The EPR in Crisis

by

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Introduction

The European Pressurised water Reactor or EPR[1] was to have been the demonstration of a new generation of nuclear reactors, so-called Generation III+, first talked about in the late 1990s. The difference between 'III+' and the earlier 'III' designs is that III+ designs are said to rely more on 'passive' rather than 'engineered' systems.[2]

The rationale for the Generation III+ plants was that they would be an evolution of existing designs but would be designed from the start with the lessons from the Three Mile Island and Chernobyl accidents fully incorporated. They would rely more on natural processes rather than engineered systems for their safety – so-called passive safety. As well as being safer, they would also be more 'buildable', cheaper to build and operate, and easier to decommission. In short, they would address the issues that had led to ordering of earlier designs to a near halt from about 1990 onwards.

The Olkiluoto order, placed in 2003, should have been on-line in 2009 and should have been a demonstration of the qualities of Generation III+ designs in general and the EPR in particular. However, by 2010, the EPR appeared to be in crisis. The two orders on which significant construction work had been completed had gone seriously wrong, obtaining safety approval from regulators in Europe and the USA was proving far more difficult than had been expected, estimated construction costs had increased by a factor of at least four in the past decade and the EPR had failed to win orders in bids for tender for nuclear capacity. Relations between the two state-controlled French companies at the heart of the development of the EPR, Areva, the vendor and Electricité de France (EDF), the utility appeared at breaking point. EDF was reportedly contemplating designing two new reactors in competition with those offered by Areva.[3]

In this report, we examine the roots of the design, existing and potential orders for the reactor, experience with construction of the EPR, issues arising from the safety assessment of the design, and economic issues. We examine the report by the Roussely Commission, a report commissioned by the French government and headed by a former Chief Executive of the French utility, Electricité de France (EDF), and its implications for the EPR.

The roots of the EPR design

In 1989, Siemens, the main German nuclear vendor and Framatome, the French nuclear vendor formed a joint venture company, Nuclear Power International (NPI) to design a new Pressurised Water Reactor (PWR). Siemens and Framatome had both been licensees of Westinghouse for their PWR technology. Design work was partly funded by German utilities and Electricité de France. This design would be based on Siemens' and Framatome's most recent PWR designs, the 'Konvoi' design and the N4 respectively. By 1992, NPI was claiming that the conceptual design of the EPR was nearly complete,[4] although the conceptual design was not actually completed until 1994. The EPR would have a thermal output of 4250MW giving an electrical output of about 1450MW. The containment was drawn mainly from the N4 design, while instrumentation was expected to be drawn from the Konvoi. A particular feature of the design was the inclusion of a 'core catcher' so that in the event of a core melt, the core would be retained within the containment. There was some uncertainty about what type of external hazards would be guarded against, with the French requiring protection only against a light aircraft, such as a Cessna, while the Germans required a military jet, like a Phantom.

In March 1995, the basic design phase was started with the expectation that EDF would order the first unit before 2000 and have it in service by 2006. However, there was then already so much nuclear capacity in France that EDF had more than enough nuclear power capacity to meet base-load. This meant that 'series' ordering, that is ordering at a predictable rate of several units per year, would not be needed before 2005.[5] The French programme had always been premised on an assumption that a nuclear power programme only made sense if series ordering was expected. The issue of aircraft protection was not fully resolved but the French containment was approved by both the German and French regulators. By November 1995, there were concerns, especially amongst EDF officials, about the cost of the design, then expected to be more than US$2000/kW.[6] The basic design work was not completed on time and in August 1997, after further concern about costs, the output of the plant was increased to 1800MW.[7]

In September 1999, the head of DSIN (the French safety regulatory body later renamed DGSNR), Andre-Claude Lacoste, stated he expected to issue an interim safety verdict on the EPR within 'a few weeks to a few months' with a final design certification, reported to be equivalent to NRC's design certification for advanced reactors. [8] The output of the reactor had been reduced back down to about 1500MW. However, by 2003, the final certification had not been issued and Andre-Claude Lacoste, the head of the French regulatory body,, stated the process carried out up till then did not correspond to US design certification and that to achieve this would take 2-3 years more.[9]

In August 2000, Framatome and Siemens agreed to a new joint venture formally merging their nuclear activities into a new company called Framatome ANP, subsequently renamed Areva NP. Framatome would hold 66 per cent of the stock and Siemens the rest.[10]

Marketing of the EPR

Continued delays to EDF's order led Areva NP to switch to Finland as the focus for its marketing. In May 2002, the Finnish Parliament approved the construction of a fifth nuclear unit in Finland. Three designs were short-listed from a list of seven for an order to be placed by the Finnish utility, Teollisuuden Voima Oy (TVO). The Finnish safety regulator, STUK, had already stated that it saw no difficulties in principle in licensing any of the seven initial candidates.[11] The three short-listed reactors were the EPR, a Russian design and a Boiling Water Reactor design also offered by Areva NP. TVO was widely reported to be looking for a 'turnkey' (fixed price) contract. Westinghouse chose not to bid overtly on the grounds that a turnkey offer would not be profitable.[12] However, there were also claims by Areva that Westinghouse's AP1000 would not have met the requirements on aircraft protection because its containment was not strong enough.[13] The AP1000 does not have a core-catcher and the head of STUK, Jukka Laaksonen has stated that on these grounds, the AP1000 would not have been acceptable in Finland.[14]

In December 2003, TVO signed a turnkey deal with Areva NP for a 1600MW EPR at a cost, including interest during construction and two fuel charges of €3bn. The Finnish regulator was by then in close contact with the French regulator, DGSNR, which was expecting that an order for France would be placed in 2004. STUK expected to complete its review of the design within a year of the placing of the order.

By December, STUK and DGSNR had agreed to opt for different approaches so that construction in Finland did not have to wait until demonstrations of safety features that were expected to reduce costs had been carried out.[15] In January 2005, STUK approved construction of Olkiluoto 3.[16]

In September 2004, DGSNR completed its review of the EPR and in October, the French government issued design approval for it, claimed to be equivalent to NRC design certification.[17] In December

2004, Areva NP wrote to the US NRC asking it to begin a review of the EPR design for the US market.[18] It expected completion of the review in 2008.

Approval by the French regulator came just after the opening of a call for tender from China in October 2004 and with further delays in ordering in France, Areva NP's marketing efforts switched to China. China's decision on the tender was delayed several times and it was not until December 2006 that it was announced that it had been won by Toshiba/Westinghouse's offer of four AP1000s. One of the factors behind Areva NP's failure to win the initial tender was reported to be its reluctance to transfer the technology as quickly and as fully as the Chinese wanted.[19] China wanted quickly to be in a position to be able to build reactors of the design it chose without any input from the original vendor and in 2010, it was planning to start placing orders for plants of the AP1000 design without major involvement from Westinghouse.[20] There were reports that Areva NP had failed to match Westinghouse's offer to 'sell the Chinese the blueprints.'[21] However, reportedly in the interests of relations with France, China subsequently ordered two EPRs in November 2007 for the Taishan site in a deal reportedly worth €8bn. It is not clear what the terms of the contract were or what it covered so it is difficult to compare this deal with others. EDF took a 30 per cent stake in the company, Guangdong Nuclear Power Company (GNPC), building the reactors.

In the meantime, EDF finally ordered its first EPR to be built at its Flamanville site in 2005. At that time, EDF expected the reactor to cost €3.3bn, although the reactor would produce 1700MW, 100MW more than the Olkiluoto order. Construction of the reactor (first structural concrete) did not start until December 2007 and it was expected to take five years to build, a year more than Olkiluoto. Unlike Olkiluoto where Areva NP carried out the architect engineering, EDF itself carried out the architect engineering, as it has done with the 58 previous reactors it had bought from Framatome.

The next tender was for South Africa launched in January 2008 calling for 3200-3600MW of new capacity from Areva NP and Toshiba Westinghouse. The tender was in two parts: the first with specific proposals for the 3200-3600MW of capacity and the second the development of a 20,000MW nuclear fleet to be in place by 2025.. The first part of the bid would require either two EPRs of 1600MW or three AP1000s each about 1200MW.[22] It was reported that the bids were in the order US$6000/kW[23] and in November 2008, it was reported that Areva had won the contest, although the scale of 20,000MW programme was to be scaled back.[24] However, in December 2008, Eskom cancelled the tender citing 'the magnitude of the investment.'[25]

In February 2009, Areva NP bid for two reactors to be constructed in Ontario.[26] Other bidders were Toshiba-Westinghouse (AP1000) and the Canadian vendor, AECL offering a new Candu design.[27] The commissioning body was Infrastructure Ontario a state-owned agency. In June 2009, the Ontario government suspended the tender citing concerns about pricing. It was reported that Areva NP's bid for one EPR was US$21bn. This was denied by Areva NP but they did not reveal the actual figure.[28]

In February 2009, the United Arab Emirates (UAE) began the assessment of bids for 5000MW of new nuclear capacity. In addition to a bid from Areva NP for three EPRs, it was reported that there were bids from General Electric-Hitachi and Toshiba/Westinghouse.[29] The EPR bid initially involved Areva NP, GDF Suez, Bechtel and Total. Subsequently, at the request of the French government, EDF was persuaded to join the EPR bid. In July, three bids were selected for assessment including a bid from GE-Hitachi for a boiling water reactor (BWR) and one from a Korean group offering its Pressurised Water Reactor (PWR), the APR-1400.[30] In December 2009, it was announced that the tender had been awarded to the Korean consortium for four APR-1400 units at a price of US$20bn. According to Korean media reports, the Korean bid was almost 30 per cent lower per kW than the

EPR bid, while the GE Hitachi offer was said to be higher than the French bid. The failure to win this bid led to much criticism of the French nuclear industry, in particular the lack of unity in the French bid. EDF, which has acted as architect engineer for all the PWRs built in France, had been unwilling to act as architect engineer for foreign bids and had only been persuaded by the French government in December to lead the bid as the UAE utility, ENEC, had requested.[31]

USA

The USA is potentially the largest nuclear market (along with China) in the world and Areva and EDF have made a major financial commitment to open up this market. EPR is one of five designs being assessed by the US safety authorities, the Nuclear Regulatory Commission (NRC), and is a candidate for Federal subsidies including Federal loan guarantees. Subsidies for new nuclear reactors were first mooted in 2002, when President Bush launched an initiative aimed at re-starting commercial ordering for nuclear reactors using the Generation III+ design in the USA, the Nuclear Power 2010 programme: no reactor order, not subsequently cancelled, had been placed since 1974 in the USA. The Bush government believed that nuclear technology was competitive and that a handful of subsidised demonstration plants were needed to show that the new designs had overcome the problems of earlier designs.[32] The publicity for the programme claimed: 'New Generation III+ designs ... have the advantage of combining technology familiar to operators of current plants with vastly improved safety features and significant simplification is expected to result in lower and more predictable construction and operating costs.'[33]

This programme has evolved considerably since it was first announced and although nominally Nuclear Power 2010 is due to end at the end of fiscal year 2010, the effort by the Federal government to re-start nuclear reactor ordering will almost certainly continue. Nuclear Power 2010 originally had the goal of having new reactors online by 2010. Time-scales have slipped substantially – the first unit is unlikely to be on-line before about 2018 if there are no more delays.

The programme was to take advantage of new licensing procedures, already passed into law in the 1992 Energy Policy Act, so that a combined Construction and Operating License (COL) license would replace the existing procedure of separate construction and operating licenses. The proposed Energy Policy Act of 2003 (EPACT 2003) offered the prospect of Federal loan guarantees for new reactors covering up to 50 per cent of the cost of the projects. When the Congressional Budget Office (CBO)[34] looked at the cost implications of this bill, it assumed that loan guarantees would be offered for six reactors. The CBO assumed that the reactors would be of 1100MW, each costing US$2.5bn (US$2300/kW) and that they would be financed by 50 per cent debt and 50 per cent equity. This meant that the guarantees required would be worth about US$7.5bn. It asserted the risk of default would be 'well above 50 percent' but that over the plant's expected operating lifetime, its creditors (which could be the federal government) could expect to recover a significant portion of the plant's construction loan so the net cost to taxpayers would be about 25 per cent of the sum guaranteed.

EPACT 2003 was not passed, but a successor bill, the Energy Policy Act of 2005 (EPACT 2005) was passed and contained much more generous levels of support for new nuclear reactors. EPACT 2005 included provisions to cover cost overruns due to regulatory delays,[35] and a production tax credit of 1.8 cents per kilowatt-hour for the first 6,000 megawatt-hours from new nuclear reactors for the first eight years of their operation, subject to a $125 million annual limit.[36]

However, the biggest incentive was the provision of loan guarantees under Title XVII of that bill. While the loan guarantees would only be available for technologies that were not 'commercial', the number of units that would be eligible was not precisely specified. The US Department of Energy stated: 'DOE has defined "commercial technologies," which are *not* eligible for loan guarantees under this program, as "in general use if it has been installed in and is being used in three or more commercial projects in the United States in the same general application as in the proposed project, and has been in operation in each such commercial project for a period of at least five years." Given that new reactors will take at least five to ten years to build, a large amount of loan guarantees for the same design could be offered before the design is considered "commercial".[37]

The potential scale of the loan guarantees programme has escalated dramatically since 2003. Let us assume that these were now available for only three units of each of the five designs being assessed by the US NRC and for up to 80 per cent of the total cost. Since the CBO made its estimate in 2003, the estimated cost of new reactors has increased to at least US$6000/kW and their average size has increased to 1200-1600MW making the cost (without finance costs) of an EPR nearly US$10bn. Under these assumptions the programme would be able to provide loan guarantees worth more than US$100bn. In July 2008, the US DOE announced it was ready to accept applications for loan guarantees, but Congress authorized only up to US$18.5bn.[38] Congress believed this might be sufficient to cover four projects (seven to eight reactors), but using more realistic cost assumptions, this seemed likely to be able to only allow three or four reactors at most. The Obama Administration asked for an additional US$36bn in loan guarantees in February 2010 , but the appropriations process was held up by election-year politics, so by November 2010, it was not clear how much the additional funds would be. There is also the issue of the fee that should be charged to borrowers for the loan guarantees. This should be an economic fee, in other words, one that reflects the risk involved. . The fees are assessed by the federal Office of Management and Budget and are supposed to reflect the risk of default for that project. As has become clear with the Calvert Cliffs project, discussed below, if the risk of a loan is assessed to be high, the fee could be more than the developers are prepared to pay.

The subsidies on offer under EPACT 2005 did stimulate utilities to announce plans for more than 30 new reactors, seven of which were for EPRs. However, a significant proportion of these never got beyond the early planning stage and by June 2010, only 27 had made applications to the NRC for COLs. Four of these were for EPRs (see Table 1) including two to be built by UniStar, a 50-50 joint venture created in 2005 between EDF and the US utility, Constellation. UniStar is a partner in the other two projects with PPL for the Bell Bend project and with Ameren UE for the Callaway reactor. By June 2010, of these 27 reactors, one application had been withdrawn and the owners of four others, two of which were for EPRs, had asked for the process to be suspended. Of the remaining 22, two were EPRs and the developer of one of these, PPL, stated that it was still 'several years from a final decision on whether to build Bell Bend.'[39] The future of the EPR therefore seemed highly dependent on the one EPR project still being actively pursued, the UniStar Calvert Cliffs project.

Table 1 EPR's proposed in USA

Plant	Owner	COL application	Loan Guarantee
Calvert Cliffs 3	UniStar	COL 3/08	Shortlist
Callaway 2	AmerenUE	Suspended 4/09	Applied
Nine Mile Pt 3	UniStar	Suspended 1/09	Applied
Bell Bend	PPL	COL 10/08	Applied

Source: Author's research

The presence of EDF in the UniStar joint venture, with its vast experience of building and operating PWRs supplied by Areva – 58 units in service in France – was seen as a major advantage. Constellation owns about 3.9GW of existing nuclear power plants at three sites (Calvert Cliffs, Nine Mile Point and Ginna).[40] In September 2008, EDF tried to take over Constellation but were outbid by

MidAmerican Energy Holdings, a private company controlled by Warren Buffet. It was reported that the rival bid for Constellation could derail EDF's nuclear ambitions in the USA if MidAmerican did not support new nuclear build. In December 2008, EDF announced an agreement with Constellation to take a 49.99% holding in Constellation's nuclear subsidiary, Constellation Energy Nuclear Group. The deal was done through the EDF subsidiary, EDF Development Inc, and cost US$4.5bn.[41] Mid American Holdings amicably withdrew its offer. The UniStar joint venture remains separate from this deal.

Whether the purchase of the stake in Constellation's nuclear assets made any sense without the new build reactors is far from clear. However, it is apparent that EDF regards it as part of its bid to build new reactors and expand the scope of its operations into plant design and construction. Nucleonics Week reported: "EDF Chairman/CEO Pierre Gadonneix defended the decision to buy what some in France are calling 'old' US nuclear plants as a ticket to what will be 'the world's largest nuclear market tomorrow'."[42] In summer 2009, Gadonneix was replaced by Henri Proglio, who has been reportedly much less enthusiastic about EDF's nuclear expansion outside France.

The Calvert Cliffs reactor was forecast to cost US$7.2bn in 2008.[43] UniStar ordered forgings and other long lead-time reactor components for Calvert Cliffs in 2006 and 2007. A partial construction and operating license application (COLA), mainly the environmental report, was submitted in July 2007 and was docketed by the NRC in January 2008. The remainder of the COLA was submitted in March 2008 and was docketed on June 4, 2008. As of November 2010, there was no schedule for issue of the COL because of the problems with certifying the design.[44] Part 1 of the application for federal loan guarantees was submitted in September 2008 and Part 2 in December 2008. In 2009, the US Department of Energy short-listed four projects for loan guarantees, including Calvert Cliffs. The first loan guarantee was offered to another project in February 2010 and an offer to Calvert Cliffs was widely expected to follow soon after. However, by August 2010, no commitment had been made and Constellation began to cut back drastically on expenditure on the Calvert Cliffs project. How far this was due to the delays in granting loan guarantees and how far it was due to deterioration in the economics of the new reactor is not clear.

The CEO of Constellation stated: 'market signals to build a baseload plant of any kind, let alone nuclear, have suffered significantly since we started the project four years ago.' He said Constellation will abandon the project if it does not receive a conditional loan guarantee for the project. The poor market signals included low natural gas prices and the short- and long-term power price outlooks.[45] EDF, in its report for the first half of 2010 published in July 2010, made a provision of €1.06bn (about US$1.45bn) related to financing delays on nuclear projects in the United States.[46]

By September, signs of strain between EDF and Constellation were clear. A particular issue was that under the terms of the purchase of the stake in Constellation's nuclear assets, Constellation could require EDF to US$2bn worth of Constellation's natural gas, coal and hydropower plants by end 2010.[47] There was speculation in September 2010 that these problems could lead to EDF selling its stake in the nuclear assets and dissolving the UniStar joint venture.[48] In October 2010, Constellation unilaterally withdrew from negotiations with the US Department of Energy for loan guarantees for the Calvert Cliffs project. It was reported that the fee to provide loan guarantees for 80 per cent of the forecast cost of the plant (US$9.6bn) was initially proposed at US$880m, or 11.6 per cent of the amount borrowed.[49] When Constellation rejected that offer, DOE proposed a 5 per cent fee, but with conditions including that Constellation fully guarantee construction and commit to sell 75 per cent of the power through a Purchase Power Agreement (PPA), presumably through its subsidiary Baltimore Gas & Electric. The Maryland Public Service Commission (PSC) would have had to approve a PPA.

Subsequently Constellation sold its 50 per cent stake in UniStar to EDF for US$140m. In addition, Constellation transferred to UniStar potential new nuclear sites at Nine Mile Point and R.E. Ginna in New York as well as Calvert Cliffs. The agreement requires EDF to transfer 3.5 million of the shares it owns in Constellation and to give up its seat on Constellation's board and in exchange, Constellation gave up the option to require EDF to buy Constellation's fossil fuel capacity.[50]

EDF was reported to be keen to proceed with the Calvert Cliffs project but US law does not allow US nuclear reactors to be owned, controlled or dominated by foreign companies or governments, so EDF would need to find a new partner to proceed. It is not clear whether loan guarantees could be offered to UniStar in advance of a new US partner being agreed and whether the fee would be the same.

While the political wrangling about how much Congress will be prepared to allow the US DOE to offer in loan guarantees, the deteriorating prospective economics for new nuclear reactors and the economic risk they pose to their owners may mean that relatively few loan guarantees are granted. The projects most likely to go ahead are those with the 'belt and braces' of Federal loan guarantees and a state regulatory body that commits to allowing the utility to recover its costs from consumers. Calvert Cliffs and Bell Bend would be exposed to the PJM electricity market and therefore could expect no support from the state regulator. If the Calvert Cliffs project does collapse and an existing project, such as Bell Bend cannot be brought in to replace it, it is hard to see how the EPR could survive in the USA. This would be a severe blow to EDF and Areva, both of which have invested a large amount of cash and their credibility in opening up the US market to the EPR.

Future prospects

The EPR is competing in a number of other markets where Areva NP hopes it will be the basis for series ordering, in particular the UK and Italy.

UK

The UK government's program is based on very different underlying assumptions than that of the United States. The UK government did not claim that nuclear power would be directly competitive with fossil fuels, but if a carbon price of €36/tonne was assumed, it would be competitive. Both the Labour government up to May 2010 and the successor Conservative/Liberal Democrat coalition seem heavily committed to reviving nuclear ordering in the United Kingdom. However, all three parties have stated that orders should only be placed if they do not involve public subsidies. Ordering would therefore take place without subsidy, provided a few non-financial enabling decisions were taken, particularly on planning processes and certification of designs. In 2008, when the government revisited nuclear economics, it assumed the construction cost was £1,250/kW ($2,000/kW).

The government's nuclear regulator, the Nuclear Installations Inspectorate of the Health and Safety Executive (HSE), started to examine four separate designs in 2007 including the Areva NP EPR and the Toshiba/Westinghouse AP1000. The rationale was that up to three designs would be finally certificated, thus giving utilities a choice of designs. In fact, the other two designs were quickly withdrawn leaving just the EPR and AP1000.

Three utilities have made significant commitments to UK ordering: EDF, RWE, and E.ON – the latter two in a consortium called Horizon. EDF took over the UK nuclear generation company, British Energy, for about €15 billion in 2008, while RWE/E.ON have purchased sites in 2009 adjacent to existing nuclear power plants for several hundred million Euros. Both EDF and the RWE/E.ON consortium expect to order 4 units, for a total of 10 to 12 GW of capacity. EDF is expected to order the EPR, while the RWE/E.ON consortium has yet to choose its supplier.

EDF heavily committed itself to nuclear ordering in the United Kingdom with its purchase in 2009 of British Energy. The price seemed far above the value of the assets being acquired and only has any logic if new nuclear orders are placed. British Energy went bankrupt in 2002 because its operating costs, then about £16/MWh, were marginally higher than the price it received for electricity. Since then, operating costs have grown every year and by 2008/09, the operating costs had risen to £41.3/MWh. British Energy only remained solvent because of the extremely high wholesale electricity prices that prevailed in that period – British Energy received £47/MWh in that period. If operating costs continue to rise and/or wholesale electricity prices fall (by the end of 2009, they were well below the 2008 peak), British Energy will be at risk of collapse again.

The RWE/E.ON consortium had invested a few hundred million pounds in options to buy sites, but if it did not take up these options, it could walk away from a British nuclear program at little cost. By the start of 2010, the UK was still 3-4 years from completing safety assessment of the design and getting planning permission for specific sites – the point when a firm order could be placed.

Italy

In 1987, a referendum led to the closure of the four operating nuclear power plants in Italy and the abandonment of work on construction of another nuclear station. The Berlusconi government has introduced legislation that would pave the way for the reintroduction of nuclear power in Italy. Four 1650 MW EPRs could be built, with construction starting as early as 2013, under an agreement signed in February 2009 by the French utility, EDF, and the largest Italian utility, ENEL. ENEL has not selected the sites for these units yet. It has said the cost would be about €4-4.5 billion each or $3,600-4,000/kW.[51] There has been speculation about other competing bids to build nuclear power plants – for example, a consortium led by A2A, the Milan-based utility offering AP1000s – but these projects are much less advanced than those of ENEL.[52]

India

It has been reported that a memorandum of understanding (MOU), including the intention to build two EPRs, would be signed in February 2009 between Areva and the state-owned Nuclear Power Corporation of India Limited.[53] Even if this MOU is signed, it is far from being a firm order and many MOUs come to nothing, for example, if financing cannot be arranged.

Other markets

President Sarkozy has announced that a second EPR in France will be ordered in 2011 for the Penly site. It is unlikely there will be scope for many further orders for France given that France already has more baseload electricity capacity than it can readily use and with plans to operate existing reactors for up to 60 years instead of the earlier expectations of 40 years, it will not be till after 2035 when the existing reactors begin to be retired. The Penly plant was to be built by EDF, which would have a 50 per cent stake in it, with the other stakes being held by the other major French utility, GDF Suez (25 per cent) and ENEL (the main Italian utility), E.ON (a large German utility and the oil company, Total, each with 8.33 per cent. However, in September 2010, GDF Suez, which was disappointed not to have been given the job of building the plant, announced their withdrawal from the project.[54] There were reports that GDF Suez was hoping to lead construction of a reactor at another site, using the Areva 'Atmea' design (see below).[55]

The Finnish Parliament has voted to allow construction of two additional nuclear reactors by two different consortia. Both consortia have named the EPR as one of three or four options they might choose. It is far from certain whether these orders will be placed, and if they are, whether the EPR will be chosen, especially given the poor performance of the EPR at the Olkiluoto site.

In July 2010 in the Canadian province of New Brunswick, Areva, the New Brunswick government and New Brunswick Power announced that they would examine the feasibility of building a light-water nuclear reactor in the province by 2020. However, in September 2010, the incoming Premier for the province announced the agreement would go on the back-burner.[56]

Construction experience

While utilities and governments will be interested in the theoretical attractions of new designs, it will be actual experience of building and operating these new designs that will be crucial in determining their success. By October 2010, no EPR was yet in service but four were under construction, one in Finland (Olkiluoto), one in France (Flamanville) and two in China (Taishan).

Olkiluoto

The Olkiluoto-3 reactor order of December 2003 was the first nuclear order in Western Europe and North America since the 1993 Civaux-2 order in France and the first order outside the Pacific Rim for a Generation III/III+ design. The Finnish electricity industry had been trying to get Parliamentary approval for a new nuclear unit since 1992. This was finally granted in 2002. The Olkiluoto-3 order was a huge boost for the nuclear industry in general and Areva NP in particular. Industry anticipated that, once complete, the plant would provide a demonstration and reference for other prospective buyers of the EPR.

The contract price for Olkiluoto-3 was reported in 2004 to be €3bn for a 1600 MW reactor.[57] Subsequently, the price was reported to be €3.2bn[58] or €3.3bn.[59] Safety approval was given by the Finnish regulator, STUK, in March 2005 and substantive work on-site started in August 2005. At the time the contract was signed, the value was equivalent to about US$3.6-4.0bn (depending on the contract price) or about $2250-2475/kW (€1=US$1.2). This cost included financing and two reactor cores, so the cost per kW in overnight terms would have been somewhat lower, although given the very low rate of interest charged (2.6%), finance costs would be low.

Although the total cost was well above the nuclear industry‘s target of US$1000/kW of only a few years previously, it was still regarded by many critics as a ‘loss-leader’. Areva NP had been trying to persuade either EDF or one of the German utilities to place an order for an EPR since the late 1990s[60] and there were fears that if an order for the EPR was not placed soon, AREVA NP would start to lose key staff[61] and the design would become obsolete.[62] Areva NP also needed a ‘shop window’ for EPR technology and Olkiluoto-3 would serve as a reference plant for other orders. As an additional incentive and at the request of the customer, Areva NP offered the plant on ‘turnkey’ or fixed price terms. It also took responsibility for the management of the site and for the architect engineering, not just the supply of the ‘nuclear island’. This was not a role it was accustomed to. For the 58 PWRs Areva NP’s predecessor, Framatome, had supplied for France, as well as for the foreign projects including those in China and South-Africa, it was EDF that had provided these services.

The Olkiluoto project has gone seriously wrong since construction started. By August 2010, Areva NP acknowledged that the estimated cost had reached €5.7bn (an additional €367m was acknowledged in the 2009 accounts), which at the prevailing exchange rate of €1=US$1.35 represented a cost of US$4800/kW.[63] The contract is also the subject of an acrimonious dispute between Areva NP and the customer, Teollisuuden Voima Oy (TVO). Areva NP claims compensation of about €1bn for alleged failures of TVO. TVO, in a January 2009 counterclaim, is demanding €2.4bn in compensation from Areva NP for delays in the project.[64]

Table 2 Timetable of problems at Olkiluoto 3

Date	Event
4/04	STUK: 'We are getting the documents late. They (Areva) aren't reserving enough time for our review and they don't have all the information required by our guides.'[65]
10/05	Pouring of base slab delayed by concerns about strength of concrete. Manufacturing of reactor pressure vessel and steam generators "a few weeks" behind the original schedule[66]
2/06	Problems with qualifying pressure vessel welds and delays in detailed engineering design put construction more than six months behind schedule[67]
3/06	STUK opened an investigation into manufacturing and construction problems[68]
5/06	Despite measures including two shifts on site and three shifts at Areva's component manufacturing plant, work is eight to nine months behind schedule.[69]
7/06	TVO acknowledges delay now 1 year. STUK investigation: An extremely tight budget and timetable, supplier inexperience, poor subcontractor control and regulators' difficulty in assessing information have caused confusion and quality control problems that have delayed the Olkiluoto-3 project[70]
10/06	Areva takes provision of ca €300m for Olkiluoto project[71] 3 out of 4 'hot legs' not made to specification. [72] Project manager replaced [73]
12/06	Delay estimated at 18 months[74]
1/07	Areva NP: Areva-Siemens cannot accept 100 % compensation responsibility, because the project is one of vast co-operation. The building site is joint so we absolutely deny 100 % compensation principle' TVO: 'I don't believe that Areva says this. The site is in the contractor's hands at the moment. Of course, in the end, TVO is responsible of what happens at the site. But the realisation of the project is Areva's responsibility'[75]
5/07	TVO and Areva agree design not complete enough when contract signed. STUK: 'a complete design would be the ideal. But I don't think there's a vendor in the world who would do that before knowing they would get a contract. That's real life.[76]
8/07	Problems meeting requirements to withstand an airplane crash mean delay 2 years[77]
9/07	Steel containment liner repaired in 12 places to fix deformations and weld problems[78] Areva acknowledges further financial provisions for losses but does not quantify them. Independent estimate €500-700m[79]
6/08	TVO site manager replaced[80]
10/08	Delay now estimated at 3 years[81] Manufacturer of containment liner failed to obey an order to stop welding after a STUK-TVO inspection discovered that an incorrect welding procedure was being used[82] Areva initiates arbitration proceedings in Arbitration Institute of the Stockholm Chamber of Commerce over 'a technical issue'[83]
12/08	Areva announces further loss provisions. Independent estimates €1.3bn[84]
12/08	Letter from STUK Director General top CEO Areva: 'I cannot see real progress being made in the design of the control and protection systems.' 'This would mean that the construction will come to a halt and it is not possible to start commissioning tests.' 'the attitude or lack of professional knowledge of some persons who speak in the expert meetings on behalf of that organisation prevent to make progress in resolving the concerns'[85]
1/09	Delay acknowledged to be 3.5 years.[86] Siemens announces withdrawal from Areva NP.[87] Areva-Siemens file a second arbitration proceeding against TVO.[88] Areva asking for €1bn in compensation. TVO counterclaiming for €2.4bn for 'gross negligence'[89] TVO expects arbitration to take several years[90]
3/09	Areva admits cost over-run now €1.7bn[91]
06/10	TVO reports further delay till 2013 to completion of the plant.[92] Delay confirmed by Areva NP[93]
07/10	Areva booked €367m in new charges on expected losses with Olkiluoto.[94]

Sources: As per endnotes

It seems unlikely that all the problems that have contributed to the delays and cost-overruns have been solved (see Table 2); the final cost could be significantly higher. The result of the claim and counter-claim arbitration between Areva NP and TVO will determine how the cost over-run will be apportioned. It is far from clear that TVO could survive financially if it had to shoulder a significant proportion of these costs. Even Areva, despite it being controlled by the French government had its credit rating reduced to BBB+, partly because of these problems[95] and it would hardly be good for business if its customer was put out of business by the purchase of an EPR.

Flamanville

EDF finally ordered an EPR reactor in January 2007, to be located at their Flamanville site. This reactor was rated at 1630 MW[96] and construction commenced in December 2007.[97] In May 2006, EDF estimated the cost would be €3.3bn.[98] At that time (€1=US$1.28), this was equivalent to US$2590/kW. This cost however did not include the first fuel or finance costs, so the overnight cost, which conventionally includes fuel but not finance costs would have been somewhat higher.

EDF did not seek a turnkey contract and chose to manage the contracting, for example, letting contracts for the turbine generator and the architect engineering. How far these decisions were influenced by the poor experience at Olkiluoto and how far they were influenced by the need EDF saw to maintain in-house skills is not clear.

In May 2008, the French safety regulatory authorities temporarily halted construction at Flamanville because of quality issues in pouring the concrete base mat.[99] Delays had led the vendor, Areva NP to forecast the reactor would not be completed until 2013, a year late, but in November 2008, EDF claimed the delays could be made up and the reactor finished by the original schedule of 2012.[100] EDF did admit that the expected construction costs for Flamanville had increased from €3.3 billion to €4 billion.[101] This was then equivalent to US$3,265/kW (€1=US$1.33), substantially more than the Olkiluoto contract price, but far below the levels being quoted in the USA and the current cost of Olkiluoto. An Areva official suggested that the cost of an EPR will now be at least €4.5bn, although it was not specified whether this was an overnight cost.[102] In January 2010, French unions reported that the project was then running at least two years behind schedule.[103] These reports, originally denied by EDF, were confirmed by them in July 2010, when it also acknowledged that costs were by then running at €1.7bn over the original €3.3bn budget.[104] In October 2010, Le Figaro reported a further delay of a year at Flamanville citing 'several' sources. EDF have denied this report.[105]

Table 3 Timetable of problems at Flamanville 3

Date	Event
5/06	EDF decides to proceed with Flamanville 3[106]
7/06	Site work commenced. Target construction time 54 months, construction cost €3.3bn excluding finance and fuel[107 108]
1/07	NSSS ordered from Areva NP[109]
4/07	French government issues construction license[110]
12/07	First concrete poured[111]
3/08	ASN asks EDF to improve work in several areas involving in particular quality control and organization[112]. Inspection had revealed several problems in the civil construction work, including errors in installation of steel reinforcing bar in the concrete and "inconsistency" between rebar blueprints and the concrete pouring plan. organization for preparing concrete pouring was "insufficient,"[113]
5/08	ASN requires EDF to stop concrete pouring on May 26 (ban lifted June 17). Problems 'show insufficient discipline on the part of the licensee and insufficient project organization'. Welding anomalies found in one of the four bottom pieces of the steel liner of the containment building [114]
10/08	ASN told Areva to improve its oversight of forgings after procedures used by Italian subcontractor Societe della Fucine were found not to conform to standards.[115]
12/08	EDF acknowledges cost had increased to €4bn due mainly to inflation, and technical & regulatory changes.[116] Construction schedule claimed still to be achievable
01/10	Unions claim construction is at least 2 years behind schedule.[117]
07/10	EDF confirms delay and announces expected costs are €1.7bn over budget.[118]
08/10	ASN asks EDF to modify the architecture of the non-safety instrumentation and control system.[119]

10/10	Le Figaro reports a further year delay[120]

Sources: As per endnotes

Note: ASN = Autorité de sûreté nucléaire

Taishan

Under the terms of the contract Areva NP won to supply two EPRs to China, the company is only supplying the nuclear island and the contract is not turnkey. EDF is involved in the management of this project and has an equity stake in the reactors.[121] Little reliable, independent information comes out of China on nuclear construction. The IAEA reported that work started on the first Taishan unit in November 2009 and on the second unit in April 2010. In July 2010, the South China Morning Post reported that work on the 'second phase' the Taishan units would not start in the third quarter of 2011 as expected.[122] No reason for the delay was given by the plant owners, but there has been speculation that China was not comfortable with the fact that delays at Olkiluoto and Flamanville meant that the Taishan units would probably be the first EPRs to enter service.

Safety assessment

As mentioned previously, there was some confusion about the level of assessment of the EPR that had been carried out by the Finnish and the French regulators when construction started at the Olkiluoto and Flamanville plants respectively. It is now clear that neither had carried out a comprehensive generic safety review.

In August 2007, the UK safety regulator, the HSE launched its Generic Design Assessment (GDA) for the EPR (and three other designs). The timetable called for completion of the generic review in June 2011. There are three possible conclusions to this process:[123] (1) if the regulators are fully content, they will issue an HSE Design Acceptance Confirmation (DAC); (2) if they are largely content, they will issue an HSE Interim Design Acceptance Confirmation (DAC) or Environment Agency Interim Statement of Design Acceptability and identify the unresolved GDA Issues; and (3) if the regulators are not content no Design Acceptance Confirmation (DAC) or Statement of Design Acceptability will be issued. By August 2010, the HSE had acknowledged the first and third outcomes were implausible.[124] In the case of the second outcome, the proposer would have to submit a Resolution Plan. However, once an interim DAC has been given, issues not covered by the Resolution Plan would not be considered. The HSE has recognised that it will probably be the first regulator to complete a generic assessment of the EPR and this would leave it in an invidious position if its requirements are seen as less stringent than those of other regulators. The HSE stated in July 2010:[125]

> 'We had originally hoped that the safety assessment of AP1000 and EPR by their 'home' regulators would be complete well before we completed GDA Step 4 in June 2011 so that we could fully consider their conclusions during our own assessment. However, we now understand that there is significant ongoing safety assessment by the home regulators for both AP1000 and EPR. This is a significant regulatory process concern for us, the implications of which are being considered at present, together with ways of ensuring the best possible international cooperation on and harmonisation of assessment outcomes.'

The HSE claims it will complete the GDA in June 2011, but 'interim' approvals, which would not suffice for construction of the reactors to begin in the UK, appear at the moment to be 'more likely' than final approvals for both designs for the June 2011 timeline.[126]

Areva submitted a Standard Design Certification Application to the NRC in December 2007 more than 3 years after Areva NP began discussions with the NRC. At that time, Areva expected that the NRC would complete its technical review in two years, and finish the rulemaking that certifies the design the following year, 2010.[127] This proved over-optimistic and in March 2010, after a number of delays, the NRC stated the final certification would not be before June 2012.[128]

Instrumentation and Control

Table 2 shows that there were conflicts between Areva and STUK, the Finnish regulator even before construction started. The extent of these was illustrated by a leaked letter from the head of STUK, Jukka Laaksonen, to the CEO of Areva, Anne Lauvergeon in December 2008 (see Annex 1). In April 2009, the HSE classified Instrumentation & Control (I&C) as a 'Regulatory Issue', a particular feature of the design that might not meet UK regulatory standards.[129] In July 2010, the I&C issue remained a Regulatory Issue and while HSE stated in July 2010 that it anticipated that an acceptable solution could be found, it had not received details of the modification proposed. The specific issue raised here, the level of redundancy in the I&C systems was subsequently taken up in a joint statement by the UK, French and Finnish regulators in November 2009.[130] In August 2010, the HSE reported that while they believe that an 'acceptable position can be reached for GDA', this would depend 'on timely and quality responses from EDF and AREVA and we have already noted difficulties with delivery on other C&I issues.'[131]

The US and Chinese regulators were not party to this process, but in July 2010, it was reported that the US NRC had found that the I&C was too complex and interconnected to meet US regulations. The issue was described by an NRC spokesman as being 'a critical path issue that is going to have to be resolved'.[132] Whether this resolution would delay completion of the review beyond June 2012 is not clear. However, the I&C systems for UK, France, Finland and the USA will now all differ from each other because it is too late to make some changes to the French and Finnish designs.[133]

Core catchers

A particular bone of contention has been the need of a 'core-catcher'. In the event of a failure of the emergency core cooling system, this would 'catch' the core if it breached the reactor pressure vessel. There is no international agreement on the need for this feature: it is widely seen as essential for mainland Europe, but not the USA and other countries like Korea. However, this is an expensive system and Anne Lauvergeon blamed the extra cost of this as one of the factors behind the loss of the contract for UAE to a Korean design that does not have a core-catcher.[134] Lauvergeon claimed that safety enhancements designed to prevent any offsite radiological impact — like the core catcher and the reinforced containment made the EPR 15 per cent more expensive than a Generation II PWR.[135]

Economic issues

When a 'Nuclear Renaissance' was first mooted, a key element was the use of so-called Generation III+ designs, which would be safer, simpler, cheaper and easier to build than earlier designs. This, it was claimed, would overcome the problems that had led to the dramatic reduction in ordering from the mid-80s onwards. Particularly strong claims were made on costs with vendors claiming their new designs could be built for US$1000/kW. As noted above, cost was a particular issue from the start with the EPR and cost claims for it were not as aggressive as for some of the other designs. Nevertheless, in 1998, NPI claimed reactors could be built for US$1415/kW.[136] In 2001, A US executive of Framatome claimed the EPR could be built in the USA for US$1320/kW.[137]

In 2003, TVO's studies for Olkiluoto envisaged that it would be able to buy a nuclear reactor for US$1800/kW or less. EDF's studies from the same year assumed a cost of €1275/kW, then about US$1450,[138] while the French government was even more optimistic in September of that year, assuming €1043/kW.[139] These forecasts were revealed to be hopelessly unrealistic when it emerged that the winning bid for Olkiluoto was actually €3bn equivalent to €1875/kW or US$2300/kW.

In May 2006, when EDF ordered Flamanville, the cost estimated by EDF was reported to be €3.3bn, essentially the same as for Olkiluoto given inflation and the higher expected output (1630MW).[140]

Costs at the Olkiluoto and Flamanville plants escalated rapidly, but it was not clear how far this was due to an underlying underestimate of costs and how far it was due to specific errors. Initial cost estimates for US EPRs were no less unrealistic with Areva and Unistar claiming overnight costs of US$1600-2000/kW in 2005.[141] By 2008, Unistar was still estimating only US$2400/kW (2005 dollars).[142] However by August of that year, the Unistar CEO, Mayo Shattuck suggested that the cost would be at the mid- to upper-end of the range US$4500-6000/kW (US$7.2-9.6bn).[143]

Reports of bids for international contests produced even higher projected costs. In South Africa, Eskom expected a construction cost of US$2,500/kW. In January 2008, Eskom received two bids in reply to its call for tenders from November of the previous year for 3200 to 3400 MW of new nuclear capacity in the near term and up to 20,000 MW by 2025. One bid was from Areva for two EPRs (plus 10 more for the long-term) and the other from Westinghouse for the three AP1000s (plus 17 more in the long term).[144] Both claimed their bids were "turnkey," but whether they were really turnkey in the fixed price sense or whether they were simply for the whole plant is not clear. It was later reported that the bids were for around $6,000/kW – more than double the expected price.[145]

In 2007, Ontario Power Authority (OPA), the public body responsible for planning the Ontario power system, had assumed nuclear power plants could be built for about C$2,900/kW.[146] In June 2008, the Canadian government announced Darlington in Ontario as the site for a two-unit new build project and on May 20, 2009, information leaked that the Ontario government had chosen AECL as the leading bidder over Areva and Westinghouse to start building the first new nuclear plants in Canada in 25 years. Two new reactors were projected to start operating by 2018. However, the provincial government reportedly conditioned any go-ahead on financial guarantees by the federal government to cover the financial risks involved. Three bids were received, one from Areva and one from AECL, although only the AECL bid complied with the requirement that the vendor assume the construction risk. There was a press report on the size of the bids. This suggested that Areva's non-compliant bid was C$23.6 billion (US$21 billion) for two EPRs (1600 MW each) or C$7,375/kW (US$6,600/kW). AECL and Westinghouse's bids were higher. Ontario decided to suspend the tender. Subsequently, Areva disputed the published bid price, but they were not willing to supply the actual price they bid.

In December 2009, the UAE ordered four nuclear reactors from Korea using AP1400 technology, beating opposition from consortia led by EDF (including GDF Suez, Areva, and Total with the EPR) and GE-Hitachi.[147] The contract is with Korean Electric to build and operate the reactors, the first coming on-line at an unspecified site in 2017 and the last by 2020. The terms of the deal and what is included are not clear, although the contract is reported to be worth $20.4 billion. The Korean bid was reported to be $16 billion lower than the French bid.[148]

The response from Areva to this failure was particularly vitriolic. The CEO , Anne Lauvergeon, blamed the extra safety features required by the European market, particularly the core-catcher and a steel-lined double concrete containment that the EPR includes, whereas the winning bid, the Korean APR-1400 has no core-catcher and a single steel containment structure. She seemed to propose that Areva could offer previous generation models (for example, the 1000MW design sold to China in 1980) for export to third world countries.[149]

The Roussely Report

The French government belatedly realised that commercialisation of the EPR was going badly and in October 2009 commissioned a former CEO of EDF, Francois Roussely, to examine the French nuclear industry. His report was given added point by the failure to win the tender for the UAE in December 2009. This failure was widely seen in France as due to the lack of an integrated offer including engineering, construction, fuel and waste, as well as equipment supply. The report, 'The Future of the French Civilian Nuclear Sector' was published in July 2010.[150]

Roussely identified two major problems:

- The credibility of the EPR had been seriously damaged by problems at Olkiluoto and Flamanville;
- The capacity factors [reliability] of reactors in France have deteriorated sharply whereas elsewhere in the world, these have improved significantly.

He makes 15 recommendations, 12 described as 'structural' and 3 as 'emergency'. Most of the structural measures seem to be aimed at creating a 'Team France', which would ensure France could offer a unified and comprehensive package for export markets in emerging countries. He recommends that the extension of reactor operating life to 60 years is supported and that further optimisation of the EPR from the feedback of the four reactors under construction and of past achievements be carried out. This optimisation should be carried out jointly by EDF and Areva.

On the problems at Olkiluoto and Flamanville, he recommends only that these reactors be completed with a few delays and as little cost over-run as possible. Lessons from this should be fed back into the construction of the Penly unit and any units ordered for the UK. The issue of poor reliability does not appear to be addressed directly by any of the recommendations. He does recommend that a charter setting out the conditions of employment applicable to all employees of nuclear power in France be introduced and that the mission of the Agence Securité Nucleaire (ASN) be reviewed, but it is not clear how this would address the issue of poor availability.

Of most interest is his diagnosis of the problems with the EPR. He attributes the problems squarely to 'complexity':

> 'The complexity of the EPR comes from design choices, notably of the power level, containment, core catcher and redundancy of systems. It is certainly a handicap for its construction, and its cost. These elements can partly explain the difficulties encountered in Finland or Flamanville.'

He recommends:

> 'The EPR should therefore be further optimised based on feedback from reactors under construction and past achievements. This optimisation would be lead jointly by EDF and Areva, in conjunction with ASN, with a view to make the detailed design as safe [as the current design].'

This recommendation does not seem realistic. The EPR was designed over a long period with the specific objective of rationalising the features of earlier designs. To assume that it would be a simple and quick process to just go through the design again to simplify it seems totally unrealistic. This is well illustrated by the issue of the I&C system noted above, which, ironically, was seen as not having enough redundancy. This problem was first identified in 2008; yet more than two years later, a detailed solution to the problem still has not been presented to the regulators. Any redesign that was comprehensive enough to significantly reduce complexity and costs would almost certainly be so extensive as to require the regulators to make a very full re-evaluation of the design.

This was the case with the problems with the AP1000 in the USA. This design received generic approval from the US regulator in 2006; yet in 2008, the supplier, Toshiba/Westinghouse, put in extensive design revisions that the US regulator is not expected to be able to approve before 2012. If we assume that this process of rationalization could be done in two years starting in 2011 and the regulators took a further four years to assess the design, this would mean that the design would not be ready to order before about 2017/18, after the Penly unit in France is expected to be on-line and at about the same time as EDF is claiming it will have the first UK EPR on-line.

Roussely recommends that the international French nuclear offering be 'diversified' with a smaller design, the Atmea, that could be brought to market quickly as a design more suitable for markets that would struggle to accommodate a reactor as large as the EPR. The Areva-Mitsubishi joint venture to develop Atmea was first announced in 2007.[151] Atmea was described as being Generation III (rather than III+). A company spokesman said Atmea would be based on 'proven technologies' with 'no technical breakthroughs or revolutionary innovations'. The design was reportedly to be submitted to the French regulator, ASN, in June 2010.[152] The target for ASN to complete its review by fall 2011 seems unrealistic. Designs of this size from Areva or Mitsubishi are now more than 30 years old and given new features such as a core catcher and aircraft crash protection, the design must be substantially new. This either suggests that a highly optimistic timetable has been adopted or that the ASN review will not be a full generic assessment. Realistically, the Atmea design is highly unlikely to be available to order for 4-5 years and it is far from clear who the customers might be. GDF-Suez has expressed interest in building one in France but given that France already has serious over-capacity in nuclear, this would make no sense. Other customers, such as Jordan, are still some way from placing an order and for a country with no nuclear experience to order a first-of-a-kind unproven design would be seen as a massive risk.

It is particularly interesting to note the things that Roussely is entirely silent on. He fails to mention the prohibitively high prices bid by Areva on Ontario and South Africa, about double what the relevant governments expected. He also says a great deal about the Atmea design but nothing about the Kerena design, a BWR design that Areva has been working on for about as long as it has been working on the Atmea. The Kerena design is one of the options if another nuclear reactor is built in Finland.

The question that Roussely should have but utterly fails to address is whether the EPR is salvageable. Given the difficulties at construction sites, dramatically soaring construction cost estimates and difficulties of getting generic safety approval, this is surely the question that begs to be asked. It may be that the consequences to France's nuclear strategy if the answer is that it is not are so severe that the question is politically impossible for an inquiry commissioned by the French government.

The fallout from the Roussely report seems set to continue with efforts by the French government to create a 'Team France' and the two key companies, EDF and Areva jockeying for position. It was reported in September that EDF was being pressed to increase its direct stake in Areva from 2.4 per cent to 15 per cent.[153] EDF was making clear its dissatisfaction with Areva. It was reported in September 2010 that EDF was contemplating a partnership with a Chinese nuclear vendor or a Russian nuclear vendor to offer their designs to South Africa[154] and that EDF was planning to develop nuclear reactors of its own design in competition with Areva.[155] Neither proposal seems realistic: the Chinese design is essentially a 1970s design imported from France, which in turn imported it from the USA; the history of the EPR suggests that the time taken from start of conceptual design to the point when the reactor could be ordered is likely to be in the order 10-15 years. A more likely explanation is that EDF is trying to ensure that in any new configuration for the French nuclear industry, it is very much in the lead.

Conclusions

The EPR design is in crisis.

- Construction has gone dramatically wrong at the two sites in Europe where it is being built;
- The prices it is being offered at are so high that all contests where the EPR has been bid have either been abandoned (South Africa and Canada) or the contract has gone to a much lower bid from a competitor (UAE);
- Potential markets such as USA, UK and Italy all look problematic and reactor orders, if placed at all, will be much later than expected
- The process of obtaining safety approval in France, UK and USA is incomplete and, even if successful, the features needed to achieve regulatory approval may add significantly to costs.

The two sites in Europe where EPR is under construction, Olkiluoto and Flamanville, have gone dramatically wrong from the start of construction. It might have been argued that the problems at Olkiluoto were due to the lack of experience of the utility and the inexperience of Areva NP in carrying out the architect engineering. However, the fact that EDF, the most experienced nuclear utility in the world seems to be doing no better at Flamanville suggests the main problems are more related to the buildability of the design itself than to specific issues at Olkiluoto.

The promise for Generation III+ plants that they would: 'have the advantage of combining technology familiar to operators of current plants with vastly improved safety features and significant simplification is expected to result in lower and more predictable construction and operating costs'[156] has clearly not been fulfilled. The Chief Executive of Areva, Anne Lauvergeon, acknowledges: 'the cost of nuclear reactors has "always" gone up with each generation, because the safety requirements are ever higher. "Safety has a cost,"'[157]. Francois Roussely, former CEO of EDF stated: 'The resulting complexity of the EPR, arising from the choice of design, specifically the level of power, the containment, the core catcher and the redundancy of the security systems is certainly a handicap for its construction and therefore its cost.'[158]

The intuitively plausible notion that a new generation of nuclear reactors, starting without a blank sheet of paper could easily come up with a more rational and cheaper, yet safer design of reactor has been shown to be an illusion by the lengthy and still incomplete process of gaining safety approval. The Finnish and French authorities' decision to allow construction to start before full generic approval had been given looks particularly ill-judged

As early as 1995 and again in 1997, there were concerns about the cost of the EPR then expected to be US$2000/kW but when other vendors began to claim they could build plants for US$1000/kW, Framatome seems to have felt obliged to follow suit. While it did not claim US$1000/kW was possible, it did claim reactors could be built for less than US$1500/kW in 1998 and 2001, less than a quarter of the prices it is now offering a decade later. At US$6000/kW or more, it seems unlikely that EPR will be affordable except where huge public subsidies are offered and/or there is a strong likelihood of full cost recovery from consumers, no matter what the cost is.

As the reality of these high costs hits home, it is likely that even markets in which government support for new nuclear orders has been strongest, such as the USA and UK, will find it difficult to support the costs.

From a business point of view, the right course for EDF and Areva seems clear. They must cut their losses and abandon the EPR now. In the short-term this will require some painful write-offs, for example, of investments in the UK and the USA, but in the long-term, the losses will be much greater if they continue to try to make the EPR work. Areva's main business is its reactor servicing and fuel activities and these would be little affected by the abandonment of the EPR. EDF already has too much nuclear generating capacity in France, so not ordering more reactors will save it from unnecessary capital expenditure at a time when it acknowledges its debts are too high.[159]

However, from a political point of view, France has invested so much political and financial capital in being the world leader in nuclear technology, such a decision to abandon the design will be politically too painful until it becomes unavoidable. However, for the governments of countries like the USA and the UK, which have invested little political capital in the French nuclear dream, the sensible course is clear: stop all investment of public money in the doomed EPR technology.

Annex 1 Letter from Jukka Laaksonen to Anne Lauvergeon

December 9, 2008

Dear Mrs. Lauvergeon,

With this letter I want to express my great concern on the lack of progress in the design of Olkiluoto 3 NPP automation.

The construction of Olkiluoto 3 plant seems to proceed generally well but I cannot see real progress being made in the design of the control and protection systems. Without a proper design that meets the basic principles of nuclear safety, and is consistently and transparently derived from the concept presented as an annex to the construction license application, I see no possibility to approve these important systems for installation. This would mean that the construction will come to a halt and it is not possible to start commissioning tests.

I expressed my concern on this already in spring 2008, in a meeting with Mr. Xavier Jacob and TVO's management. After that Areva organised a workshop at professional level in Erlangen on April 23-25, 2008. The goal of the workshop was to clarify the open technical issues. I was told afterwards that it was a successful event where our concerns were conveyed to your experts and were well understood by them. It was especially encouraging to hear that after the workshop a group led by an expert of high repute, Dr. Graf, was given a task to make sure that the issues be addressed promptly.

Since then there have been several meetings among our experts but we have not seen expected progress in the work on Areva side. The systems with highest safety importance are to be designed by Areva NP SAS but unfortunately the attitude or lack of professional knowledge of some persons who speak in the expert meetings on behalf of that organisation prevent to make progress in resolving the concerns. Therefore, evident design errors are not corrected and we are not receiving design documentation with adequate information and verifiable design requirements. This is unfortunate because I am convinced that within your organisation there is enough competence to resolve all open issues. I wonder how this competence is actually being used in this project and whether an input by Dr. Graf and his group has been actually utilised.

I sincerely hope you could initiate some action in this area, in order to ensure bringing the construction of Olkiluoto 3 to a successful end.

With my best regards,

Jukka Laaksonen
Director General, STUK

Endnotes

[1] European Pressurised water Reactor or Evolutionary Pressurised water Reactor for the US market.
[2] Nucleonics Week 'Areva, Mitsubishi introduce mid-size 'Atmea 1' PWR design' Sept 6, 2007, p 1.
[3] Agence France Presse 'France's EDF designs reactor to challenge Areva: report' September 28, 2010.
[4] Nuclear News 'Joint Franco-German design partly unveiled', Aug 1992, p 52.
[5] Nucleonics Week 'EPR basic design goes forward: EDF to build first unit by 2000' Mar 2, 1995, p 5.
[6] Nucleonics Week 'France-German advanced reactor may be too expensive to buy' Nov 16, 1995.
[7] Nucleonics Week 'EPR becoming 1,800-MW plant to meet competitive targets' Aug 21, 1997, p 5.
[8] Nucleonics Week 'EPR design certification expected in mid-2000: interim opinion sooner' Sept 13, 1999, p 11.
[9] Inside NRC 'Lacoste says licensing advanced PWR in France would take 2 to 3 years' Dec 30, 2002.
[10] Nuclear News 'Siemens/Framatome nuclear merger completed' Aug 2000, p 109.
[11] Nuclear News, 'Proposal for fifth reactor should fulfill licensing reqs' Apr 2001, p 46.
[12] Nucleonics Week 'Westinghouse will sit out bid for single unit in Finland' Nov 14, 2002, p 1.
[13] Nucleonics Week 'Framatome claim AP1000 couldn't win Finnish bid on economics is denied' Apr 10, 2003.
[14] Nucleonics Week 'ENEC says it considered designs with core catchers for new reactors' January 28, 2010, p 1.
[15] Inside NRC 'French and Finnish EPRs will march to different regulatory drums' Dec 13, 2004, p 10.
[16] Nucleonics Week 'STUK okays Olkiluoto-3, sets limit on initial fuel burnup' Jan 27, 2005, p 1.
[17] Nucleonics Week 'EPR wins design approval from French government' Oct 14, 2004, p 6.
[18] Inside NRC 'Areva ready for NRC to start design review process for EPR' Feb 7, 2005, p 1.
[19] Xinhua Economic News Service 'China Focus: China, France sign 8-bln-Euro nuclear energy deal' Nov 27, 2007.
[20] TendersInfo 'China : Shaw Signs Contract to Support Additional AP1000 Nuclear Power Plants in China' August 22, 2010.
[21] Nucleonics Week 'Westinghouse may win China bid as Areva balks at tech transfer' March 16, 2006, p 15.
[22] Nucleonics Week 'French consortium to submit bids to build two EPRs in South Africa' Jan 24, 2008, p 5.
[23] Nucleonics Week 'Big cost hikes make vendors wary of releasing reactor cost estimates' Sept 14, 2008.
[24] Nucleonics Week 'Eskom to build initial reactors, but long-term plan to be curtailed' Nov 20, 2008.
[25] Nucleonics Week 'Eskom cancels tender for initial reactors' Dec 11, 2008, p 1.
[26] Nucleonics Week 'AECL, Areva, Westinghouse submit bids for new reactors at Darlington' Mar 5, 2009, p 3.
[27] The Candu reactor uses heavy water as moderator rather than light water as in the PWR.
[28] Nucleonics Week 'Areva disputes EPR cost figure as Canadians grapple with risk issue' Jul 23, 2009, p 1.
[29] Nucleonics Week 'UAE starts selection process for multi-unit nuclear program' Feb 12, 2009, p 3.
[30] Nucleonics Week 'Three consortia submit bids to UAE to build new reactors' Jul 9, 2009.
[31] Nucleonics Week 'Bidders said to be making last-ditch efforts to supply reactors to UAE' December 10, 2009, p 1.
[32] The US Department of Energy commissioned a cost study from the University of Chicago, which was published in 2004 and concluded that nuclear power was competitive with power from coal and natural gas. Office of nuclear energy, science and technology (2004) 'University of Chicago: "Nuclear Power Competitive With Coal & Natural Gas"' Press Release, September 20, 2004. http://nuclear.gov/home/09-20-04.html
[33] http://nuclear.gov/home/11-21-03.html
[34] Congressional Budget Office (2003) 'Congressional Budget Office cost estimate: S14 Energy Policy Act of 2003' Congressional Budget Office, Washington. http://www.cbo.gov/ftpdocs/42xx/doc4206/s14.pdf
[35] Up to $500 million each for the first two new nuclear reactors, and half of the overruns due to such delays (up to $250 million each) for the next four reactors. See http://www.ne.doe.gov/energypolicyact2005/neepact2a.html
[36] http://www.irs.gov/irb/2006-18_IRB/ar07.html
[37] http://edocket.access.gpo.gov/cfr_2008/janqtr/pdf/10cfr609.2.pdf
[38] http://lpo.energy.gov/wp-content/uploads/2010/09/NuclPowerSol7-11-08Amend1.pdf
[39] Inside NRC 'NRC extends US EPR design review by six months; COL delays not expected' Mar 1, 2010, p 5.
[40] Constellation Energy Nuclear Group, undated 'Fact Sheet'. Accessed on Jan 27, 2009 at http://www.constellation.com/vcmfiles/Constellation/Files/Press-Kit_Corp_NuclearGrp_2008-09-17.pdf
[41] Nucleonics Week, 2008 'EDF to acquire nearly half of Constellation's nuclear business' Dec 18, 2008, p 1.

[42] Nucleonics Week, 2008 'In France, EDF/CEG deal draws fire, but seen as key to EPR series cost' Dec 25, 2008.
[43] Electric Utility Week, 2008 'Regulators back expansion of Calvert Cliffs, but environmentalists ask for preconditions' Dec 1, 2008, p 28.
[44] http://www.nrc.gov/reactors/new-reactors/col/calvert-cliffs/review-schedule.html
[45] SNL Coal Report 'Optimism fades to frustration on Constellation's nuclear expansion' Aug 9, 2010.
[46] http://shareholders-and-investors.edf.com/fichiers/fckeditor/Commun/Finance/Publications/Annee/2010/H12010/H12010EDFGroupResultats_100802_va.pdf
[47] Washington Post 'Constellation, EDF in purchase dispute' September 25, 2010.
[48] Baltimore Sun 'Daily Briefing' September 28, 2010.
[49] International Herald Tribune 'EDF partner sees impasse in plan for U.S. reactor: Cost of loan guarantee dooms joint project, Maryland utility says' October 11, 2010, p 15
[50] EDF (2010) 'Constellation Energy Group, Inc' Form SC 13D/A. Filed 10/28/10 with the United States Securities and Exchange Commission.
[51] Nucleonics Week, 'Enel Targets 2020 for Operation of First Italian EPR Unit,' Oct 8, 2009.
[52] Nucleonics Week, 'Milan Utility A2A Could Become Hub of AP1000 Consortium for Italy,' Oct 22, 2009.
[53] The Hindu, 2009. 'Areva to sign MoU with NPCIL; to set up two reactors' January 22, 2009. Accessed on Jan 27, 2009 at http://www.hindu.com/thehindu/holnus/006200901221224.htm
[54] European Daily Electricity Markets 'Penly project less certain after GDF SUEZ pullout' September 24, 2010.
[55] European Daily Electricity Markets 'GDF SUEZ may seek partner for new French nuclear unit' September 27, 2010.
[56] The Telegraph-Journal 'Alward to shelve Areva deal; Generation Premier-elect says he plans to put future nuclear plans with Areva on ice and concentrate on the ongoing completion of Point Lepreau power plant refurbishment' September 29, 2010.
[57] Project Director Martin Landtman stated: 'The value of the whole Olkiluoto 3 investment including the Turn-key Contract is about EUR 3 billion in year 2003 money. No other figures are published', personal communication, e-mail to Mycle Schneider, dated 8 Oct 2004.
[58] Nucleonics Week, 'EC probing claims Olkiluoto loan guarantees were state aid', 26 Oct 2006.
[59] Nucleonics Week, 'Areva reveals 47% cost overrun on contract for Olkiluoto-3', 5 Mar 2009, p 1.
[60] Nucleonics Week, 'Giant EPR said to be competitive: EDF to decide on order next year', 6 Nov 1998, p 1.
[61] Petroleum Economist, 'France mulls nuclear future', Mar 2001.
[62] Nucleonics Week, 'EPR safety approval won't last beyond 2002, regulator warns', 6 Mar 1997.
[63] Agence France Presse 'Areva reports profit surge from sale of asset', July 30, 2010.
[64] Agence France Presse, 'Setbacks plague Finland's French-built reactor', 30 Jan 2009.
[65] Nucleonics Week 'Problems in getting information could delay review of Olkiluoto-3' Apr 1, 2004, p 4.
[66] Nucleonics Week, 'Olkiluoto-3 base slab pour delay not expected to impact end date' Oct 20, 2005, p 4.
[67] Nucleonics Week 'Construction of Olkiluoto-3 behind schedule' Feb 2, 2006, p 1.
[68] Nucleonics Week 'STUK begins investigating construction delay at Olkiluoto-3' Mar 2, 2006, p 8.
[69] Nucleonics Week 'Olkiluoto-3 containment liner set in place, but project still lags' Mar 2, 2006, p 8.
[70] Nucleonics Week 'Host of problems caused delays at Olkiluoto-3, regulators say' Jul 13, 2006, p 1.
[71] Nucleonics Week 'Olkiluoto-3 delays lower Areva nuclear profits by Eur 300 million' Oct 5, 2006, p 4.
[72] Nucleonics Week 'Problems found with Olkiluoto-3 hot legs' Oct 19, 2006, p 1.
[73] Nucleonics Week 'Areva puts star engineer in charge of Olkiluoto-3 project' Nov 2, 2006.
[74] Nucleonics Week 'Olkiluoto-3 commercial date slips to late 2010 at earliest' Dec 7, 2006, p 1.
[75] Finnish Broadcasting Company TV news, 30 Jan 2007.
[76] Nucleonics Week 'Lack of complete design blamed for problems with Olkiluoto-3' May 17, 2007, p 4.
[77]Nucleonics Week 'Areva: Plane crash requirements to delay Olkiluoto-3 construction' Aug 16, 2007, p 1.
[78] Nucleonics Week 'Regulator requires repairs to welds on Olkiluoto-3 containment liner' Sept 20, 2007, p 1.
[79] Nucleonics Week 'Areva, TVO at odds over resolution of Olkiluoto-3 cost overruns' Sept 6, 2007 p 9.
[80] Nucleonics Week 'Second top TVO executive leaving Olkiluoto-3' June 26, 2008, p 1.
[81] Nucleonics Week 'Target date for operating Olkiluoto-3 again delayed, this time until 2012' Oct 23, 2008.
[82] Nucleonics Week 'STUK finds more problems with Olkiluoto-3 liner, forgings' Nov 13, 2008, p 3.
[83] Nucleonics Week 'TVO CEO sees improved workflow, potential for problems at Olkiluoto-3' Nov 20, 2008, p 11.
[84] Nucleonics Week 'Olkiluoto costs weigh on Areva 2008 profits; TVO rejects blame' Dec 25, 2008, p 9.
[85] Letter from Jukka Laaksonen to Anne Lauvergeon, Dec 9, 2008.
[86] Nucleonics Week 'TVO: Olkiluoto-3 operation delayed to June 2012' Jan 15, 2009, p 1.
[87] Nucleonics Week 'Siemens' departure seen putting Areva under financial stress' Jan 29, 2009, p 14.

[88] Nucleonics Week 'TVO: Olkiluoto-3 operation delayed to June 2012' Jan 15, 2009, p 1.
[89] Nucleonics Week 'Areva reveals 47% cost overrun on contract for Olkiluoto-3' Mar 5, 2009, p 1.
[90] Nucleonics Week 'Olkiluoto-3 arbitration could last 'several years,' TVO says' Mar 19, 2009, p 9.
[91] Nucleonics Week 'Areva reveals 47% cost overrun on contract for Olkiluoto-3' Mar 5, 2009, p 1.
[92] TVO 'Finland: Olkiluoto 3 nuclear power plant to start operation in 2013' Press Release, June 7, 2010.
[93] Business Wire 'AREVA: Olkiluoto 3 project: nuclear operation to start end of 2012' June 7, 2010.
[94] Associated Press 'Areva net profit soars despite new EPR charge' July 30, 2010.
[95] European Daily Electricity Markets 'Embattled AREVA suffers ratings downgrade' June 29, 2010.
[96] Nucleonics Week, 'EDF orders Flamanville-3 EPR NSSS, with startup targeted in 2012', 5 Jan 2007, p 1.
[97] Nucleonics Week, 'Flamanville-3 concrete pour marks start of nuclear construction' 6 Dec 2007, p 3.
[98] Nucleonics Week, 'EDF to build Flamanville-3, says first EPR competitive with CCGT', 11 May 2006, p 1.
[99] Nucleonics Week, 'Concrete pouring at Flamanville-3 stopped after new problems found', 29 May 2008, p 18.
[100] Nucleonics Week, 'EDF confirms target of starting up Flamanville-3 in 2012', 20 Nov 2008, p 1.
[101] Associated Press Worldstream, 'EDF to lead up to euro50B in nuclear plant investment', 4 Dec 2008.
[102] Nucleonics Week, 'Areva official says costs for new EPR rising, exceeding $6.5 billion', 4 Sept 2008, p.1.
[103] French Business Digest 'Unions confirm 2-yr delay at EDF's nuclear project in N France – report' Jan 21, 2010.
[104] Agence France Presse 'EDF announces 2-year delay, cost hike at new reactor' July 30, 2010.
[105] Le Figaro, October 27, 2010, p 17.
[106] Nucleonics Week 'EDF to build Flamanville-3, says first EPR competitive with CCGT' May 11, 2006, p 1.
[107] Nucleonics Week 'Site preparation work for EPR at Flamanville gets under way' July 13, 2006, p 9.
[108] Nucleonics Week 'Cost estimate for Flamanville-3 unchanged, EDF official says' Sept 7, 2006, p 9.
[109] Nucleonics Week 'EDF orders Flamanville-3 EPR NSSS, with startup targeted in 2012', Jan 25, 2007, p 1.
[110] Nucleonics Week 'On brink of election cycle, French government licenses EPR' Apr 19, 2007, p 6.
[111] Nucleonics Week 'Flamanville-3 concrete pour marks start of nuclear construction' Dec 6, 2007, p 3.
[112] Nucleonics Week 'ASN asks EDF to improve quality, organization at Flamanville-3' Mar 27, 2008, p 1.
[113] Nucleonics Week 'Regulator seeks EDF's response to QA findings at Flamanville-3' Apr 3, 2008, p 5.
[114] Nucleonics Week 'Concrete pouring at Flamanville-3 stopped after new problems found' May 29, 2008, p 14.
[115] Nucleonics Week 'Areva tasked to prove quality of EPR forgings' Oct 30, 2008 p 1.
[116] Nucleonics Week 'EDF: Flamanville-3 cost rise due to inflation, technical/regulatory changes' Dec 11, 2008.
[117] French Business Digest 'Unions confirm 2-yr delay at EDF's nuclear project in N France – report' Jan 21, 2010.
[118] Agence France Presse 'EDF announces 2-year delay, cost hike at new reactor' July 30, 2010.
[119] Nucleonics Week 'ASN asks EDF to make changes to Flamanville-3 I&C system' August 5, 2010, p 10.
[120] Le Figaro, October 27, 2010, p 17.
[121] European Daily Electricity Markets 'EDF's past efforts pay off with two EPR deals sealed in China', 15 Aug 2008.
[122] South China Morning Post 'Hold-ups in construction of Taishan nuclear power plant; Atomic plant first in China to use latest European technology' July 31, 2010, p 3.
[123] Health and Safety Executive (2010) ' New nuclear power stations Generic Design Assessment: Guidance on the management of GDA outcomes' HSE, London.
http://www.hse.gov.uk/newreactors/reports/management-gda-outcomes.pdf
[124] Inside NRC 'Areva and Westinghouse unlikely to get 'clean' UK design reviews' Sept 14, 2009.
[125] http://www.hse.gov.uk/newreactors/reports/gda-q1-10.pdf
[126] Nucleonics Week 'UK reviews of AP1000 and EPR might not be fully closed by 2011' June 24, 2010, p 1.
[127] Nucleonics Week 'Areva files application with NRC for certification of US-EPR design' Dec 13, 2007, p 5.
[128] Inside NRC 'NRC extends US EPR design review by six months; COL delays not expected' Mar 1, 2010, p 5.
[129] http://www.hse.gov.uk/newreactors/reports/gda-q2-09.pdf
[130] Health and Safety Executive (2009) 'Joint Regulatory Position Statement on the EPR Pressurised Water Reactor' HSE, London. http://www.hse.gov.uk/press/2009/hse221009.htm
[131] http://www.hse.gov.uk/newreactors/reports/gda-q2-10.pdf p 12.
[132] Inside NRC 'Areva must modify I&C for US-EPR design, says NRC' July 5, 2010, p 3.
[133] Inside NRC 'I&C designs will differ for Finnish, French, UK and US EPRs' July 5, 2010.
[134] Nucleonics Week 'Lauvergeon: French lost UAE bid because of expensive EPR safety features' Jan 14, 2010, p 1.
[135] Nucleonics Week 'Atmea 1 design to be submitted to French regulators for safety review' Apr 1, 2010, p 3.

[136] Nucleonics Week ‘Giant EPR said to be competitive: EDF to decide on order next year’ Nov 6, 1998, p 1.
[137] Nucleonics Week ‘Framatome offers turnkey plant as US nuclear competition entry’ Dec 20, 2001, p 1.
[138] Nucleonics Week ‘Bids give TVO a range of choices for fifth Finnish reactor project’ Apr 3, 2003, p 1.
[139] Nucleonics Week ‘French government study sees EPR at overnight cost of 1,043 euros/KW’ Sept 11,2003, p 7.
[140] Nucleonics Week ‘EDF to build Flamanville-3, says first EPR competitive with CCGT’ May 11, 2006, p 1.
[141] Nucleonics Week ‘Constellation sites 'reserved' for part of U.S. EPR fleet’ Sept 22, 2005, p 1.
[142] Public Utilities Fortnightly ‘Financing New Nukes; Federal loan guarantees raise hopes for new reactors planned by affiliates of Constellation and NRG.’ February 2008, p 19.
[143] Nucleonics Week ‘Loan guarantee sought for Calvert Cliffs-3’ Aug 7 2008, p 1.
[144] Nucleonics Week “Eskom Gets Bids for Two EPRS, Three AP1000s, Bigger ‘Fleet,’” Feb 7, 2008.
[145] Nucleonics Week ‘Big Cost Hikes Make Vendors Wary of Releasing Reactor Cost Estimates’ Sept 11, 2008.
[146] Toronto Star ‘Nuclear Bid Rejected for 26 Billion: Ontario Ditched Plan for New Reactors over High Price Tag That Would Wipe Out 20-Year Budget’ July 14, 2009.
[147] Korea Herald ‘Korea Wins Landmark Nuclear Deal’ Dec 28, 2009.
[148] Right Vision News ‘UAE: Middle East Leads Rally in Nuclear Plant Orders’ Jan 12, 2010.
[149] Nucleonics Week ‘French regulatory chief rejects idea of tailoring reactor safety to market’ Jan 21, 2010.
[150] For an English translation, see http://www.psr.org/nuclear-bailout/resources/roussely-report-france-nuclear-epr.pdf
Quotes used are from this translation.
[151] Nucleonics Week ‘Areva, Mitsubishi introduce mid-size 'Atmea 1' PWR design’ Sept 6, 2007, p 1.
[152] Nuclear News ‘The safety of the Atmea1 reactor will be reviewed’ July 2010.
[153] Agence France Presse ‘France pushes EDF to raise stake in Areva: report’ September 27, 2010.
[154] http://af.reuters.com/article/energyOilNews/idAFLDE68E03220100915
[155] Agence France Presse ‘France's EDF designs reactor to challenge Areva: report’ September 28, 2010.
[156] http://nuclear.gov/home/11-21-03.html
[157] Nucleonics Week, ‘Lauvergeon: French lost UAE bid because of expensive EPR safety features’ January 14, 2010, p 1.
[158] http://www.psr.org/nuclear-bailout/resources/roussely-report-france-nuclear-epr.pdf
[159] For a detailed analysis of the business prospects for EDF and Areva, see S Thomas (2009) ‘Areva and EDF: Business prospects and risks in nuclear energy’ Greenpeace, Amsterdam. http://www.greenpeace.org.uk/files/pdfs/nuclear/Areva_EDF_Final.pdf