 p/kWh have yet to be built anywhere in the world.
- These uncertainties about construction cost are made more serious by the fact that the capital-related items of total generating cost for nuclear power are over 70% of total cost (Grimston and Beck, 2002, Table 3.5, p. 72). Consequently, total generating costs are especially sensitive to any escalation in cost or time, or any failure to achieve expected operating performance. For all these reasons, nuclear vendors are unlikely to match the cost or performance guarantees now commonplace for CCGTs and the required rate of return for nuclear power is likely to be higher than for CCGTs, inflating total capital costs significantly.
- The lower end of the generating cost estimates is only expected to be achieved if there is a large programme of identical reactor construction. BNFL argue that only by the time of the eighth reactor will costs fall to 2.2 p/kWh and that the first will cost 3 p/kWh or possibly even more (PIU, 2002a, Table 2). BE, in their submission to PIU, argued that a programme of 10 reactors (minimum of 10,000 MW) would be needed to get costs down to the lowest level possible (British Energy, 2001, especially Chapter 3). The problem here is inflexibility: private markets are unwilling to commit easily to 1000 MW of new capacity of a new and untried technology, and attempting to commit at one moment to 10,000 MW is virtually unimaginable. While this problem might be at least partly overcome if it were possible to build the 10 reactors in a number of different countries under a common international licensing regime, there is not real sign yet that such a regime is feasible.
- Given the delay in the construction process for nuclear power in the UK, the eighth reactor at 2.2 p/kWh—supposing it really could be delivered—will not be in service until around 2025 or later. By that time it is reasonable to expect the cost of alternative technologies, via learning and technical progress, to have reduced substantially compared to today's costs. It is because of the long delays in the process of new nuclear construction that there is little point in pursuing the current generation of nuclear designs for UK use. Instead, and as argued below, if it will be 20 years before significant nuclear capacity can be on stream, it seems necessary to concentrate on new reactor designs, of a type which both the competitive market *and* public opinion would prefer compared to today's designs.

All this means that the superficial appearance of overlap between the costs of building new nuclear and CCGT capacity is misleading. Private investors judge that the economic status of nuclear power is substantially poorer than that of CCGTs. Even before the White Paper's dismissal of nuclear power and the recent sharp falls in wholesale electricity prices, there were no serious proposals from investors for nuclear construction. The White Paper makes the prospect even more remote.

7. Cost structures for nuclear power and renewables

The comparison so far has covered only CCGTs and nuclear power. Given that public policy for low carbon supply options in electricity is concentrating on renewables at present, it is worth comparing the economic characteristics of the two types of generation ahead of the more explicit public policy discussion of low carbon options below. While there is substantial investment activity in renewables in the UK currently, this is almost entirely because of the relatively high subsidy available to renewable energy in the Renewables Obligation.

Renewable energy is highly diverse though in current UK conditions onshore and increasingly offshore wind are the main practical options. Wind power, like most renewables, has one major economic characteristic that is very similar to nuclear power, in being highly capital-intensive. While 70% or so of all generating costs for nuclear power are capital-related, this proportion can rise to as much as 90% for some renewables, given the absence of any fuel costs.

But in other respects, nuclear power and renewables diverge substantially in investment characteristics. The main difference is that most renewables operate at much smaller scale than nuclear power and are much less subject to economies of scale or unit size. The smaller scale contributes to the fact that renewables are generally much quicker to construct than nuclear power and allow investors to start earning a return within a few months of the decision to invest. Equally, although large-scale renewables investments are increasingly planned (e.g. very large wind farms) the fact of small minimum economic size allows investment to proceed in small and 'digestible' amounts. These characteristics also permit much more rapid learning than for renewables, because feedback from earlier designs to later models can be much more rapid. Finally, it will often be possible to reduce renewables' costs more quickly (for any given state of technology) if a decision to build relatively large numbers of plants is made. This is via conventional economies of manufacturing scale. Wind turbine installation can easily reach hundreds of units annually, and this can substantially reduce manufacturing costs. The corollary of these characteristics is that if a renewable technology turns out to be inherently more expensive than is acceptable, there is greater flexibility in decision-making and unpromising routes can be stopped with limited cost (PIU, 2002a). The main counter-argument is that several renewables, especially wind power, display inflexibility in the form of intermittency and their consequent inability to match output to demand. This will undoubtedly be an issue if wind power achieves a large market share, but this remains a relatively distant problem.

By comparison, current nuclear technology is much less flexible as an investment option. The nuclear industry proposal for a 10 GW programme was almost the minimum needed to reduce costs to acceptable levels, and in practice a 10 GW programme would have crowded out most other generating investment. This does not mean that nuclear power will always be less attractive or more expensive than renewables. Nuclear could in principle be substantially cheaper than renewables, and its different operating characteristics (well-suited to baseload and poorly suited to mid- or high-merit operation) will make it more profitable in some systems than others. Equally there could well be situations in which both types of technology could provide profitable investment opportunities.

8. Sustainable development, public policy and nuclear power

This paper has shown why, under current market conditions, there is unlikely to investment in nuclear power for some time to come in the UK. The argument can be extended to other liberalising electricity markets. However, it is equally clear that in current market conditions of low wholesale electricity prices, private investors would also be uninterested in almost all renewable energy investment, and that current investment activity is largely a consequence of a programme of Government support, principally in the form of the Renewables Obligation. The question then becomes whether or not nuclear power, having equally desirable low carbon characteristics to renewable energy, should receive similar support.

All areas of UK Government policy-making are now in principle evaluated in terms of their ability to contribute to sustainable development. This latter idea is defined as progress in meeting economic, social and environmental goals (PIU, 2002b, para. 3.9). It is difficult to guarantee that any given policy initiative can simultaneously meet all three sets of objective and in practice the sustainable development framework is more useful as a way of checking trade-offs that frequently occur in the policy-making process. And in terms of specific policy initiatives, Government tends to view proposed public interventions in terms of a narrower and more economics-based framework—that of market failure (PIU, 2002b, pp. 33–34).[2] This reflects the fact that UK Governments for the last two decades or so have become convinced that markets make the best resource allocation decisions and Governments exist as a backstop to correct failures in market provision.

[2] There are other possible reasons for Government intervention—mainly pursuit of equity objectives and for strategic or military reasons, but in the domain of energy policy the debate has principally been about economic efficiency and the ability of markets to provide efficiency.

New energy policies under consideration by Government therefore need first to identify a market failure, according to fairly rigorous economic-theoretical criteria, and then to demonstrate that the proposed intervention will act to correct such failures. These are quite stringent tests and the market failure framework is, in operational terms, much more important than the rather grander sustainable development framework in determining the details of public policy.

9. Market failures and nuclear power

Policies which might assist nuclear power (and other energy technologies or policies) therefore need to pass the market failure test. The two market failures[3] that are most relevant in assessing low carbon energy policy are:

- The existence of unpriced environmental externalities. Specifically the issue is the marginal damage cost of greenhouse gas emissions (principally carbon dioxide), which a recent Government report tentatively places at £70/tC (within a range of £35 to £140: HM Treasury and DEFRA, 2002, p. 6). Governments can therefore intervene to address this market failure with policy instruments which explicitly or implicitly place a value on carbon or other GHGs.
- The existence of positive externalities associated with research and development. The argument here is that the benefits of new knowledge created by R&D cannot always be privately appropriated by those who finance it, and that markets will tend to underprovide R&D for this reason. Governments may then finance the development of embryonic low carbon technology up to the point at which markets find it privately profitable to develop technology further.

An argument in favour of supporting renewables or other low carbon technology can be in principle made on either of the above grounds. The nuclear industry submissions to the UK Government made a case for public support of nuclear power on largely the environmental externality argument. British Energy argued that while the provision of extra power from renewables would cost a premium of roughly 3 p/kWh via the Renewables Obligation[4] the cost to consumers of providing equivalent amounts of nuclear power would be only 1 p/kWh (British Energy, 2002, Chapter 4). The industry thus argued in favour of a 'Carbon-free Obligation' in place of the Renewables Obligation.

This argument potentially has force if the justification for the Renewables Obligation is primarily based on the environmental externality argument. The PIU report suggested that both market failure arguments are valid for current UK support for renewables. However, it is clear that Government does not take the view that the same arguments apply to nuclear power. There are no obligations on electricity suppliers to source any part of their electricity from nuclear power and nuclear power is not exempted (unlike renewables) from the Climate Change Levy.

10. Policy differences between nuclear power and renewables

How is this apparently asymmetrical policy treatment between nuclear power and renewables to be explained? The arguments against treating nuclear and renewables equivalently in relation to environmental externalities presumably stem from the idea that nuclear power suffers from non-climate change externalities that 'compensate' for its climate change advantages. Government has not formally made such an argument. The most likely candidate for non-climate change externalities affecting nuclear power is the issue of nuclear clean-up costs. While the nuclear industry has made financial provision for clean-up (decommissioning and waste management) since 1976 (MacKerron and Sadnicki, 1997, Chapter 3) there have been persistent doubts about the adequacy of the scale and nature of the funding undertaken. The recent severe financial difficulties experienced by British Energy, a private company which was apparently funding all its clean-up costs, has resulted in Government agreeing to pay up to £2bn. over the next 10 years, and further sums thereafter, to meet any part of these costs that the company cannot meet itself (British Energy, 2002).

For potential future nuclear investment, the main doubt is whether or not current (and necessarily very crude) estimates of long-term waste costs are realistic, and whether industry cost estimates for waste are therefore under-estimating the extent of long-term clean-up. It seems unlikely that such potential under-estimation of clean-up costs constitutes a cost that is large enough to balance the positive benefits of nuclear being free of carbon emissions: the scale of such under-estimation would need to be very large indeed to outweigh an advantage of £70/tonne of carbon saved. But no precise analysis is possible in the current state of uncertainty about clean-up costs. The 'non-climate externality' afflicting nuclear power is probably political, rather than a precise economic calculation. It is most likely a judgment about the political problems—in

[3] The White Paper (DTI, 2003, especially Chapter 4) decisively rejected the argument that there is sufficient market failure in the provision of adequate levels of energy security to warrant public support for technologies that (like renewables or nuclear power) might be expected to increase levels of energy security.

[4] (see http://www.dti.gov.uk/energy/renewables/policy/renewables_obligation.shtml for further details)

terms of public acceptability—of giving nuclear power similar advantages to renewables in low carbon policy-making.[5]

In relation to the second externality argument (inadequate levels of private R&D), the case for nuclear power is superficially much poorer than for renewables. The case for renewables support is that there is a diversity of renewable options, mostly under-developed and potentially lacking the private support for R&D and technology commercialisation that would be sufficient to deliver the expected net benefit from such support. This argument can be combined with the (related) view that public support for renewables enables a portfolio of new options to be available for market deployment when the need to take action to reduce carbon emissions becomes more pressing than at present. Renewable technologies tend to show evidence of high learning rates (McDonald and Schrattenholzer, 2001), further encouraging the idea of public support.

The argument against nuclear power in these technology development terms is that nuclear power, unlike renewables, has had a very substantial volume of public resources devoted to it for many years, though a limited expenditure in recent years (ICCEPT, 2002, Chapter 6). On this argument, nuclear power has 'had its chance'. However nuclear technology is in principle also very diverse—there are many ways in which nuclear fission can produce power. While it is true that past support for nuclear power has been very extensive, it has also been very ill-directed because the great bulk of spending has been on the commercially unsuccessful fast breeder reactor and the still-distant fusion reactor.

Given that prospects for nuclear deployment in the UK mean that there is unlikely to be new operating capacity until around 2020 and that current nuclear technology will be economically obsolete by that time, there is a case for public support for long-term R&D into new reactor technologies that offer prospects of meeting the criteria of 'ordinariness'. What characteristics would nuclear technology need in order to become ordinary? These characteristics mostly emerge from earlier discussion. The suggested criteria are:

- Resolution, to the satisfaction of the wider public, most stakeholders and any affected local communities, of the nuclear waste management problem. New nuclear build is unlikely to be acceptable without such resolution. However, 'resolution' is primarily a political not a scientific/technical or physical attribute. What is necessary is the construction of enough trust and consent so as to allow the progress of the construction of, say, a deep repository to become a matter of limited political consequence. While more scientific and technical work will be needed, the critical path is political.
- Assurance that new nuclear technologies will have high resistance to proliferation and provide general reassurance about security issues and terrorism threats. This means, at a minimum, that any new technologies will need to dispose of spent fuel directly rather than separate plutonium through reprocessing spent fuel. This need for 'once-through' future cycles is also emphasised in a major new study on the future of nuclear power from the MIT (MIT, 2003). It is important to emphasise that none of the nuclear technologies currently likely to be used require reprocessing of spent fuel to take place.
- New technologies will need to display a high degree of passive (i.e. not engineered) safety in all operating circumstances. As in the case of the nuclear waste issue, this high degree of passive safety will need to be demonstrated to the satisfaction of relevant publics.
- Equally critical, new technologies will need to be compatible with the demands of liberalised electricity markets, where long-term power purchase contracts are unlikely to be a realistic possibility. Technologies will therefore not only need to be cheap in standard terms of pence per kilowatt hour, they will also need to offer protection against risk of the kind now routinely available to investors purchasing CCGTs. This has a number of implications: a need for relatively small minimum economic size of individual units and an escape from the inflexibility inherent in the current need to build very large total capacity in order to minimise overall cost; rapid construction, so that investors can start to receive returns with a minimum delay; and contractual guarantees of fixed construction costs and minimum but high operating availability. In other words, investors will need to have the same kinds of assurance about project risk as they can get with any other commercial project.

11. Ordinary technologies, the short term and the long term

If nuclear power could achieve ordinariness in these ways it would also become, as an investment choice, a 'short-term' technology, a label often applied pejoratively. But this misses an important distinction between *objectives* on the one hand and *projects* on the other. The essential long-term part of energy policy is the pursuit of stable objectives, in this case climate change mitigation. But as long as individual technologies have characteristics that contribute directly to such long-term objectives, it is desirable that the projects in which they are embodied be as short-term (i.e. profitable and

[5] Conventional analysis of the external costs of different generating technologies nearly always suggest that the external (unpaid) costs of nuclear power are substantially below those of fossil-fired electricity. See some results of the large EU ExternE project, for instance at http://externe.jrc.es/UnitedKingdom+Introduction.htm.

flexible), as possible. Nuclear power would in an important—policy-sense remain a long-term technology.

To the extent that nuclear technologies meeting the criteria of ordinariness can be pursued for the medium and long term then nuclear power may well warrant public R&D support on similar grounds to those argued for renewables support—the creation of long-term options.

Under the criteria for ordinariness set out above, however, current large-scale nuclear technology and fusion would not qualify. However, the current US Department of Energy-led initiative to create so-called Generation IV reactor designs (Department of Energy, 2003) shows how extensive a range of small-scale potential nuclear technologies exist. There seems a good case for some public support for the development of such long-term technologies, and an early task for the Government's planned Energy Research Centre might be consideration of this issue, bearing in mind the need for international efforts in this area.

In the longer term, nuclear power will almost certainly benefit from other policy initiatives designed to benefit low carbon options. The most important area here is the EU Emission Trading Scheme which should result in the start of Europe-wide trading (and hence valuation) of carbon from 2005, moving to full implementation in 2008. The UK Government places substantial weight on this scheme in its White Paper, and it will clearly benefit nuclear power just as much as renewables.

The difficult question to answer is whether or not the evolution of such generic policy instruments in favour of low carbon options, as well as some small-scale possible moves to help in nuclear technology development, will outweigh the current market disadvantages of nuclear power. When might private investors in these circumstances look seriously at nuclear power again as an investment option? The probable answer seems to be that it will take several years at least before such reversal is likely, and the political issues will still then need to be faced. The alternative view—that Governments may intervene more directly to require new nuclear capacity to be built—will depend on significant changes to current Government policy on the liberalised operation of electricity markets as well as a much more urgent view of the need to reduce carbon emissions than is currently the case.

12. Conclusions

UK energy policy now has explicitly long-term objectives. Among these, climate change mitigation is central, involving pursuit of a radically lower carbon economy over the next half century. Nuclear power is, all else equal, an extremely attractive source of low carbon energy on a large scale, and if sustainability depended only on carbon emissions it would rank very high indeed. However, nuclear power is currently unattractive to private investors in the UK because current technology is relatively expensive, and there is substantial political risk, much of it concentrated on the issue of nuclear waste and clean-up more generally. Further, public policy does not currently give nuclear power any credit for its low carbon status.

There is no realistic chance, given current politics, that nuclear power could deliver new power before about 2020. For the medium term and beyond, the issues are therefore the extent to which public policy should change in favour of nuclear power on account of its low carbon characteristics. A case for treating nuclear power more favourably than at present can be made in relation to both environmental externalities and R&D/technology development. The lack of policy equivalence as between renewables and nuclear power seems to be based on the other (non-climate change) disadvantages of nuclear power in relation to sustainability. Whether these disadvantages can fairly be described as environmental externalities, with values implicitly just cancelling out the climate change externality benefits of nuclear power, seems doubtful. Rather there seems to be a political rather than economic judgment about the non-carbon problems of nuclear power concerning waste and possibly general public acceptability.

There is a case for public support for nuclear technology development in relation to the kinds of technology which might become commercial by 2020 and beyond and which meet the criteria of 'ordinariness' set out above. By that time, it is also likely that carbon valuation mechanisms (such as the EU Emissions Trading Scheme) will also recognise the carbon benefits of nuclear power. If nuclear power can become politically unremarkable, it will have become a short-term (profitable, flexible) technology but in pursuit of a long-term objective. But the criteria for successfully transforming both nuclear power technology and its wider context (waste management, proliferation resistance, etc.) from their currently politically special status to ordinariness are stringent, and it will be some time before it becomes clear how or even whether the transition can be made.

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