ENERGY: SOURCES AND STRATEGIES

PROSPECTS FOR NUCLEAR POWER IN EUROPE

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There is a common perception that the fortunes of nuclear power have been shaped by three major accidents at civil nuclear power plants: Three Mile Island (TMI) in 1978, Chernobyl in 1986 and Fukushima in 2011. These accidents were seen as triggering public opposition that made it politically difficult and sometimes impossible to proceed with nuclear power. The reality is more complex. Public opposition has been decisive in a few countries but in most, the outcome has been driven more by the connected problems of poor and deteriorating economics, finance and design issues.

In the developed world, the optimism of a decade ago – the 'Nuclear Renaissance' – that a new generation of nuclear power plant designs (so-called Generation III+[1]) could compete successfully on cost grounds had largely evaporated well before the Fukushima disaster. The claim for these new designs was that they would offer a cheaper, more reliable way than renewables to reduce greenhouse gas emissions and that nuclear power was a cost-effective way to reduce reliance on unreliable suppliers of fossil fuels, especially natural gas.

In the wake of the Fukushima disaster, the countries in Europe can be divided into five groups, each with rather different prospects:

1. Those in which nuclear power was never a serious option in recent decades. These include Denmark, Norway, Ireland, Austria and Portugal;
2. Those where governments are trying to proceed with nuclear power programmes, including UK, France and Finland;
3. Those where phase-out policies had previously been in place before Fukushima or where there had little prospect of new orders for a long time, including Netherlands, Sweden, Spain and Belgium;
4. Those which took decisive decisions against nuclear power in the wake of Fukushima, including Germany, Italy and Switzerland; and
5. Eastern Europe and Russia.

The first group of countries will not be considered further in this article, but they may be able to form new alliances with politically more powerful, now anti-nuclear countries, especially Germany and Italy, tipping the political balance in Europe against nuclear power.

Techno-economic issues

Before examining the prospects in each of these regions, it is useful to briefly identify the major techno-economic issues that nuclear power faces. The paradox with nuclear power is that despite more than half a century of commercial experience, real costs have only ever gone upwards. Even in France, where the huge programme of reactor orders from 1970–1990 should have given every opportunity to take advantage of 'learning', scale economies and technical progress, the real cost of reactors more than doubled (Cooper 2010). The last four of the 58 reactors ordered in that period took on average over 13 years from construction start (first structural concrete) to commercial operation. A former Chief Executive of the French utility, Electricité De France (Roussely 2010) has acknowledged that while the reliability of nuclear plants has improved in recent years, in France, it has deteriorated. So experience with nuclear power seems to fly in the face of that with most successful technologies, where costs would be expected to fall and performance would improve.

The selling point for Generation III+ designs was that they would take account of 'learning' from ear-

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[1] There is no clear set of technological characteristics that distinguishes one nuclear design generation from another. Generation I includes the demonstration plants built in the 1960s, Generation II includes most of the plants currently operating and covers designs completed from the mid-60s to about 1980, Generation III includes post TMI designs and accounts for a relatively small number of reactors, while Generation III+ covers designs evolved from Generation III but taking account of lessons from the Chernobyl disaster.

lier generations and this would mean that they could be safer, but simpler and therefore cheaper and easier to build. Greater safety was to be achieved by use of 'passive' safety features whereby reactors would be prevented from going out of control in an accident situation by natural processes, rather than the start-up of engineered systems.[2] Reduced complexity would make them cheaper and would lower the risk of construction delays and cost overruns because complex on-site installation work, seen as one of the factors contributing to construction problems, would be reduced.

This would mean finance was cheaper because financiers would see nuclear projects as less risky. In the UK and the USA, governments have decided to help reduce construction risk by requiring a full generic design assessment on new designs before construction starts. The rationale for this was that delays have, in the past, been caused by design changes or safety issues arising in mid-construction. It was hoped the generic reviews would mean all design issues would be resolved in advance once and for all so the full design was known and approved in advance of construction. It was assumed that because these were new designs with a clear view of regulatory requirements, the design reviews would be straightforward.

There are a number of Generation III+ designs now commercially on offer[3], but none of these is in operation yet and only two, the French European Pressurised Water Reactor (EPR) offered by Areva NP[4] and the AP1000 (Advanced Passive, also a Pressurised Water Reactor) offered by Westinghouse (based in the USA but owned by Toshiba) have firm orders, four for the EPR and six for the AP1000. However, two of the EPRs and four of the AP1000s are under construction in China and there is little reliable independent information on progress. Construction work on the other two AP1000s, both for the USA, had not started by August 2012. So the only substantial construction experience in the West is the EPRs in Finland (Olkiluoto 3) and France (Flamanville 3).

Both plants have been plagued with delays and cost overruns. In 2012, after seven years of construction, the Finnish Olkiluoto plant (scheduled to take four years to build) was still more than two years from completion[5] and about 100 percent over budget. Areva and the customer, TVO, were in conflict over who would pay the EUR three billion extra costs and this dispute was being resolved in the International Chamber of Commerce Court of Arbitration in Stockholm[6]. In 2012, the Flamanville project (scheduled to take five years to build) was still four years from completion after nearly five years of construction and also about 100 percent over budget.[7] Unlike the USA and the UK, France and Finland did not require full generic reviews of the designs before construction start and the designs are being reviewed during construction. Design issues have arisen during construction, for example the degree of redundancy in the Instrumentation and Control system (Thomas 2010). How far these issues have contributed to the delays is hard to determine.

The generic design reviews in the USA and the UK have also been problematic. The AP1000 received design approval in the USA in 2006, but soon after Westinghouse submitted design changes that reopened the reviews and these were not finally resolved until December 2011. The UK authorities issued an Interim Design Acceptance Certificate (IDAC) in December 2011 after a period of more than four years, but there are a number of significant issues still to be resolved.[9] Westinghouse has chosen not to proceed to sort out these issues until it has a customer for the AP1000.[10] The EPR also received an IDAC in the UK in December 2011 and in the summer of 2012, Areva was working on dealing with these issues. This process will not be complete before 2013.[11] In the USA, the EPR review has been consistently delayed and in summer 2012, was not expected to be completed before end 2014.[12] How far the need to take account of the lessons from Fukushima will cause new requirements and further delays to the regulatory process remains to be seen.

[2] For example, reactors would be cooled by natural convection rather than the by a mechanical cooling system.
[3] All are Pressurised Water Reactors (PWRs) or Boiling Water Reactors (BWRs) in which the reactor is cooled and 'moderated' by water.
[4] Areva is 92 percent owned by the French state. Its reactor division was a joint venture between Areva (66 percent) and Siemens (34 percent). Siemens announced it was exiting the joint venture in 2009 and completed its withdrawal in 2011.

[5] In July 2012, the plant owner, TVO, announced that it could no longer meet the 2014 completion date that had set a year earlier.
[6] Nucleonics Week 'Olkiluoto safety upgrades to be completed in 2012, TVO' March 8, 2012.
[7] Nucleonics Week 'ASN tells EDF to improve quality of Flamanville-3 concrete work', September 8, 2011.
[9] http://www.hse.gov.uk/newreactors/reports/ap1000-onr-gda-idac-11-002-issue-1-131211.pdf.
[10] http://www.nuclearpowerdeliveryuk.co.uk/news.php?subaction=showfull&id=1323863036&archive=&start_from=&ucat=&.
[11] Nucleonics Week 'UK regulators give interim approval to AP1000, EPR reactor designs' December 15, 2011.
[12] http://www.nrc.gov/reactors/new-reactors/design-cert/epr/review-schedule.html.

From a financial point of view, it is now clear that the cost of power from new nuclear power stations will be high, especially if the financial community continues to see nuclear as a risky investment and imposes a high real cost of capital. Ultimately the decision whether to build nuclear power plants will depend on whether the proposals are financeable. It is clear that if, as has been the case in the past, consumers implicitly guarantee to pay whatever costs are incurred, nuclear power will be seen by financiers as low-risk because the risk will fall entirely on consumers. However, such a guarantee is going to be difficult to sell to consumers given the very poor economic record of nuclear power to date.

Renaissance countries

Finland, UK and France have been the countries in Western Europe with the best prospects for nuclear orders for some time now. Finland and France were the first two countries to order Generation III+ designs, in both cases the European Pressurised Water Reactor (EPR) supplied by the French state-controlled company, Areva NP. As noted above, both projects have gone disastrously wrong, making further orders problematic.

France stands out as the one European country where its nuclear capabilities are seen as a key national capability. It has a controlling stake in the utility (EDF) and the vendor (Areva NP), so the option of not proceeding with its nuclear programme is not one it can easily contemplate. Nevertheless, a plan to start construction on a new EPR reactor (Penly) in 2011 has been quietly abandoned and the new Socialist government appears less committed to nuclear power than its predecessors.

France is now in a difficult position. The large number of reactors completed between 1977 and 1985[13] is coming up to the point where there will need to be major investment to life-extend them[14] or they will have to retire and replace them. Given the high level of EDF debts and the real cost escalation in construction costs since 1980, full-scale replacement is not an option because of the cost, especially given the remaining issues with EPR technology. However, full-scale life extension would close the door to new EPR orders in France and if the EPR was not bought by France, that would be a serious blow to its credibility and therefore its prospects elsewhere.

For Finland, there is a surprising determination to place further orders given how badly Olkiluoto 3 has gone and the Finnish government has approved the construction of two more reactors with construction expected to start in 2015, one of which would be built by TVO at the Olkiluoto site. It remains to be seen whether these reactors will go ahead, and in view of the poor experience with Olkiluoto 3 in particular, how willing financiers will be to provide the finance. One of the driving forces behind the Finnish government's support for the nuclear programme seems to be a strong objective not to increase dependence on supplies of Russian gas.

The UK programme has a special influence because of the UK's long history as a pioneer of nuclear power and because when it was announced in 2006, the government promised that no public subsidies would be offered for new reactors. The government's 2006 Review stated:

> 'Any new nuclear power stations would be proposed, developed, constructed and operated by the private sector, who would also meet full decommissioning costs and their full share of long-term waste management costs. The government does not take a view on the future relative costs of different generating technologies. It is for the private sector to make these judgements, within the market framework established by government. The actual costs and economics of new nuclear will depend on, amongst other things, the contracts into which developers enter, and their cost of capital for financing the project.' [15]

The implication was that nuclear reactors would be chosen on cost grounds by utilities and would compete with all other generation types, including gas, on equal terms. This never seemed a realistic prospect and by 2012, while the government was still asserting that no subsidies would be offered, the reality was very different. The formal position was (emphasis added):

> 'To be clear, this means that there will be no levy, direct payment or market support for electricity

[13] Between 1977 and 1985, 36 reactors were completed in France. If they are given a 40 year life, replacements would be needed from 2017 onwards.
[14] In the USA, most nuclear reactors have now been life-extended to give a life of 60 years.

[15] Department of Trade and Industry (2006) 'The Energy Challenge: Energy Review Report' Cm 6887, HMSO, p 113. http://www.berr.gov.uk/files/file31890.pdf.

> supplied or capacity provided by a private sector new nuclear operator, *unless similar support is also made available more widely to other types of generation.*'[16]

The proviso makes the commitment not to offer subsidies meaningless and in 2010, the government announced the effective abandonment of price signals from the electricity market as the mechanism for stimulating construction of new power plants. The Energy Minister, Ed Miliband told the Times:

> 'The Neta system [the British wholesale market], in which electricity is traded via contracts between buyers and sellers or power exchanges, does not give sufficient guarantees to developers of wind turbines and nuclear plants. He said that one alternative would be a return to "capacity payments" – in which power station operators would be paid for the electricity they generate and also for capacity made available. The idea of such payments is to give greater certainty to investors in renewable and nuclear energy.'[17]

Under proposals published in a draft bill in May 2012,[18] there will be essentially a 'single buyer' to commission and provide long-term power purchase agreements in the form of Contracts for Differences (CfDs) for all forms of new capacity. The bill envisages three forms of support for new low carbon generating capacity in addition to the long-term CfDs:

- Capacity payments: these would be expected to be designed to give incentives for peaking plants to remain available;
- Emissions performance standards: these are expected to be set so that new coal-fired power stations would not be built unless they included carbon capture and storage;
- Guaranteed carbon price: this was already introduced in the 2011 Budget, which featured a carbon floor price rising from EUR 12/ton in 2013 to EUR 36/ton by 2020.

By August 2012, the terms of the CfDs were being discussed and while most public attention has focused on the initial price, of at least equal importance will be the detailed terms of the contract, particularly how the economic risks will be dealt with. If the contract does not allow pass-through of any construction cost escalation, financiers may well see the contract as too risky to finance. The British government will be reluctant to abandon the nuclear programme, but if EDF's demands are too high, the Treasury may veto the contract. For its part, EDF has a heavy investment programme to finance in France and may not be willing to undertake a risky investment.

Marginal countries

In these countries (Sweden, Belgium, Spain and the Netherlands), the process of planning for new nuclear capacity is much less advanced than in the countries above, so it is more difficult to evaluate prospects. Some projects have been announced, for example, in July 2012, the main Swedish utility, Vattenfall applied to the Swedish safety authority to replace one or two of its existing reactors with new ones. However, there are many hurdles to be crossed before a firm order can be placed in any of these countries. In the short-term, the main question is how long the existing plants can be kept in service. In Spain (eight operating reactors, 7.6GW) and Sweden (ten operating reactors, 9.4GW), there did not appear to be much pressure to close the existing plants and they may continue in service for 20 years or more. For the Netherlands, with only one small operating reactor (Borsselle, 482MW), the decision whether to keep it on-line is more of a symbolic than a real significance. For Belgium (seven operating reactors, 5.9GW), there is more controversy. In October 2011, Belgium's then coalition government decided to phase out nuclear power altogether from 2015, with full phase-out by 2030. Two small reactors at Doel (466MW each) are likely to be the first to be shut, but the timing of the closure of the other reactors, all about 1,000MW, is not clear. In all these countries, a significant element of the decision-making process for existing reactors will be how much compensation the utilities can extract from the government for what the utilities will claim is a premature closure of the plants.

Phase-out countries

Realistically, any proposals for new nuclear orders in Italy and Switzerland would have been bitterly opposed and the prospects for new orders were limited. However, from the pre-Fukushima position of a

[16] http://www.decc.gov.uk/en/content/cms/news/en_statement/.
[17] The Times (2010) 'Labour prepares to tear up 12 years of energy policy', February 1, 2010.
[18] http://www.decc.gov.uk/en/content/cms/legislation/energy-bill2012/energybill2012.aspx.

relaxation of the phase-out targets and the long-term possibility of new orders, Germany is now apparently irrevocably committed to phasing-out nuclear power by 2022 and in the immediate aftermath of Fukushima, eight of the 17 reactors operating before Fukushima were permanently closed with the rest to be shut by 2022. While this is effectively the policy that applied for more than a decade, apart from the six months before Fukushima, the phase-out is now seen as irrevocable, whereas before, some utilities harboured ambitions for new orders. The importance of Germany as an example for other countries is high. With nuclear no longer available as a fall-back if renewables and energy efficiency policies do not work and a return to fossil fuels implausible, the government must give full commitment to a non-nuclear future. If a low-carbon, non-nuclear electricity system can be achieved efficiently and at affordable cost, this will be a powerful example for other countries to emulate.

Russia and Eastern Europe

Russia and the countries of Eastern Europe are the most optimistic about the prospects for nuclear power. In some cases, such as Romania (Cernavoda), Slovakia (Mochovce) and Bulgaria (Belene) the policy is to complete orders dating back 25 years or more, while others (Russia, Poland, Hungary, Lithuania and Czech Republic) are trying to place new orders. Natural gas is an important issue in all cases. For Russia, new nuclear capacity will release gas for export, while for the Eastern European countries, new nuclear capacity will reduce or prevent future dependence on imports of natural gas from Russia.

For Eastern Europe, the ability to obtain finance is likely to be the limiting factor. The Bulgarian Belene project (completing two Russian design 1,000MW WWERs) was effectively abandoned in 2012 because of the high cost. The Romanian Cernavoda project (two Canadian design plants of 700MW) is also proving difficult to finance.

The Czech Republic had a call for tenders for two new reactors underway in 2012, with the winning bid to be selected in 2013. However, construction is not expected to start until 2019. So even if a winning bid is selected, there is ample scope for the project to be derailed before construction starts. Hungary and Poland are also carrying calls for tenders for nuclear capacity, while Lithuania appears to have selected Hitachi as its preferred supplier. As with the Czech Republic, it is far from certain that any of these projects will go ahead despite powerful political backing, because of the problems of obtaining finance.

For Russia, the situation is different as finance is much less a problem. After 20 years when the only construction activity was the completion of a handful of plants under construction at the time of the Chernobyl disaster, Russia began to move aggressively into home and export markets with a new design (VVER-1200)[19] that it claims can be seen in safety terms as Generation III+. Outside Europe, Russia is competing successfully in Vietnam, India and Turkey and in Europe, it will respond to tenders in Eastern Europe. It has also been reported to be considering building nuclear capacity in the UK. If it could win an order in the UK – the odds are against this – this would be seen as a strong endorsement of its technology that might open up new markets in the developed world to it.

After 25 years with no new orders for commercial reactors, Russia began ordering again in 2008 and has started construction on eight new reactors since then, six of which use the new design.

Conclusions

On several occasions, events in the energy markets seem to have provided the ideal opportunity for nuclear power to expand rapidly. These events include the energy crises of 1975 and 1979, the problem of acid rain, the strategic challenge provided by the highly concentrated supply structure for oil and gas and, most recently, the need to reduce emissions of greenhouse gases. However, on each occasion, and despite generally having strong political backing at the highest level, optimism about the prospects for nuclear power was short-lived.

However, the nuclear accidents at TMI, Chernobyl and Fukushima were not the defining events in the history of nuclear power that they are often seen as. They merely served to spotlight the already existing techno-economic issues that have prevented nuclear power from achieving the dominance of electricity markets that was expected when nuclear power was

[19] Most Russian plants use the Russian version of the PWR, known as the VVER. The Chernobyl design accounts for only a handful of operating reactors and is not an option for new reactors.

launched as a commercial technology. These accidents threw up design issues and dealing with these issues seems to have been one of the factors that have led to the intuitively unlikely outcome that the real cost of nuclear power has consistently risen throughout its life-time.

The 'Nuclear Renaissance' is just the latest of a number of forecast nuclear revivals and even before Fukushima the Renaissance appeared to be faltering badly. While climate change seemed to have provided the most compelling strategic reason to pursue nuclear power, the opening up of electricity markets to competition created a new hurdle to ordering. Until nuclear power has a solid record of projects being built to time and cost and operating reliably, ordering is clearly a risk that banks are not willing to take. The poor experience with the few Generation III+ plants under construction will only reinforce the banks' poor perception of nuclear power.

In Europe, the balance between pro-nuclear and anti-nuclear countries has shifted with the move of Germany and Italy into the firmly anti-nuclear camp. In Western Europe, it is hard to see more than a handful of orders being placed in the next decade. In Eastern Europe, there appears to be more optimism and an additional strong reason – avoiding over-dependence on Russia for energy supplies – to pursue nuclear power. However, the issues of finance are even more serious in this region.

While it would be wrong to assume nuclear power will wither away, if the Generation III+ design generation is seen as a failure, it will be a long road back for nuclear power. The nuclear skills base is eroding rapidly. This may also be the last chance for reactor designs based on water as a coolant and moderator, which make up the vast majority of orders placed to date. Radical new designs have been proposed under the international Generation IV Forum,[20] but these are a long way from commercial deployment and it is hard to see where the vast funds will come from to turn designs that look attractive on paper into commercial technologies.

[20] http://www.gen-4.org/.

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