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A nuclear renaissance for Europe?

Presented to BIEE Conference

Oxford, 19 September 2012

Abstract

As is well-known, nuclear power has made, at least rhetorically, a significant return as a new generating option in recent years. In the context of the EU the debate about nuclear power has concentrated on its potential contribution both to supply security and to ambitious European targets/commitments to reductions in carbon emissions. This paper argues that (a) nuclear power would be in principle an effective way to reduce carbon emissions, all else equal (b) there are no significant impediments to nuclear power on grounds of uranium scarcity (c) the contribution of nuclear power to energy security is at best ambiguous (d) despite the attractions of nuclear power, issues of the cost of currently available reactors means that the scope of the European 'renaissance' is likely to be limited (e) the apparent attraction of small reactors is illusory, and so-called Generation IV reactors are at best several decades away from possible commercialization.

Introduction

In the EU at the turn of the millennium nuclear power seemed to be a technology in terminal retreat. By around 2005, however, there had been an apparent turnaround in its fortunes, and ambitious new plans developed over the next five or six years for the development of new nuclear capacity. Even before the accident at Fukushima-Daiichi, however, these plans were becoming significantly bogged down and they are now in considerable doubt in almost all the European countries with these ambitions. Before considering why this has been so, some ground-clearing is needed.

Unconvincing arguments against the nuclear renaissance

An argument sometimes heard that casts doubt on the nuclear renaissance, at least in the medium term, is the idea that uranium will soon become scarce and expensive, so causing the renaissance to become self-defeating. Enthusiasts for nuclear power can also sometimes be heard opportunistically using this fear to advocate fast reactors (which economise drastically on uranium use) or thorium reactors (which do not need uranium inputs at all). The economic arguments deployed later in this paper to suggest that a renaissance of conventional reactors is most likely going to be muted apply with substantially greater force to fast and thorium reactors and so these technologies will not be considered further here.

However this leaves the argument about the adequacy of uranium supplies. Both geology and economics suggest that the argument about imminent scarcity is threadbare. Currently known reserves of uranium at moderate cost are sufficient to fuel even a quite rapid growth in nuclear capacity for 50-100 years (NEA/IAEA 2012), and relative to oil there has been quite limited worldwide exploration for uranium resources. The fact that uranium ore constitutes no more than around 2% of the price of nuclear electricity means that the price of uranium could in any case rise several-fold before major inroads into the cost of nuclear electricity would begin to kick in.

A second argument to cast doubt on the prospects for renaissance is that nuclear power is not a genuinely low-carbon option. This does not stand up to serious scrutiny (Sustainable Development Commission 2006). The evidence is strong that carbon emissions in the life-cycle of nuclear power, from uranium mining to final waste disposal, is around an order of magnitude lower than efficient fossil fuel generation, and comparable to those of a range of renewable energy technologies. Emissions from fuel production, reactor construction, decommissioning and waste management are substantial, but are heavily offset by the very long periods of carbon-free operations of nuclear power plant. There is a more subtle potential argument here – that the resources consumed by building nuclear plant may crowd out the building of even lower-carbon options among renewables, and this is a possibility, though not, in my view, a very strong one, as few renewables are much more carbon–efficient than nuclear power.

Of course there are other arguments that may be deployed against nuclear power – especially ethical and practical issues of waste disposal, risks of nuclear proliferation, and safety issues raised anew by Fukushima-Daiichi – but these are beyond the scope of this paper and are not considered further. It is however worth saying that the setbacks to the prospects of nuclear power over the last year or two seem to have been mostly in the domain of underlying economic problems even though the Fukushima-Daiichi issue has had visible impact in some (but not all) countries using or contemplating new nuclear construction.

An ambiguous argument about nuclear power: energy security

Within the EU it has become conventional to think of energy policy as having three primary objectives (in no particular order): security, carbon emission reductions and economic efficiency (the latter variously expressed as competitiveness, low costs and low prices). In recent years the security agenda has risen through the hierarchy of these three. Because security is often a vague or implicit notion, with no simple or agreed definition or scope, most technologies can claim to score well on at least some attributes of security, and nuclear is no exception.

Watson and Scott (2009) have provided a useful analysis of the security issues related to nuclear power from a UK perspective, but one that has potentially wider application. They argue that threats to energy security can be unpacked into four categories:

- Fossil fuel scarcity and external disruption
- Lack of domestic investment in infrastructure
- Technology or infrastructure failure

- Domestic activism or terrorism.

They argue that while nuclear power may make a modest contribution to improving security along some of these dimensions (for example reducing the exposure of the UK economy to rapid increases in fossil fuel prices) it may be powerless to help mitigate other security risks (inadequate gas infrastructure investment) and could give rise to other security concerns (domestic activism and terrorism).

Perhaps even more important is that security issues are generally discussed over a relatively short future time frame. For example in the UK electricity system the main security risk debated in the recent past (though admittedly a risk oversold by some parties) has been a shortage of generating capacity in mid-decade. As new nuclear power could not make any contribution to any shortfall in generating capacity till around 2020 at the earliest, advocacy of nuclear power on security grounds has in any case been muted in recent UK debates.

The major obstacle: cost

Within the 'old' EU (15) only Finland and France have started new reactor construction in the last decade. Even in the newer 12 – many of which with a former Soviet inheritance have traditionally been enthusiastic for nuclear expansion – plans for new construction have largely stalled, even if they are not abandoned. The travails of the Finnish and French projects have been widely publicized. The context is that some two-thirds or so of the total cost of nuclear generation consists of construction costs, so control of these costs is vital.

The history of nuclear construction cost outturns compared to 'definitive' estimates at project start has been one of persistent and large-scale escalation (Kessides 2012). With improved design and construction methods, it was hoped that this history of 'appraisal optimism' would be much less apparent in the new European projects. However this has not turned out to be the case. Olkiluoto in Finland was originally expected to cost 3.2. bn. euros. (Thomas 2010). After a number of delays and re-estimations of cost, the project is now five years behind schedule and is now expected to cost 'more or less double' (I-Nuclear 2012) the original estimate. Flamanville in France has a similar history: long delays and a cost that has gone from and original 3.3 bn. euros to 6 billion euros (Reuters 2011). Neither project is close to completion, and commissioning dates may be further postponed, with costs rising again. Ominously, the Finnish contract was originally signed as a turnkey (fixed price) contract and this has dissolved in a welter of litigation between the Finnish utility and the main supplier, Areva.

It was however relatively easy to explain the Finnish case as resulting from the project's characteristic as a first-of-a-kind – no Areva EPR reactor had been built anywhere in the world, and although the design is a modest evolution from the earlier N4 design, it was still new. The French case has been more difficult to explain in such terms: there was earlier experience in Finland, and France is above all the country with an industrial, regulatory and political culture best suited, within Europe, to nuclear power. There are not yet full or convincing explanations for why the French project has experienced substantial cost escalation, other perhaps that it is the ‘second-of-a-kind’ - that learning to build a new reactor type is not a simple or rapid process.

EDF is close to commitment to build two, and possibly four, EPRs in the UK and expects construction time and experience to be better than in these earlier projects. It is conducting discussions with the UK Government about the ‘strike price’ at which nuclear electricity could be sold from new reactors and while these are not yet concluded it is widely reported that the asking price from EDF is well over double the current wholesale price of electricity, and seems to imply a substantially higher generating cost than either EDF or the UK Government had previously expected. The most plausible explanation for this apparent change is that EDF in attempting to pass as much of the commercial risk as possible of its projects on to UK consumers, now considers that the cost and/or commercial risk of the project is much greater than originally hoped.

Despite this difficult recent history, there is a widespread assumption in the nuclear industry that both scale effects (for individual reactors) and learning effects (as more reactors of common design are built) will allow the costs of nuclear power to fall over time. However the evidence in practice is weak in the case of scale effects, and suggests a perverse effect in the learning case.

The EPR is expected to have lower costs than earlier reactor designs because it is bigger than its predecessors: it is rated at around 1650 MWe (or potentially higher) as against 1400 MWe for the earlier N4 design, itself scaled up from earlier 1300 MWe and 900 MWe designs. Equally the Westinghouse AP designs – the main rival to EPRs – began as a 600 MWe design, in response to then-expressed utility desires to have smaller units, but then moved to 1000 MWe and 1100MWe size, again in response to an expectation that bigger would mean cheaper unit costs.

Arguments for individual unit economies of scale seem entirely plausible. Nuclear units have large fixed costs, for example licensing and regulatory costs, and in addition there appear to be classic engineering economies: for example as a pressure vessel gets bigger the extent of the material needed does not increase as rapidly as the volume enclosed. However econometric studies of such scale economies as units get larger suggest either very limited economies of scale or in at least one case, diseconomies (Kessides 2012). Most of these studies were conducted on US data from the 1970s and 1980s and the intuitive explanations for the lack of scale economies were that economies were counteracted by increasing regulatory stringency and a greater attention to more complex safety-related design features.

In a more stable climate than that of the USA it might be expected that scale economies would resume. It is of course impossible to know how much more expensive smaller EPRs would be, as none are contemplated. But while there may be economies of scale at 1650 MWe size relative to putatively smaller versions of the same technology, the level of costs being experienced in both Finland and France suggests that any such economies have not been very helpful in establishing the competitiveness of current designs.

The nuclear industry has always argued that there would also be large economies of replication and learning, wherever it is possible to build a substantial number of reactors of (broadly) the same design. The place where this proposition can most easily be tested is France where 58 PWRs were built from the early 1970s to the late 1990s, using three (arguably four) standard designs, rising in output from 900 MWe to 1400 MWe. Grubler (2010), using detailed official French data, conducted an analysis of the changes in real costs of these reactors. Surprisingly it turns out that a conservative estimate of this experience is that reactors built at the end of the period cost (at constant 1998 French francs) some 2.4 times more than those built in the earliest period. The escalation was greatest for the last 'all French' N4 design but the pattern was one of persistent escalation throughout the period of reactor construction. Explanations for this counter-intuitive result are not entirely clear but there were clearly significant changes in design, both in scaling up to 1300 MW and with the N4 series and also a deliberate stretching in schedules for later reactors.

Faced with this depressing historical evidence about both scale economies and learning, as well as the large escalation in cost over early estimates in Finland and France, it is difficult to argue that nuclear power will be reliably competitive with alternative sources. Two kinds of argument are now sometimes advanced to suggest that over time nuclear costs can indeed fall substantially: the first is that the radically new 'Generation IV' designs will solve the problem and the second (partly connected to the first) is that small, often modular, reactors will offer lower costs.

New reactor designs

There has been a great deal of R&D activity in recent years into a wide variety of Generation IV reactors. These take many technical forms of which six have been selected for more serious R&D work. Four of the six would operate at very high temperatures (above 700 degrees C) and five of the six would use radically different coolants (helium, sodium, lead and fluoride salts) compared to the light and heavy water used universally at present for commercial projects. Four of the six are fast reactors, which have historically involved major safety issues. Developers of these radical new reactors suggest that they might in one or two cases become commercially available around 2030: more detached observers (e.g. MIT 2009) suggest that it will take around 50 years for a radical new technology of this kind to become established.

More apparently practical within a reasonable time frame is the idea that small reactors (not all of them deriving from Generation IV) might offer major cost savings compared to the large units now commercially on offer. This case has been put by Kessides (2012) and, in the context of CHP, by Carlsson (2012). The most widely publicized small reactor until quite recently – and possibly the most developed - was the Pebble Bed Modular Reactor most actively pursued in South Africa by Eskom, the state utility. This was to have been a modular high temperature reactor using a gas turbine, with unit sizes variously expected to be in the range 80 MWe to 165 MWe. However the design work has now been abandoned after international partners from the US, UK and Japan withdrew support.

There are many other small reactor designs at some stage of development (Kessides, 2012, lists 22, varying in size from 4 MWe to 300 MWE with sizes often in the 100 MWe to 150 MWe range). However none of these designs is close to commercial readiness and consequently no credible cost data exists for any of them. It is worth noting that while there have been barely detectable economies of scale as reactors have moved from around 300 MWe to 1650 MWe, there may well be significant diseconomies as reactor sizes get smaller and smaller. The conclusion then is that small reactors are some distance from commercialisation and there is as yet no clear evidence that they might be any cheaper in unit terms than existing commercial designs. They have one clear potential advantage over large current designs – shorter construction times and lower total costs – but this is only likely to translate into easier financing once their licensability, reliability and acceptability are established, and this is decades away.

Conclusion

This paper has been deliberately limited to the 'real' or 'engineering' economics of new nuclear power. It has not considered issues of the market and regulatory context into which nuclear power would be inserted, nor the different financing and commercial risk issues to which different contexts would give rise – often adding, in liberalized markets, extra problems for nuclear viability. And I have not considered factors affecting the competition to nuclear power – in particular the better commercial prospects for natural gas prices consequent on the US development of shale gas, nor the long-term cost trends for many renewables, where – unlike nuclear – learning effects have been strongly favourable.

These 'external' factors tend to be unfavourable to nuclear power, and need to be seen alongside the recent poor experiences in new nuclear construction in western Europe and the historic evidence suggesting that it would be at best optimistic to expect significant cost reductions in nuclear construction costs in the near future. All this suggests that prospects for an early renaissance of nuclear power in Europe seem poor, and the main remedies suggested (newer and/or smaller reactors) are clearly many years away.

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Categories/keywords: Electricity and nuclear; Energy security; Energy economics; Energy policy