Cour des comptes

ENTITIES AND PUBLIC POLICIES

THE EPR SECTOR

Thematic public report

Summary

July 2020

AVERTISSEMENT

This summary report is intended to facilitate the reading and use of the Audit Office report.

The Cour des comptes [Audit Office] is only accountable for the report.

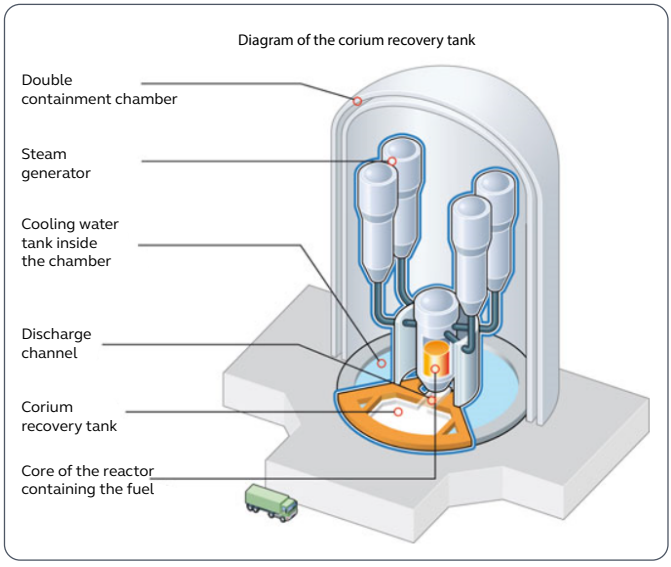
The responses from the administrative bodies and ministries concerned appear in the follow-up to the report.

Summary

An EPR reactor project drawn up under unfavourable conditions

In 1989 the French group Framatome and the German group Siemens started to design a new nuclear reactor called, in 1992, the "European Pressurized Water Reactor" (EPR). This project drew on the lessons learned from several decades of electronuclear production and also met increased security requirements after the accidents at Three Mile Island, in the United States, in 1979, and Chernobyl, in Ukraine, in 1986. The French and German governments supported this Franco-German reactor project from its inception, and electrical engineers from both countries joined it in 1992, although they did not share the same goals. German engineers intended to evolve the "Konvoi" reactor used on the other side of the Rhine, while EDF wanted to evolve the N4 series, the last reactor model then under construction. After the decision by the Germans to phase out nuclear energy in 1998, France became the sole backer of this project, whose acronym assumed the meaning « Evolutionary Pressurized Reactor » (EPR). However, the broad design options jointly defined by engineers from both countries, although they led to difficulties, were not called into question.

View of the vessel and the EPR reactor building (including corium recovery tank located under the vessel)



Source: IRSN

An EPR reactor project drawn up under unfavourable conditions

From 2001, the newly created Areva group developed a "turnkey" EPR sales strategy, thus opposing that of EDF, which intended to remain the frontrunner in "new nuclear power" in France and abroad. The rivalry between these two public groups, not arbitrated by the public authorities of the time, turned into dangerous overbidding within the French nuclear sector.

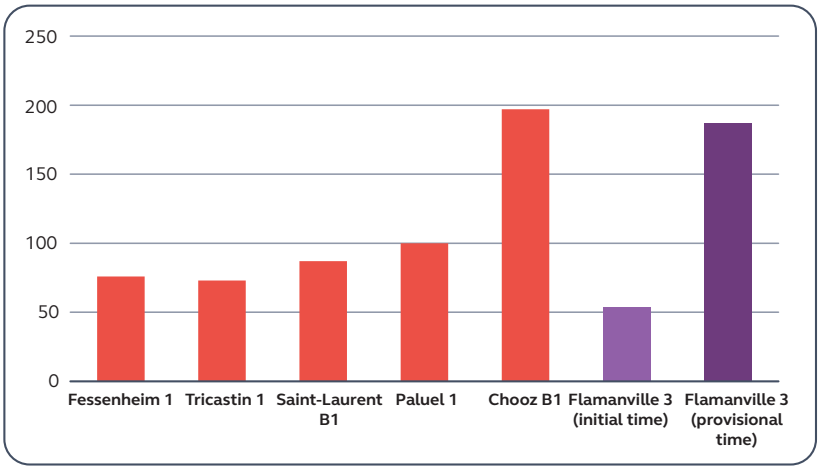
It was under these conditions that in 2003 Areva signed a contract to sell an EPR to the Finnish electrical engineering company TVO and that EDF launched, in 2004, the construction of the first EPR in France, in Flamanville. This race between the two French companies led to the hasty launch of construction sites for these first two EPRs, based on incorrect technical references and insufficient detailed studies. This lack of preparation also led to an underestimation of the difficulties in building the EPRs. The nuclear industry has shown too much self-confidence, inspired by the successful building and operation of a fleet of 58 reactors.

The building of the Flamanville EPR: an operational failure with multiple causes

On the date of publication of the report, the 3.3 times increase in the construction cost and at least 3.5 times increase in the commissioning time of the Flamanville EPR compared to the initial forecasts represented a considerable deviation, even for a "pilot" reactor.

This development is the result, first of all, of an initial unrealistic estimate of the duration and the cost of building the Flamanville 3 EPR. While the average reactor construction time worldwide was 121 months between 1996 and 2000, the initial construction time scheduled for the Flamanville EPR was 54 months - six months longer than the initial time planned for the construction of the Finnish Olkiluoto 3 reactor. This flagrant underestimation of the construction time created huge pressure to try to keep to the very tight delivery times. The duration of construction of the Flamanville EPR is today estimated at 187 months, before taking into account the impact of the covid-19 epidemic, thereby risking a further extension of this duration.

Construction time of pilot reactors (in months)



Source: Cour des comptes based on EDF data

The building of the Flamanville EPR: an operational failure with multiple causes

The construction engineering time was estimated at 5 million hours' work; 22 million will be needed. Almost 4,500 modifications have been made since construction started, regularly leading to suspension of the project, in order to give engineers the time to deal with the difficulties encountered.

This deviation is the result, furthermore, of a lack of organisation of EDF's monitoring of the project and a lack of monitoring by the supervisory authorities. The Board of Directors did not hold regular meetings to discuss this strategic project, did not respond to the alert messages from the audit committee, and was satisfied with the information it was provided with, without taking any corrective measures. The company did not have the structure to execute a project of this scale: the concept of «architectural designer» concealed a confusion between the respective functions of the client and of the project manager. Until 2015, the project was not managed by a bona fide project team. The contractual relationship aggravated the weakness of the technical management of the project since the contracts did not include, on their signing, either the vagaries - which were foreseeable given the «pilot» status of the reactor - nor the incentives that would have encouraged acknowledgment of the incomplete nature of the design. Eleven out of the 12 main Flamanville EPR contracts were thus subject to cost increases of between 100% and 700%. The company was late in organising itself to financially coordinate this project: it was only after 2015 that it followed up the expenses and then assessed the construction cost on completion, now estimated in 2015 at an €12.4 billion expressed in euros.

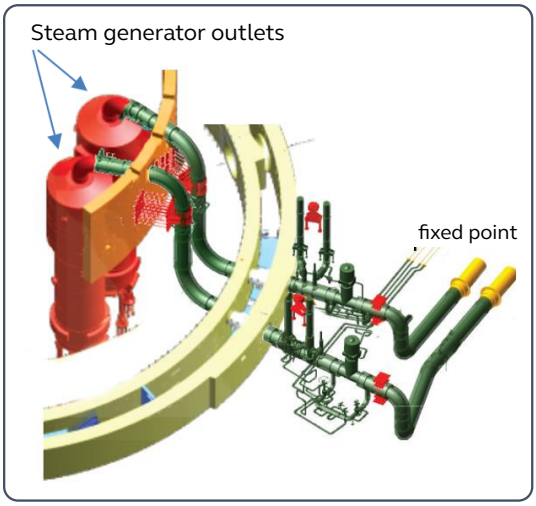
Furthermore, the administrative authorities in question have not performed their roles properly. While the initial estimates of the construction time and of the cost of Flamanville 3 EPR were clearly underestimated, they did not conduct either an assessment of the project's socio-economic profitability or a specific analysis of the impact of the successive problems encountered during its execution. Nor did they alert ministers to the importance of the vagaries of the Olkiluoto 3 and Flamanville 3 construction yards and their consequences. The Government was forced to embark on a costly restructuring of the nuclear sector, without the alarm signals having been sent in due time.

The loss of technical skills and quality culture in the nuclear industry has today been admitted and highlighted to explain the EPRs' construction problems. But actors were not aware of this at the start of the 2000s and this diagnosis was only made late, in the face of difficulties, and this notwithstanding the gap of fifteen years between the launches of the projects Civaux 2 (most recently built French reactor in service) and Flamanville 3. In December 2019 EDF announced the implementation of an action plan aiming to re-establish the necessary technical skills level and quality culture. This examination was therefore not carried out before the decision was taken to launch the construction of a new type of reactor.

EDF decided to design certain components of the reactor in a so-called failure exclusion process, which involves strengthening the technical requirements in the design, manufacture and in-service monitoring of this equipment in order to make it

extremely unlikely to fail. The former Areva NP and its subcontractors were not able to execute a number of parts and welds adhering to these high requirements. EDF did not inform the nuclear safety authority of the existence of a deviation from the failure exclusion standard for crossing welds until 2017, while it had known about them since October 2013. The delayed sending of this key safety information to the safety authority reflects a lack of smooth interaction between the sector's stakeholders and their safety authority.

Piping components covered by the failure exclusion



Source: IRSN.
Note: the double wall that figures on the diagram is that of the reactor building

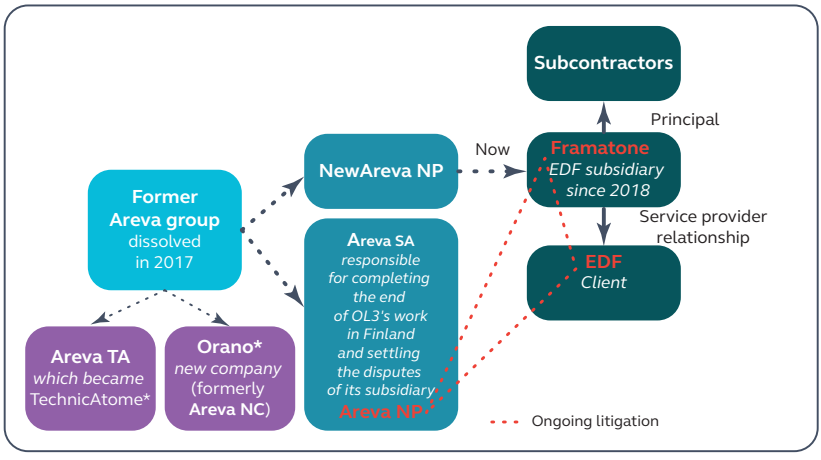
The financial impacts of these technical and organisational inadequacies are high. The repair of the crossing welds alone leads to additional building costs of around €1.5 billion 2015. The time spent by EDF, between 2015 and 2019, trying to convince the nuclear safety authority that the discrepancies between the technical requirements and what had been achieved could be considered acceptable, led to the suspension of the project, which added to its cost.

Serious consequences for the entire sector

Risks weigh in on the financial situation of certain companies which have recently benefited from a recapitalisation by the public authorities. The state raised €4.5 billion to provide capital to Areva SA (€2 billion) and Orano (€2.5 billion) following Areva's restructuring. EDF received a capital injection of €3 billion which enabled it to take control of the reactor business of the former Areva NP, now Framotome.

Due to the magnitude of EDF's current or potential claims against Areva SA, the risk of financial failure of this 100% state-owned company cannot be completely ruled out. The risks of litigation brought by EDF against its subsidiary Framatome are also likely to weaken this company. The state must therefore closely follow the results of the current or future litigation processes between these companies, of which it is the main shareholder. The strategy of the state shareholder in this sector needs to be confirmed.

Relationship between the industrial stakeholders in the sector involved in the litigation process



Source: Cour des comptes, April 2020
**Companies outside of the scope of the relationship.*
Note: The capital distribution of the different companies is as follows:
- For Framatome: the capital is 75% held by EDF, 19.5 % by Mitsubishi Heavy Industries (MHI), and 5 % by Assystem
- For Areva SA: the capital is 100 % held by the state
- For EDF: the capital is 83.6 % held by the state, 12.9 % by institutional shareholders, 2 % by individual shareholders and 1.3 % by employee shareholders (the remainder in treasury shares).

Serious consequences for the entire sector

The consequences of these deviations obviously impact the costs and profitability of the Flamanville EPR. Its construction cost is estimated by EDF at €12.4 billion2015, to which additional costs will be added which could reach nearly €6.7 billion2015 on the commissioning of the reactor, still being scheduled for mid 2023, including around €4.2 billion in financial costs. Under these conditions, it is regrettable that neither EDF nor the public authorities concerned calculated the profitability forecast of the Flamanville 3 EPR, apparently considering it normal that it should be absorbed into the average profitability of all electronuclear reactors. In the absence of data produced by the company, the Cour has estimated, based on hypotheses set out in the report, that the cost of the electricity produced by the Flamanville EPR could be between €110 and €120 / MWh.

Evolution of the building cost of Flamanville 3 between 2006 and 2019 (billions of €2015)

Source: Cour des comptes based on EDF data

An international strategy that cannot be continued under the same conditions

The Olkiluoto project, in Finland, was launched in 2005 by Areva, with its commissioning scheduled for 2009. It experienced setbacks, delays and additional costs which contributed to the disappearance of the former Areva group. The provisional acceptance of the project was, in March 2020, scheduled for the end of May 2021, but uncertainty lingers and is, according to a recent announcement by the electrical engineering company TVO, the plant's purchaser, added to by the probable impact of the covid-19 health crisis on the works still necessary. The construction cost would amount to €8.2 billion (in current euro) for the part insured by Areva, without taking into account that of the turbine (€684 billion), according to the information provided by Areva SA, i.e. nearly 4 times the amount planned in the initial contract (€2.28 billion for the consortium formed by Areva and Siemens).

The EDF's investments in the United Kingdom and the Hinkley Point project are high-risk operations. EDF has disbursed €15.7 billion for the acquisition of British Energy and will have to disburse €16 to 17 billion for the construction of the two Hinkley Point C reactors (HPC), if there are no further deviations from costs. Risks remain after the announcement of a £3bn increase in construction costs and of longer reactor construction times in 2019. The profitability of the Hinkley Point project has been revised downward several times since the launch of the project. Financing is provided by EDF, in the amount of its participation in the project company's capital, which has had a huge impact on its financial situation.

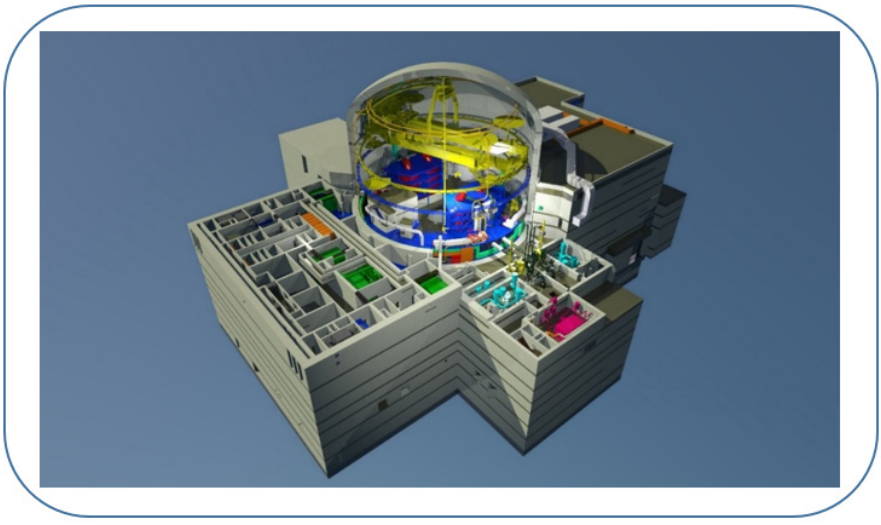
The Taishan 1 and Taishan 2 reactors were successfully commissioned in China in 2018 and 2019, but five years late with respect to the schedule laid out in the order, and with an additional cost of 60% compared to the estimated budget. Questions remain regarding the setting of the purchase price of the electricity produced by these reactors and the project's profitability for EDF.

The other EPR export projects are full of uncertainties. Despite EDF's marketing efforts and those made by the French government to offer India very favourable financial conditions, the negotiations, which began a long time ago, are making little progress. As for the EPR reactor construction projects in Sizewell in the United Kingdom, their execution is subject to guaranteeing their financing, EDF no longer having sufficient capacity to do so.

The construction of a series of EPR2 in France: a technological, economic and energy policy choice

Drawing lessons from the difficulties encountered in building the EPR reactors, but comforted by the fact that those at Taishan are working well, which validates this technological choice, EDF offers the ASN and the administrative authorities a new EPR model, called «EPR2» presented as simpler and cheaper to build.

Three-dimensional representation of the EPR 2 nuclear island



Source: EDF

The construction of a series of EPR2 in France: a technological, economic and energy policy choice

By making this choice, EDF moved away from the process of optimising the EPR technology based on reaping the benefits from the lessons learned. The Olkiluoto 3 and Flamanville 3 projects have shown that prioritising innovation over accumulated experience entails risks and that the cost of this innovation should not be underestimated. However, it is impossible to determine with any reasonable degree of certainty that the savings in building future EPR2s compared to the cost of building Flamanville-type EPRs will materialise. However, the only hypothesis currently being studied by the public authorities in terms of new nuclear energy is that of building six EPR2 type reactors, in pairs.

The financial stake is major: the cost of building three pairs of EPR2 is estimated at €46 billion2018. The decision as to whether or not to build future EPRs will have consequences through to the 22nd century. It must therefore be taken on the basis of a feedback process that is not only carried out internally at EDF, but involves all of the players involved in the building of all the EPR reactors built or in the process of being built, so that all stakeholders learn the same lessons from the way the EPR construction projects have unfolded.

In this scenario, electronuclear financing methods must be implemented. EDF cannot finance the construction of new reactors by itself and can no longer engage itself without guarantees on the revenue generated by them. No new project can be launched without a form of public guarantee, whatever the mechanism adopted. However, the burden thus transferred to the consumer or to the taxpayer would only be justified if the electricity produced by the new nuclear power reactors proved sufficiently competitive with respect to other modes of electricity production, renewable in particular, or if other considerations justified keeping nuclear power in the electricity mix.

This is why a complete analysis of the electricity mix by 2050, presenting challenges and solutions regarding the assurance of supply, adaptation of electricity transport and distribution networks, management of radioactive waste, dismantling of plants currently in operation, and of course the cost of operation of the electricity system, which must be conducted before any decision is made concerning the development of a new fleet of electronuclear reactors.

This decision having been put off by the Government to beyond the commissioning of the Flamanville 3 reactor, i.e. mid 2023 at the earliest, it is possible to draw up, by then, both the complete lessons learned about the building of the EPRs and the long-term planning of the electricity mix recommended by the Cour.

Recommendations

Recommendations on the execution of large-scale projects

1. Reconsider the concept of architectural designer by separating the functions of client and project manager *(EDF, 2020)*.

2. Incorporate in contracts provisions sharing the construction risk between the client and the contractors and others, engaging them in the management of the works execution schedule *(EDF, 2020)*.

3. Carry out a six-monthly review of the strategic projects and the risks associated with them, at meetings of the EDF board of directors *(EDF, MTES, MEF, 2020)*.

4. Make sure that the managers of large-scale projects have authority over the resources, especially the engineering resources, required for their execution (*EDF, 2020)*.

5. List in a shared reference document the terms of application of the failure exclusion in order clarify the industrial consequences of the specifications in question *(EDF, Framatome, immédiat)*.

Recommendations concerning the preparation of forthcoming decisions

6. Calculate the provisional profitability of the Flamanville 3 reactor and of the EPR2 and follow it up *(EDF, 2020)*.

7. Define, before engaging in international projects, their risk level and expected profitability and their financing conditions, and keep to them *(APE, DG Trésor, EDF, 2020)*.

8. Conduct a complete lesson learned exercise on all the EPRs built or being built in France and abroad, with all the stakeholders concerned, before launching any new electronuclear reactor project *(EDF, MTES, MEF, 2020)*.

9. Extend the planning of the electricity mix through to 2050, before taking the decision to launch any new electronuclear reactor project*(EDF, RTE, MTES, MEF, 2020)*.