The British nuclear programme

By
Professor Steve Thomas
Stephen.Thomas@gre.ac.uk
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The Public Services International Research Unit (PSIRU) investigates the impact of privatisation and liberalisation on public services, with a specific focus on water, energy, waste management, health and social care sectors. Other research topics include the function and structure of public services, the strategies of multinational companies and influence of international finance institutions on public services. PSIRU is based in the Business Faculty, University of Greenwich, London, UK. Researchers: Prof. Steve Thomas, Dr. Jane Lethbridge (Director), Dr. Emanuele Lobina, Prof. David Hall, Dr. Jeff Powell, Sandra Van Niekerk, Dr. Yuliya Yurchenko

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1. Introduction

In 2017, the British government had plans to have 16GW of new nuclear power plants in operation by 2030, by far the most ambitious nuclear new-build programme in the world apart from those of India and China. However, more than a decade after the British government announced its intention to pursue new-build, start of construction on the first reactor is at least two years away and the whole programme is in greater doubt than ever (Thomas, 2016). This is due to a combination of dramatically escalating cost, the difficulty of obtaining finance for the projects, the ever-deteriorating record of the designs and the financial collapse of two out of three of the reactor vendors. In this paper, we look at the issues behind these uncertainties and identify the factors that might lead to the abandonment of the programme and the steps necessary to salvage at least part of the programme

2. The programme

The programme is to be built by three separate consortia, each using a different design (see Table 1). The NNBG consortium, led by the French state-controlled (84.5%) utility Electricité de France (EDF) with the state-owned China General Nuclear (CGN) plans to build two of the Areva (87% French state-owned) European Pressurised Water Reactor (EPR) design at both of its Hinkley and Sizewell sites. The Horizon consortium, wholly owned by the Japanese reactor vendor, Hitachi-GE, plans to build two of its Advanced Boiling Water Reactors (ABWRs) at both of its Wylfa and Oldbury sites. The NuGen consortium, led by the Japanese reactor vendor, Toshiba, with the French utility, ENGIE (formerly known as GDF Suez) plans to build three of the Advanced Passive 1000 (AP1000) design at its Moorside site. A fourth consortium led by CGN with EDF taking a minority stake plans to build its own technology, the Hualong One (HPR-1000), at the Bradwell site. However, the timing and the number of reactors to be built has yet to be announced and this project is not included in the UK government plans.

Table 1 The UK nuclear power programme

Consortium	Shareholders	Site	Technology	Construction start
NNBG	EDF 66.5%, CGN 33.5%	Hinkley Point	2x1600MW EPR	2019/20
NNBG	EDF 80%, CGN 20%	Sizewell	2x1600MW EPR	?
Horizon	Hitachi-GE	Wylfa	2x1350MW ABWR	2020
Horizon	Hitachi-GE	Oldbury	2x1350MW ABWR	?
NuGen	Toshiba 60%, ENGIE 40%	Moorside	2x1150MW AP1000	2020
CGN	CGN 66.5%, EDF 33.5%	Bradwell	1150MW HPR-1000	?

Source: Author's research

The most advanced project is Hinkley Point C for which the main terms were announced in October 2013[1] and updated in October 2015.[2] It is widely expected that the other projects depend on comparable terms being offered to them. The details of the Hinkley agreement are complex but the key points are:

- a 35 year contract with a UK government agency to purchase all the power produced;
- a power purchase price of £92.5/MWH (2012 prices) indexed to inflation based on an overnight (excluding finance charges) cost of £9bn per reactor; and
- UK sovereign loan guarantees to cover the borrowing.

The 2013 deal was submitted to the European Commission to determine whether it complied with EU state-aid legislation and in September 2014, approval was given.[3] This approval is subject to a challenge by the Austrian government and others, but by March 2017, the appeal had yet to be heard.

3. Cost

If we take the Hinkley cost as a guide and we include the cost of finance – this might add 50% to the overnight cost – the total cost of the 16GW programme would be about £125bn.

The UK government's White Paper of 2008[4] forecast that an EPR would cost £2bn (overnight) to support the government claim that no public subsidies would be needed because the power cost would be comparable to that of the lowest cost alternative (gas-fired generation). Allowing for inflation, this means the estimated real cost had increased four-fold in only seven years to 2015 and before construction had started. As costs increased, the government was forced to concede a number of subsidies such as a long-term fixed price power purchase agreement and sovereign loan guarantees, although it was not till November 2015 that the government finally acknowledged that its no-subsidies policy had been abandoned.[5]

The high power purchase price, at least double the prevailing wholesale electricity price in 2015/16, made the deal unpopular with many interests. However, NuGen and Horizon have expressed no more than a hope that power from their projects will be cheaper,[6] but there is firm commitment from either consortium that the power purchase price for the other projects will be any lower.

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[1] https://www.gov.uk/government/speeches/agreement-reached-on-new-nuclear-power-station-at-hinkley (Accessed March 20, 2017)
[2] https://www.gov.uk/government/news/hinkley-point-c-to-power-six-million-uk-homes (Accessed March 20, 2017)
[3] http://europa.eu/rapid/press-release_IP-14-1093_en.htm (Accessed March 20, 2017)
[4] http://webarchive.nationalarchives.gov.uk/+/http:/www.berr.gov.uk/files/file43006.pdf (Accessed March 20, 2017)
[5] It stated: 'The Government confirms that it is not continuing the 'no public subsidy policy' of the previous administration'. https://www.gov.uk/government/news/hinkley-point-c-to-power-six-million-uk-homes (Accessed March 21, 2017).
[6] In evidence to the UK House of Lords committee, an official from NuGen said: 'Our aspiration and goal is to deliver a strike price that is less than Hinkley.' An official from Horizon said: 'We believe it [the cost of Wylfa] will be certainly less than Hinkley, and I say that as well from a strike price perspective.'

4. Finance

Obtaining finance for nuclear projects has become one of the largest hurdles to nuclear projects. Large projects like nuclear power plants are typically financed by a mixture of debt (borrowing from banks) accounting for about 70% of the needs and equity (the owner's own money) for the balance. Few companies can finance more than a small proportion of large projects' needs from equity. The limited cash they have must also finance other projects and shareholders may well prefer to be paid these funds as dividends rather than have their money reinvested on a large risky investment. While equity attracts no formal interest charges, this high 'opportunity cost' of equity means in project appraisal the cost of equity is counted as higher than debt.

The very poor record of nuclear plants being built to time and cost makes nuclear projects financially risky and banks are unwilling to lend money unless there are strong measures in place to ensure loans are repaid. Increasingly, this means sovereign loan guarantees will be required provided either by the vendor's home country or by the country of installation.

The British government was initially unwilling to give such guarantees[7] but in June 2013, the government announced that Hinkley had pre-qualified for loan guarantees and an indicative figure of £10bn in guarantees was given. The Commission Inquiry suggested the loan guarantees would be worth £17bn. Assuming borrowing makes up 70% of the finance and loan guarantees are required to cover all the borrowing, the whole 16GW programme would require the British government to provide loan guarantees worth about £85bn.

The loan guarantees for Hinkley were offered subject to the fulfilment of a 'Base Case Condition'.[8] 'During the period up to the Base Case Condition being met there is a cap on the amount of debt drawn [figure removed]'. In September 2015, the British government announced it was releasing £2bn in guarantees so it seems likely the deleted figure was £2bn. The guarantees took the form of a guarantee for a bond sale EDF had to organise and the guarantees expired in 2020. Unsurprisingly, given that it is hard to see the value of loans that had to be repaid soon after construction had started, EDF chose not to take up this offer.[9]

'The Base Case Condition is that satisfactory evidence has been provided that Flamanville 3 has completed the trial operation period and that the requirements of the Guarantor in respect of performance during such period have been met. The Base Case Condition date cannot fall later than 31 December 2020.'

In short, until Flamanville 3 is in commercial operation the majority of the guarantees cannot be released and the offer will be withdrawn if this has not happened by the end of 2020. As argued below, there must be serious doubts whether Flamanville can be completed in time, if at all. If the

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http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/economic-affairs-committee/the-economics-of-uk-energy-policy/oral/42755.html (Accessed March 22, 2017)

[7] At a meeting in 2011 at which the author was present, the then Secretary of State for Energy and Climate Change, Chris Huhne, claimed loan guarantees would not be given because the Treasury would never allow it.

[8] http://ec.europa.eu/competition/state_aid/cases/251157/251157_1615983_2292_4.pdf (accessed March 20, 2017)

[9] Nucleonics Week 'EDF will not use GBP2 billion Hinkley loan guarantee from UK government' October 6, 2016

Base Case Condition is not fulfilled, EDF will not be able to finance its share of the project from equity. The British government will then either have to abandon the Base Case Condition or allow the project to collapse unless France is willing to guarantee the loans. However, the French government has shown no interest in providing loan guarantees.

EDF is trying to raise capital so that it can supply its share of the equity for Hinkley (about £3.5bn) and for its other equity needs. In particular, the French Corps des Comptes estimated that EDF would have to spend about €100bn by 2030 to life extend and upgrade its 58 reactors in France.[10] In 2015, it launched a sale of what it claimed were non-core assets aimed at raising €10bn. However, by March 2017, the only substantial sale that seemed in prospect was a 49% stake in its French electricity transmission business, RTE, which would be sold to a state-owned French bank, the Caisses des Dépôts for €4.1bn.[11] EDF also launched a €4bn share sale in March 2017 of which the French government took €3bn.[12]

Finance for the Horizon and NuGen projects will be no less problematic. These consortia are owned or controlled by Japanese reactor vendors. The model of the reactor vendor taking an equity stake in a reactor is being increasingly proposed and for the Russian and Chinese vendors and perhaps the Korean vendor with the full backing of their powerful governments, this may be a viable model but for other vendors, they have neither the financial scale nor skills to operate a reactor long-term. The likely plan would be to complete the plant, with the construction risk falling on them and then sell the plant on to a utility as an operating reactor.

A NuGen official told a UK House of Lords Committee[13]:

'For us, the financing challenge is quite unique. We need to build on the technology, experience and delivery capability of our consortium with Westinghouse and Toshiba and look at ways, if possible, of attracting debt, and share that funding burden with sources of capital that might be willing to provide loans or investments against a technology of this nature. Certainly, with export credit agencies, that is something that is a viable path to pursue and something that we are actively pursuing.'

While a Horizon official told the Committee:

'Very similar to almost any nuclear new-build project, however, in competitive energy markets and competitive financial markets, we are faced with a funding gap. We are looking under all the different rocks. We are looking everywhere to see where that funding might come from, be it equity or debt. We would not preclude or exclude anybody at this point in time. But we are solving,

[10] http://www.world-nuclear-news.org/RS-EDF-faces-EUR100-billion-reactor-upgrade-bill-says-audit-office-1102164.html (Accessed March 22, 2017)
[11] https://www.cnp.fr/en/Journalist/All-our-press-releases/2016/RTE-EDF-Caisse-des-Depots-and-CNP-Assurances-sign-a-binding-agreement-for-a-long-term-partnership (Accessed March 22, 2017)
[12] https://www.bloomberg.com/news/articles/2017-03-07/edf-begins-4-2-billion-share-sale-to-bolster-finances (Accessed March 22, 2017)
[13] http://data.parliament.uk/writtenevidence/committeeevidence.svc/evidencedocument/economic-affairs-committee/the-economics-of-uk-energy-policy/oral/42755.html (Accessed March 22, 2017)

ultimately, what is and what should be a private sector asset. There is no reason long term for an operating nuclear power plant to be necessarily in the hands of a Government. It could be.'

ENGIE is a large utility with comparable financial muscle to EDF but it is widely reported as wanting to reduce its stake or exit the NuGen consortium[14] with no replacement investors in sight. Reactor vendors are financially very small by comparison and, for example, the Areva reactor business is valued at only €2.5bn, while Toshiba has had to write off the entire value of its nuclear business. The Hitachi-GE reactor business is also very small. Such companies will not be able to raise the finance needed for such projects by themselves, but it is difficult to see who might provide the financial muscle. Of the three other large European utilities, the two German utilities, RWE and E.ON are exiting the nuclear business and they sold the Horizon consortium to Hitachi-GE in 2012. ENEL, the Italian utility also has no interest in expanding nuclear capacity. The other options talked about are the Korean state-owned utility and reactor vendor, Korean Electric Power Company, KEPCO (discussed below), Chinese investors or Middle East wealth funds. However, only KEPCO has shown any interest in the UK (see section on reactor vendors for more details).[15]

The Japanese government is examining the possibility of providing some loan guarantees for the Toshiba and Hitachi-GE projects[16] but Japanese vendors have only exported four reactors (the four AP1000s to the USA) and in this case, the projects were offered loan guarantees by the US government. Similarly, China might also consider guaranteeing loans but the only reactors exported by China are six reactors all sold to Pakistan, all supplied by CNNC, not CGN.

Given the difficulty of funding Hinkley and the likely difficulty of funding Wylfa, the follow-on projects at Sizewell and Oldbury appear no more than a distant prospect. It therefore seems unlikely that even if Hinkley and Wylfa go ahead, that more than 9.5GW. Reducing the number of reactors to be built at Moorside to two would also ease the funding burden for the NuGen consortium.

5. The designs

There is no operating experience with the EPR, the AP1000 or the HPR-1000 and the operating experience with the ABWR is only with a design from the mid-1980s which has undergone two major updates since then.

5.1. Experience

5.1.1. The EPR

In 2017, there were four EPRs under construction, one in Finland (Olkiluoto), one in France (Flamanville) and two in China (Taishan). All plants are very late in completion and where costs are known, far over budget (see Table 2). In addition, as discussed below, the completion dates for Flamanville and Taishan are in serious doubt because of concerns about the strength of the reactor

[14] China Daily 'UK Moorside nuclear project in doubt after Toshiba writedown' February 16, 2017.
[15] http://english.yonhapnews.co.kr/news/2017/03/22/0200000000AEN20170322004151320.html?input=rss (Accessed March 22, 2017)
[16] Nucleonics Week 'Hitachi's UK project could get funding support from Japan: officials' January 12, 2017

vessel and it is possible that the cost of completion of these plants will be prohibitive and the plants will have to be abandoned.

Table 2 Construction record of the EPR

Site	Construction start	Original/latest completion date	Original/latest cost estimate
Olkiluoto	2005	2009/2018	€3bn/€8.5bn
Flamanville	2007	2012/2018	€3.3bn/€10.5bn[17]
Taishan 1	2009	2014/2017	?
Taishan 2	2010	2014/2018	?

Source: Various

5.1.2. The AP1000

The AP1000 was developed from the smaller AP600 which was given approval by the US safety authorities in 1999. In 1997, the Westinghouse nuclear business, based in Pennsylvania, had been taken over by the state-owned British Nuclear Fuels Limited (BNFL) for US$1.2bn. This AP600 design proved too expensive to market and was scaled up to about 1150MW with the AP1000. This was submitted to the US authorities in 2002 but its review was not completed until 2011.[18] During this period, the Westinghouse nuclear business was sold by the British government in 2007 to Toshiba for US$5.4bn,[19] although its main base remains in Pittsburgh.

In 2017, there were eight AP1000s under construction (see Table 3), four in China (Sanmen and Haiyang) and four in the USA (Summer and Vogtle). Their construction record is just as bad as that of the EPR at the equivalent stage of construction.

Table 3 Construction record of the AP1000

Site	Construction start	Original/latest completion date	Original/latest cost estimate
Sanmen 1	2009	2013/2017	?
Sanmen 2	2009	2014/2018	?
Haiyang 1	2009	2014/	?
Haiyang 2	2010	2015/	?
Summer 2	2013	2016/2020	$5.2bn/
Summer 3	2013	2018/2020	$5.2bn/
Vogtle 3	2013	2016/	$6.65bn/
Vogtle 4	2013	2018/	$6.65bn/

Source: Various

5.1.3. The ABWR

By the end of 2010, there were four ABWRs in operation, all in Japan plus two more under construction in Japan and two in Taiwan (Lungmen), all using a version of the design dating from the mid-80s (see Table 4). The four plants in Japan have operated very little since then, while it is not

[17] https://www.bloomberg.com/news/articles/2017-01-11/bouygues-gets-1-8-billion-hinkley-point-nuclear-plant-contract (Access 21 March 2017)
[18] https://www.nrc.gov/reactors/new-reactors/design-cert/ap1000.html (Accessed March 22, 2017)
[19] https://www.toshiba.co.jp/about/press/2006_02/pr0601.htm (Accessed March 22, 2017)

clear whether the two under construction in Japan will be completed. Construction of the plants in Taiwan has been suspended for several years and these are unlikely to be completed. These ABWR orders were split between Hitachi, Toshiba and GE, all of whom cooperated in the development of the design. In 2007, when Toshiba bought GE's main US rival, Westinghouse, the cooperation ended. Toshiba offers its own version of the ABWR, while for Hitachi and GE, orders outside the USA are handled by Hitachi-GE (80% Hitachi) and those in the USA by GE-Hitachi (80% GE). None of these new companies have won an ABWR order since 2007. The construction time of the completed reactors was only 4-5 years but the operating performance is very poor. In July 2007, an earthquake measuring 6.6 on the Richter scale near the Kashiwazaki Kariwa plant caused significant damage to the plants requiring them to be shut down for about two years.[20]

In the 1990s, Hitachi/Toshiba/GE submitted an updated ABWR design for review by the US safety authorities and the design was given generic approval (see below) lasting 15 years in 1997. This design was never ordered and is being updated again for review by the UK authorities, for example, including the requirement for protection against aircraft impact that resulted from the 2002 '9/11' attack in the USA.

Table 4 Record of the ABWR

Site	Vendor	Construction start/ Commercial operation	Lifetime load factor to end 2010 (%)
Hamaoka 5	Toshiba	2000/2005	47.4
Kashiwazaki Kariwa 6	Toshiba/Hitachi	1992/1996	71.2
Kashiwazaki Kariwa 7	Toshiba/Hitachi	1993/1997	68.6
Shika 2	Hitachi	2001/2006	49.7
Ohma	Hitachi	2010	-
Shimane 3	Hitachi	2007	-
Lungmen 1	GE	1999	-
Lungmen 2	GE	1999	-

Source: https://www.iaea.org/PRIS/CountryStatistics/CountryDetails.aspx?current=JP (Accessed March 20, 2017).

Note: Load factor is calculated as power produced as a percentage of the power that would have been produced had the plant operated uninterrupted at full design rating.

5.1.4. The HPR-1000

The two largest Chinese reactor vendors, CGN and China National Nuclear Corporation (CNNC) both developed 'advanced' designs offered after the Fukushima disaster, ACPR1000 and ACP1000 respectively (for more details on the Chinese nuclear industry, see Thomas, 2017). In 2013, the Chinese government asked the two companies to 'merge' these designs into a single design, Hualong One and while both companies have recently started construction of Hualong One reactors in China, there remain significant differences between the two versions and the Chinese government has not yet decided which version should form the basis for reactor exports.[21]

[20] LNG Daily 'Tepco sets May 9 restart date for Kashiwazaki-Kariwa No. 7 unit' May 8, 2009
[21] Nuclear Intelligence Weekly 'China: Disappointment in 2016, But Progress Expected' January 6, 2017

Table 3 Construction record of the HPR-1000

Site	Vendor	Construction start
Fangchenggang 3	CGN	12/15
Fangchenggang 4	CGN	12/16
Fuqing 5	CNNC	5/15
Fuqing 6	CNNC	12/15

Source: Various

5.2. The Generic Design Assessment

From 1992 onwards, the USA has used a process of generic design review under which a new design is reviewed in exhaustive detail and, if successful, the design is given generic approval for construction at any site (subject to local issues) for up to 15 years. A similar system was adopted in the UK in 2007 (approval lasting for up to 12 years) and is known as Generic Design Acceptance (GDA). A buyer could choose a design with generic approval and be confident no significant design safety issues would arise. The rationale for this was that previously construction was started with only an outline of the design with the details filled in and reviewed by the safety authorities during construction. However, if the proposed detailed design was not accepted by the safety authorities, this could delay construction in mid-stream while the issue was resolved.

An example of the problems caused by not having the design fully approved prior to construction start was given by EPR construction in Finland and France. Here, the regulators were not satisfied with the redundancy in the back-up instrumentation and control (I&C) system. While this was by no means the only cause of delay at these projects, it does appear it did cause some delay particularly at Olkiluoto.[22]

Reviews of the AP1000 and the EPR designs by the UK's Office of Nuclear Regulation (then Nuclear Installations Inspectorate, NII) began in 2007 and was due to be complete in June 2011. This was delayed by six months by regulatory work arising from the Fukushima disaster and in December 2011, the NII issued Interim Design Acceptance Certificates for both designs with 51 and 30 issues for the AP1000[23] and the EPR[24] respectively still to be resolved. The I&C system for the EPR was a particular problem, but in December 2012, the NII issued a Design Acceptance Certificate. Detailed examination of the final report suggests the issues surrounding the I&C have not been resolved. The closure document stated:[25]

'A BSC [Basic Safety Case] is powerful specification for the final safety case that will be produced for the NCCS [Non-Computerised Safety System], which cannot be completed until the first system has been tested in the factory, when all the evidence that can be assembled demonstrates the system meets its requirements. The production of the operational safety case will be the responsibility of a

[22] For more details on the I&C issue, see Thomas (2015)
[23] http://www.onr.org.uk/new-reactors/reports/ap1000-onr-gda-idac-11-002-issue-1-131211.pdf (Accessed March 20, 2017)
[24] http://www.onr.org.uk/new-reactors/reports/step-four/technical-assessment/ukepr-onr-gda-sr-11-001-rev-0.pdf (Accessed March 20, 2017)
[25] http://www.onr.org.uk/new-reactors/reports/step-four/close-out/summary.pdf (Accessed March 20, 2017)

future licensee and will be completed during the site specific phase before the delivery of the NCSS to the site.'

Westinghouse chose, in 2011 not to pursue resolution of the 51 remaining issues because at that time, it had no prospective UK customer. However, following it taking a stake in NuGen in 2013 it announced it would re-open the procedure and in August 2014, the GDA for the AP1000 was restarted. Completion is scheduled for March 2017 although the progress report for the five months to end October 2016 cast doubt on completion of the GDA. It stated:[26]

'Our delivery confidence for this project is amber/red, which means that successful delivery of the project is in doubt with major risks or issues apparent in a number of key areas.'

The next progress report covering the two months to end January was more optimistic: 'This increase in pace and delivery has dramatically improved the Westinghouse position and increased the likelihood of the project completing on time at the end of March 2017.'

Work on the ABWR GDA started in January 2014 following the take-over of the Horizon consortium by Hitachi-GE. The GDA seems to be going more smoothly than those of the EPR and the AP1000 and in its October 2016 progress report, the ONR stated:[27]

'There are technical issues outstanding and a large volume of work remaining; however Hitachi-GE continues to respond well and at this juncture we consider the project stable overall, and are confident in Hitachi-GE's projected completion date of December 2017.'

The Bradwell project was announced when the Hinkley deal was published in October 2015, when CGN stated they expected to submit their design to the ONR in 2016. In January 2017, the UK government formally requested ONR to carry out a GDA on the Hualong One although by March 2017 substantive review had not started.[28] Until a choice is made between CNNC's and CGN's design, and the design is available in full detail, it is hard to see how the process can start.

6. The Vendors

Since the beginning of 2015, the financial position of Areva and Toshiba has dramatically declined so that by March 2017, both were effectively bankrupt because of losses on reactor orders and their future as reactor vendors was in serious doubt. In the case of Areva, its future was further clouded by revelations that it had been falsifying quality control documentation for up to 50 years.

[26] http://www.onr.org.uk/new-reactors/reports/gda-quarterly-report-may16-oct16.pdf (Accessed March 20, 2017)
[27] http://www.onr.org.uk/new-reactors/reports/gda-quarterly-report-may16-oct16.pdf (Accessed March 20, 2017)
[28] http://www.onr.org.uk/new-reactors/reports/gda-quarterly-report-nov16-jan17.pdf (Accessed March 22, 2017)

6.1. Areva

In March 2015, Areva announced annual losses for the fifth consecutive year, this time of nearly €5bn[29] and it became clear it could not continue to trade legally without substantial assistance. The French government provided short-term loans to allow it to continue to trade while a rescue was put in place. Areva comprised two main businesses, the fuel cycle business, Areva NC, and the reactor business Areva NP and the rescue requires the splitting up of Areva into these two new businesses. These are provisionally being called New Co for fuel cycle and New NP for the reactor business. The rump companies, Areva SA and Areva NP will remain to deal with some of the historic liabilities and will be 100% owned by the French state.[30]

The rescue of the fuel cycle company is more straightforward because it has limited liabilities and for the UK reactor programme, it is the reactor business that is most important. The rescue of the fuel cycle company was approved by the European Commission in March 2017. This included approval of a capital injection by the French government of €4.5bn.[31] This will not take place until the New NP business had been divested (see below) and to tide the business over until then a loan by the French government of €3.3bn was also approved. The rescue of the reactor business, New NP, has yet to be considered by the Commission.

The scale of the reactor business's historic liabilities is such that a rescue may be impossible. One major liability is the cost of the overruns at the Olkiluoto plant. Areva gave a fixed price contract for €3bn to build the plant, but current estimates are that the final cost will be at least €8.5bn.[32] Areva has long disputed its responsibility for all the cost overruns and the case is being heard in the International Chamber of Commerce although a final verdict is not expected soon. The liability is likely to be in the order of €2-3bn and the French government has agreed to meet the liability with the project being completed by Areva SA.

The rescue of the reactor business requires EDF to buy 75% of New NP based on a company valuation of €2.5bn. It would then hope to sell a minority stake in the company leaving it with 51%. However, the deal, announced in November 2016, is dependent on a number of conditions mainly to do with QC issues uncovered in Areva, discussed below.[33]

In April 2015, the French nuclear safety regulator, Autorité Sûreté Nucléaire (ASN), announced that the reactor bases and lids Areva had supplied from its Creusot forge to the Flamanville and Taishan reactors did not meet specification with too much carbon in the steel.[34] The reactor vessel is of key

[29] http://www.areva.com/mediatheque/liblocal/docs/groupe/Documentreference/2014/DDR_EN_310315.pdf (Accessed March 22, 2017)
[30] http://www.areva.com/EN/group-749/provide-access-to-cleaner-safer-and-more-economical-energy-to-as-many-people-as-possible.html (Accessed March 22, 2017)
[31] http://europa.eu/rapid/press-release_IP-17-36_en.htm (Accessed March 22, 2017)
[32] http://uk.reuters.com/article/uk-tvo-areva-olkiluoto-arbitration-idUKKBN1350UA (Accessed March 22, 2017)
[33] http://www.areva.com/EN/news-10873/edf-and-areva-sign-binding-agreements-for-the-sale-of-areva-np-s-activities.html (Accessed March 22, 2017)
[34] http://www.french-nuclear-safety.fr/Information/News-releases/Flamanville-EPR-reactor-vessel-manufacturing-anomalies (Accessed March 22, 2017)

importance to the safety case and a reactor vessel failure must be not credible. Since the admission of the problem, Areva has been putting together the case that these parts are strong enough and it was reported this would be delivered to the French safety regulator, ASN, in December 2016 (its delivery has not been confirmed).[35] ASN said it would need at least 6 months to evaluate the case, although, as discussed below, reviews of a reactor not yet in service may not be the highest priority.

As these parts had been installed a few years earlier, they will not be readily accessible and therefore reparable or replaceable and if they are not the Flamanville and Taishan plants will have to be abandoned. It would seem inevitable that Areva would be held responsible and would be liable for a large amount of compensation.

As a result of this problem, ASN asked Areva to review its records at the Creusot plant going back ten years. Areva clearly found additional serious problems and extended the review back to 1965 and brought in two other plants, Jeumont and Saint-Marcel.[36] No information had been given on the findings at these other two plants by March 2017. However, an initial review covering 9000 records at Creusot found 400 irregularities for equipment such as reactor vessels, steam generators, main primary system piping and transport packaging. This equipment has been installed not only in France but other countries that have bought Areva parts including the UK, USA, China, Japan and Switzerland. The French prosecutor is examining bringing criminal charges against Areva.[37]

In October 2016, the President of ASN, Pierre-Franck Chevet stated: 'this "purge" of documentation irregularities would continue. There is still one to two years' work. We will find other irregularities. It is obvious.' While the President of Areva, Bernard Fontana, said: 'This [audit] will take place throughout the year 2017, with priority given to files related to the operating fleet. We are expecting to find the same type of practices to those discovered as part of the marked files.'[38] In March 2017, Areva said: 'For now we have had no claims from any clients. We are in talks with the clients & regulators concerned.'[39] The clear implication is that they expect claims and if they have installed equipment that does not meet the required specification, especially if the QC documentation has been falsified, it would be surprising if there were not such claims.

Also in March 2017, the head of nuclear equipment at ASN, Remy Catteau said that an inspection of the plant late last year showed that it did not have the right equipment to produce the parts for the nuclear reactors.[40] "Creusot Forge is at the limit of its technical capacity. The tools at its disposal are not adequate to manufacture such huge components. In such a situation, errors are made. The

[35] http://www.areva.com/EN/news-10753/flamanville-epr-advancement-of-reactor-vessel-testing-programme.html (Accessed March 22, 2017)
[36] http://www.areva.com/EN/news-10777/quality-audit-at-the-le-creusot-plant-end-of-may-status-update.html (Accessed March 22, 2017)
[37] http://www.french-nuclear-safety.fr/Inspections/Supervision-of-the-epr-reactor/Anomaly-affecting-the-Flamanville-EPR-reactor-vessel/Falsification-of-materials-analysis-reports-ASN-is-collaborating-with-the-ongoing-judicial-inquiry (Accessed March 22, 2017)
[38] European Power Daily 'Further Areva review likely to find irregularities' October 27, 2016.
[39] http://uk.reuters.com/article/us-areva-results-idUKKBN1683H0 (Accessed March 22, 2017)
[40] http://uk.reuters.com/article/uk-areva-safety-creusot-idUKKBN16N1SL (Accessed March 22, 2017)

inspection brought to light the fact that the safety culture in the plant is not sufficient to produce nuclear components." It seems unlikely the Creusot plant can survive such a crushing condemnation.

The 'binding agreement' announced in November 2016 on the sale of New NP[41] to EDF is dependent on:

- Obtaining favourable conclusions from the ASN regarding the outcome of the tests on the primary circuit of the Flamanville 3 reactor;
- Completion and satisfactory conclusions of the quality audits at the Creusot, Saint-Marcel and Jeumont plants;
- Approval from the relevant merger control authorities.

It may be that approval from the merger control authorities will be forthcoming but the other two conditions appear problematic. Areva's claim that the takeover of New NP would be completed in the second part of 2017[42] does not appear plausible as the quality audits are likely to continue into 2018. Even when the reviews are complete, there is the issue of the liabilities that will arise. If the Flamanville and Taishan reactors cannot be completed they will be huge. If significant numbers of large components, like steam generators or reactor vessel heads, have to be replaced because they do not meet specification or that there can be no confidence they do meet specification, the liabilities will also be substantial. Clearly EDF cannot contemplate facing them and will only buy New NP if the French government extends its guarantees from Olkiluoto to cover these issues. Whether the French government can afford to underwrite losses that might run into tens of billions of Euro without damage to its credit rating is questionable. There is also the issue of state-aid and it is clear that the rescue of the Areva reactor business would require state-aid from the French government on a massive scale. Whether the European Commission could stomach aid on this scale is open to question.

France clearly needs Areva's fuel cycle capability and its reactor servicing and maintenance capability to keep its 58 operating reactors in service. However, with no reactor orders in sight and only a highly suspect design available that has done severe damage to EDF's claim to be the world's reactor expert it is not clear that it needs a reactor vendor capability. It appears that the fuel cycle business can be re-launched, but if the reactor business cannot be saved as a going concern, it may be possible to allow the reactor business to fail and rebuild a servicing and maintenance business from the ruins.

6.2. Toshiba

The common perception of Toshiba is of a diversified company offering a wide range of products including consumer goods such as televisions and computers. In fact, it has sold off most of its businesses other than its two core businesses, the nuclear business and its computer chips business.

[41] http://www.areva.com/EN/news-10873/edf-and-areva-sign-binding-agreements-for-the-sale-of-areva-np-s-activities.html (Accessed March 20, 2017)
[42] http://www.areva.com/EN/news-10923/2016-annual-results.html (Accessed March 22, 2017)

From 2016 onwards, there have been persistent reports it wanted to sell a majority or all of its profitable chips business leaving it as primarily a nuclear company.[43]

While experience of construction of the eight AP1000 orders won since Toshiba took over Westinghouse has been very poor[44], it was not till 2015 that the company really began to unravel. In July 2015, it admitted that it had overstated its profits during the period 2008-14 by Yen152bn.[45] This led to a large number of board member resignations and a record fine imposed by the Japanese Stock Exchange of Yen91m. An investigation on this issue by the US Securities & Exchange Commission is still ongoing.

In October 2015, in response to a view that the problems with the AP1000 were in large part due to failures, particularly of quality control, with its equipment suppliers, it took over the nuclear business of its major supplier Chicago Bridge & Iron (CB&I). The CB&I assets included Stone & Webster, an architect engineering company with a long history in nuclear power and the Shaw Group.[46]

In October 2015, it also renegotiated the Engineering Procurement and Construction (EPC) contracts for its Vogtle and Summer projects on a fixed price basis as a way to settle disputes that had arisen with the customers for these plants. At the time, Westinghouse was claiming it could improve efficiency by 30%, a target it has totally failed to meet.

In February 2017, it admitted that it would make a loss of US$6.1bn on these fixed price contracts throwing the future of the company in doubt. Toshiba said it was considering abandoning its reactor sales business[47] and that it would consider selling its Westinghouse business.[48] By March 2017, Toshiba's survival was in serious doubt, its credit rating had fallen to CCC- (S&P) far into 'junk' status and it had postponed publication of its annual report due in February until April 11. There was talk of filing for bankruptcy.

As with Areva, relaunching the company as a servicing and maintenance business selling the Westinghouse assets may be viable although Toshiba will be reluctant to abandon the Moorside project as this project would add significantly to the attractiveness of the Westinghouse reactor business to potential buyers.

[43] https://www.bloomberg.com/news/articles/2017-03-17/toshiba-said-to-attract-10-potential-bidders-for-chips-business (Accessed March 22, 2017)
[44] For an account of the construction problems up to 2015, see Thomas (2015)
[45] The Independent 'Accounting scandal forces mass resignations at Toshiba; Chief executive and senior board members step down over inflated profits' July22, 2015
[46] Nuclear Intelligence Weekly 'Westinghouse's Strategy in CB&I Stone & Webster Acquisition' October 30, 2015
[47] Energy Monitor Worldwide 'Toshiba to exit nuclear construction business' February 1, 2017.
[48] Japan Times 'Toshiba turnaround hopes, planned sale of Westinghouse find skeptics' March 20, 2017

There would appear to be two potential buyers, KEPCO and the third Chinese reactor vendor, State Power Investment Corporation (SPI). The latter was set up as late as 2007 to import AP1000 technology to China. It has subsequently scaled up the AP1000 design to 1400MW, the CAP14000. However, despite the expectation in 2007 that the AP1000 would take over as the main technology for China, no orders for the AP1000 beyond the initial four orders placed in 2007 have been placed. There appears to be a reluctance to place further orders until the first AP1000 is in service and has proved its reliability. Nevertheless, in 2017 the Chinese authorities approved construction for eight reactors, six using the AP1000 design and two the CAP1400.[49] Despite the logic of an SPI takeover, there is no indication that SPI is considering a bid.

While KEPCO is the main Korean publicly owned utility, it is also the country's reactor vendor. Its latest design is based on a design (never ordered) licensed from Combustion Engineering (a company subsequently bought by BNFL and absorbed into Westinghouse), the APR1400. The first reactor of this design entered service in Korea in December 2016. Three more reactors of this design are under construction in Korea and four in the UAE (Korea's only nuclear exports) and the design was submitted to the US regulator for generic review in 2014. KEPCO has increasingly been mentioned as an investor in Moorside, presumably to replace ENGIE. It is difficult to see the rationale for this move as it would involve giving business and credibility to its reactor vendor competitor, Toshiba, with its AP1000. If it were to substitute its own design, this would set the timetable back more than five years while the design was reviewed by the ONR. However, assuming KEPCO believes the AP1000 is a commercially viable design, if it was to take-over Westinghouse, it could add the AP1000 to its list of products. Despite this logic, KEPCO has stated that it has no interest in taking over the Westinghouse business.[50]

As with SPI, a deal would almost certainly require that the US$6.1bn liability for Vogtle and Summer would not fall on the buyer. It would appear that the only candidate to take this loss if Toshiba's guarantees to meet this fail, would be the Japanese government. However, it is difficult to see what the incentive would be for them to save a capability as a going concern based in the USA so it can be taken over by either a state-owned Korean or Chinese company. In March 2017, there were therefore no obvious candidates to take on the Toshiba/Westinghouse reactor vendor business.

6.3. Hitachi-GE

Given that Hitachi-GE has not suffered the solvency problems, the QC issues, the delays and cost over-runs with its current design Areva and Toshiba have faced, it might appear that Hitachi-GE is in a better position. However, it has no orders for its current design and operating performance with the reactors using the old design is very poor. Like the NuGen consortium, as it acknowledges Horizon needs a powerful investor if it is to finance its UK projects. However, none of the large European industries would be interested, while China and Korea have no interest in BWR technology so it is hard to see who its partner could be.

[49] Nuclear Intelligence Weekly 'China Plans Eight Reactor Construction Starts in 2017' February 17, 2017.
[50] Financial Times 'Kepco rules out buying Westinghouse stake' March 22, 2017.

6.4. CGN

CGN has no experience outside China and is a relatively small company but it appears to have the backing of the Chinese government so it might have the financial muscle to finance a UK project. Experience in China suggests CGN is able to construct a well-established old design reasonably efficiently but its ability to develop its own designs is untested and Hualong One remains an unknown quantity. It is expanding rapidly in China and it is seeking new capital to fund this and its overseas activities such as Hinkley and Bradwell.[51]

7. Conclusions

The extent of the compromises to the initial promises made for the UK's nuclear new-build programme are remarkable and if it had been known in 2006 what would have to be offered to get the programme this far, there is little doubt the policy would not have been adopted. It would therefore be unwise to rule out any option that might still allow the programme to proceed. One option increasingly talked about is for the UK government to take a large direct stake in the consortia to ensure finance can be obtained.[52] The rhetoric of this option is that UK taxpayers will be taking the project risk by supplying loan guarantees so it would make sense to take an equity stake. If the project is profitable, some of the potential upside as well as the project risk would be held by taxpayers.

However, if Areva and Toshiba do not survive as reactor vendors, even this might not be sufficient to save the programme. The risk to Toshiba is more immediate because it is privately owned and does not have the backing of a strong government but in the longer term, the problems of Areva look as intractable.

References

S Thomas 'Nuclear construction problems' PSIRU, University of Greenwich. http://www.psiru.org/reports/nuclear-construction-problems.html (Accessed March 22, 2017)

S Thomas (2016) 'The Hinkley Point decision: An analysis of the policy process' Energy Policy 96 (2016) 421–431.

S Thomas (2017) 'China's nuclear export drive: Trojan Horse or Marshall Plan?' Energy Policy 101 (2017) 683–691

[51] Nuclear Intelligence Weekly 'CGN's Search for More Capital' December 16, 2016

[52] See for example: The Telegraph 'Government could part-fund new UK nuclear plants, NuGen suggests' November 5, 2016. http://www.telegraph.co.uk/business/2016/11/05/government-could-part-fund-new-uk-nuclear-plants-nugen-suggests/ (Accessed March 22, 2017)