The French nuclear dream: promises for disillusion

Nuclear energy might be marginal on a world-wide scale, but see how successful it can be in France, from an economical, industrial or environmental perspective! In view of such benefits, why not follow the French path?

The idea deserves consideration: what lies behind the repetitive vulgate of an industry selling its technical and economical success, claiming that it guarantees French energy independency, protects the climate, controls its waste and preserves the environment, that it is safe against terrorism, etc.?

What is the reality of the French nuclear experience in terms of industrial policy, safety, proliferation, waste management or economy? This chapter explores, on each of these issues, the gap between the talks and the facts.

Global Chance

Basics

The nuclear industry in France – An overview

French scientists contributed to the main stages in the discovery of radioactivity and its properties. Right after the Second World War, the country embarked on a nuclear development programme – initially military and then civil. The nuclear industry's organisation is still heavily based upon the structures created at this key period, even if their status has developed.

The Commissariat à l'Énergie Atomique (CEA – Atomic Energy Commission), set up in 1946, was charged with overseeing the research and development, up to the industrial stage, of all the processes necessary for the military programme and subsequently for nuclear electricity generation, including the uranium extraction and fuel manufacture (upstream) stages and the management of spent fuel and waste (downstream). A branch of the public research body CEA was created to manage all its industrial activities, mainly through the Compagnie Générale des Matières Nucléaires (Cogema – General Company for Nuclear Materials), a private company set up in 1976. In 2001 this merged with Framatome, the nuclear reactor builder, to create the Areva group.

Electricité de France (EDF), a company also established in 1946 by the nationalisation of the numerous state and private companies that existed at the time, was first and foremost responsible for overseeing the development of the electricity supply across the country. From the 1960s and even more from the 1970s, this development relied very heavily upon the construction and operation of nuclear reactors. Today EDF operates all 59 nuclear reactors in service in France. In 2005–06 EDF ceased to be a public enterprise entirely controlled by the State and was privatised, although the State retained a controlling share.

In 1991 the Agence Nationale de Gestion des Déchets Radioactifs (Andra – National Agency for Radioactive Waste Management), and in 1998 the Institut National de Radioprotection et de Sûreté Nucléaire (IRSN – National Institute for Radiological Protection and Nuclear Safety, known until 2002 as the Institut National de Protection et de Sûreté Nucléaire, IPSN), were formed from internal departments of the CEA. The IRSN is a public expert body responsible in particular for supporting the Autorité de Sûreté Nucléaire (ASN – Nuclear Safety Authority). The latter, which for a long time remained an internal department of the Ministry of Industry, has gradually evolved: after initially coming under the joint responsibility of the Ministry of the Environment and the Ministry of Health (under the name of Direction de la Sûreté et de l'Information Nucléaire (DSIN – Department of Nuclear Safety and Information) and then of Direction Générale de la Sûreté Nucléaire et de la Radioprotection (DGSNR – General Department of Nuclear Safety and Radiological Protection)), it has been an independent authority since 2006.

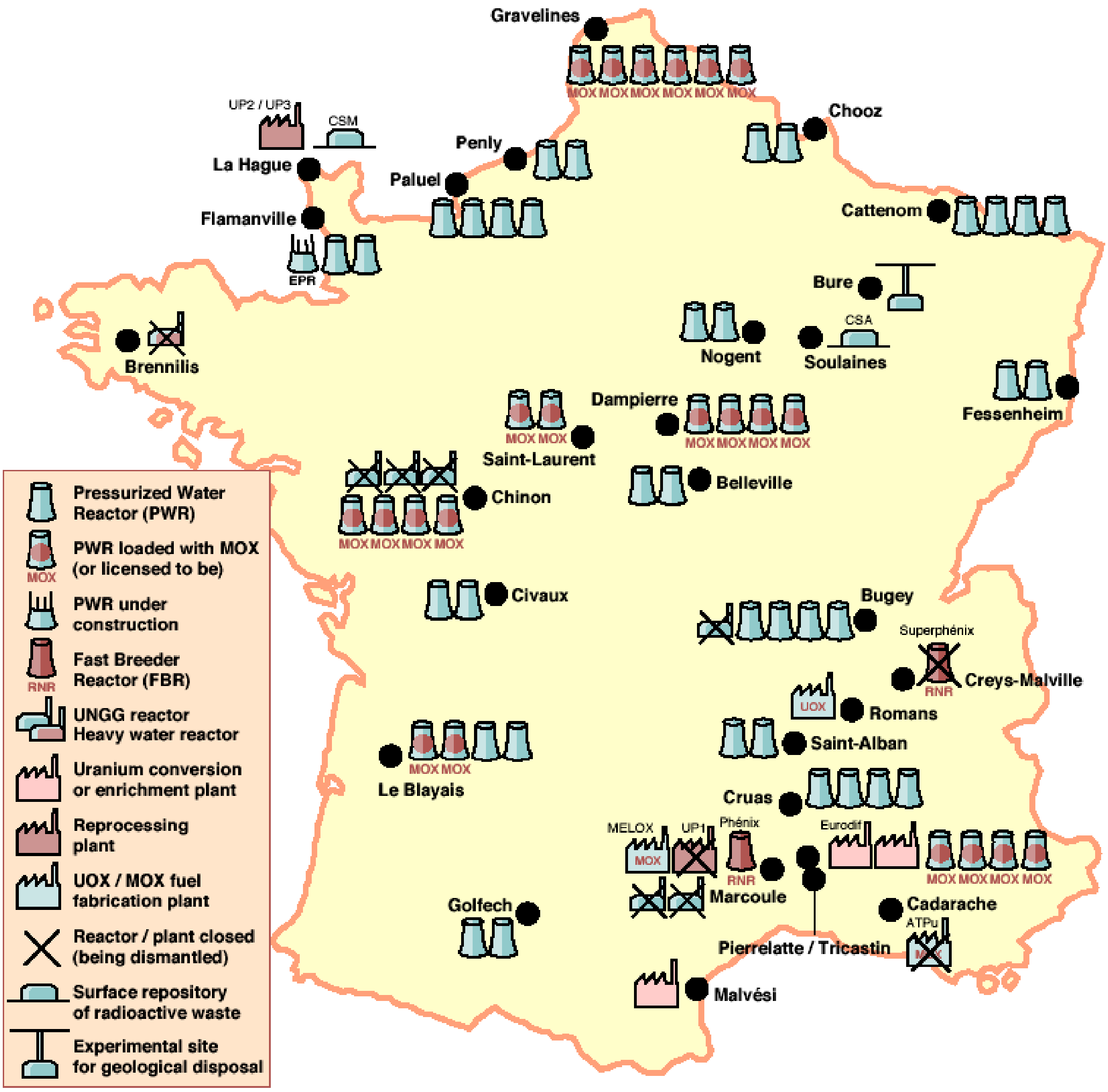
The first nuclear reactors operated by EDF from the end of the 1950s belonged to the natural uranium/graphite/gas (UNGG) line, initially developed by the CEA to produce plutonium. These reactors, as well as several industrial-scale prototypes tested as part of the development of other lines during the 1960s, have now been shut down and are being dismantled. In 1973 the French authorities opted for a massive development of the pressurised water reactor line, using low enriched uranium. The 58 pressurised water reactors now operated by EDF on 19 sites were for the most part put into service from 1977 until the end of the 1980s. A new reactor in this line, the EPR, is under construction at Flamanville. France has also developed the rapid neutron reactor (RNR) line with two reactors: Phénix, still operated by EDF, and Superphénix, which was finally shut down in 1998.

The French nuclear industry has moreover endeavoured to control all stages of the nuclear process. The CEA developed a uranium mining industry from the 1950s, although the last French mine closed in 2001. The various stages of uranium conversion are carried out for the most part at the Pierrelatte/Tricastin site, where in 1976 France also established an enrichment plant, Eurodif. Finally, the manufacture of enriched uranium oxide fuel (UOX) is carried out in the FBFC factory at Romans-sur-Isère.

Particularly characteristic of France is its establishment of the various stages of a plutonium industry. Reprocessing began in 1957 in the plant at Marcoule, which essentially fulfilled military demands and closed in 1977; since 1966 it has also been carried out at La Hague, whose capacity has gradually been increased in response to French and foreign requirements. In addition, the industry has acquired the capacity to manufacture mixed uranium/plutonium oxide fuel (MOX), first at Cadarache with the ATPu, closed in 2003, and then at Marcoule with the Melox plant, which entered service in 1995.

The decision to conduct reprocessing has a significant effect on the options for radioactive waste management. Solutions exist for the least radioactive waste: low- and medium-level short-term waste is stockpiled at the Centre de Stockage de la Manche (CSM – Manche Disposal Centre) near La Hague, opened in 1966 and closed in 2003, and the Centre de Stockage de l'Aube (CSA – Aube Disposal Centre), opened in 1992. But the search for solutions for all long-term waste continues – most notably research into geological disposal for the most active waste in the underground laboratory at Bure. Meanwhile the waste and nuclear material awaiting long-term solution is accumulating in more or less perpetual temporary storage facilities at the various sites, in particular at La Hague.

Figure 10 Principal sites associated with the nuclear industry in France (2008)



Source: WISE-Paris

Industrial policy

Beyond the ideal image of a highly successful industry

> *"Thanks to our experience with nuclear energy and our nuclear technologies, France is a major player in that strategic sector. […] France has always taken its responsibilities. These techniques that it has a recognized and respected mastery of deserve to become available to the nations."*
>
> **Bernard Kouchner, Minister of Foreign Affairs,**
> ***Les Echos*, 29 April 2008**

The success story of the French nuclear programme, as related by the nuclear industry and successive governments, conveys a strong image of highly skilled engineering and far-sighted industrial policy. This glittering image is surprisingly far from the reality of 50 years or so of development of nuclear energy in France, which has been marked by a history of technological dead-ends, failed industrial challenges and planning mistakes.

But the successive mistakes of the state-controlled industry have never been acknowledged, either by the state or the industry. At least, not in public terms, or only sketchily. On the contrary, while problems have been fiercely disputed behind close curtains, and some corrective actions taken, the public discourse has always remained as much as possible one of denial of any failure. The pursuit of the nuclear choice, declared once and forever the major pillar of French energy policy, is worth the price of covering, politically and financially, some dramatic reassessments.

Better pay the expenses than confess faults: the case for reprocessing

The future of French industry, or even of nuclear energy worldwide – as much as it is highly influenced by the French showcase – was actually mentioned in an official document as the main reason for maintaining existing reprocessing plans when they had just been critically reassessed, in 1985. Reprocessing had originally been developed for other purposes. In 1958, the first 'plutonium factory' (*usine de plutonium*), or UP1, was built and operated in Marcoule to produce raw material for the French nuclear weapons programme. Later, with the second plant, UP2, in La Hague opening in 1966, came the original rationale for civilian reprocessing as the core of a large programme of fast breeder reactors. Superphénix, a 1,250 MWe sodium-cooled fast breeder reactor (FBR) was ordered in 1976, and the following years reprocessing contracts were signed with EDF and foreign companies with the intention to fuel that programme. In 1976, CEA chairman, André Giraud, forecasted 540 such FBR units to be operated worldwide by 2000 – of which 20 would be in France – and 2,766 by 2025, because of increased tensions on uranium resources. By the end of the 1970s, an advisory report to the government planned that at least 40 GWe, or 25% of the total French nuclear-installed capacity by 2000 (which it also highly overestimated) would be provided by reactors of the same type as Superphénix.[42]

[42] Not a single order of FBR the size of Superphénix has been placed or is currently planned in the world.

A further step was taken with the ordering of new builds in La Hague, including the extension of UP2 into UP2-800 for reprocessing of EDF's light water reactor (LWR) fuel, and the addition of a new reprocessing plant, UP3, dedicated to the reprocessing of foreign LWR fuel. Ratified within days after the election of François Mitterrand, in May 1981, the decisions were seen as a fait accompli by the industry. Yet by that time, the forecasts on the price of uranium and the related development of fast breeder reactors had already been proved totally wrong.

The large-scale reprocessing plans had lost their ground. But instead of adapting them, the industry developed a new justification for them. A technological option that had been previously discarded provided a way out of this industrial dead-end. The separated plutonium would be used in existing LWRs in the form of mixed-oxide fuel, or MOX, blending 5% or more of plutonium with depleted uranium. This shift in justifying unchanged developments planned at La Hague was made as early as 1982. The choice was strongly criticised internally, and a report by a member of CEA to a consultative body for the French government, the CSSIN (Superior Council for Nuclear Safety and Information) concluded in 1982 that "interim storage (40 to 100 years, or more) of light water reactor spent fuel followed by geological disposal (non-reprocessing option) is infinitely less costly than the reprocessing option", adding that "recycling plutonium in light water reactors is an economic aberration."[43]

In 1985, an internal assessment conducted by the Ministry of Industry with a working group gathering industrial players to support the MOX programme showed no clear advantage to this option. Yet it led to the final decisions launching a 'reprocessing-recycling" scheme to a commercial scale, namely the completion of the new reprocessing plants in La Hague, the building of a commercial MOX fabrication plant in Marcoule (MELOX), and a contract between EDF and La Hague's operator Cogema (now Areva) covering the reprocessing of 8,000 tons of spent fuel over the 1990-2000 period.

An internal report by the department of fuel management of EDF, in 1989 – or two years after the first loading of MOX fuel in one of the utility's reactors – summarised the process.[44] It explained that "in 1982, when it appeared that the development of [fast breeder] reactors was to be postponed for a long time, EDF had to reassess the situation to know whether recycling plutonium in light water reactors would present sufficient advantages to legitimate pursuing the reprocessing programme", which would only be the case if uranium prices were high, a condition that did not materialise. The higher costs than planned for reprocessing and MOX fuel fabrication made it even worse. Every part of the assessment became negative, except for the conclusion: "given the investments already spent, even with the significant drop of MOX fuel competitiveness compared to natural uranium, the reprocessing option should be maintained […]. Questioning it has no economic basis, yet it would have a strong impact in the world, harmful to the whole nuclear industry." In other words, the increased operational cost of € 350 million over ten years, according to the low estimate of EDF at that time (to which one could add the investment costs of the reprocessing and MOX fuel plants), is a convenient price to pay to preserve a good image of the industry…

The 'reactor line war': France's late choice for US LWR technology

The French national utility would not lose the case against the fuel chain industry every time. Strategic discussions had started as early as the 1950s between the two industrial giants created in the first year after the end of the World War, in 1946: Electricité de France (EDF) and the Commissariat à l'énergie atomique (Atomic Energy Commission, CEA). The CEA was in charge of developing the use of nuclear energy in France, which it did in tandem with its other task, of running the weapons programme. Its industrial branch, later to become the publicly owned, private status company Cogema, developed technologies covering the whole fuel chain. EDF gathered French generating capacities and was in charge of developing them and the electric network to power economic development on the whole territory.

[43] J.L. Fensch, *Finalités du Retraitement*, Report presented to the Conseil Supérieur de la Sûreté Nucléaire, Paris, 1982.
[44] J. Beaufrère et al., *Combustible MOX – Aspects techniques, économiques et stratégiques*, 24 November 1989.

EDF began generating nuclear electricity in six reactors operated with natural uranium (UNGG, moderated with graphite and gas-cooled), started between 1963 and 1972, totalling a capacity of 2,375 MWe.[45] The CEA had developed this technology mostly because of the high-grade quality of the plutonium produced in its low burn-up fuel, and intended to base any further development of nuclear generation on the same kind of reactors. EDF developed another vision and favoured the technology promoted by the US company Westinghouse of light water reactors using low-enriched uranium.

The choice between the two technologies turned into a tug of war between the two branches of the industry, intensifying throughout the end of the 1960s and the beginning of the 1970s as plans to launch a large nuclear programme gained political momentum. The issue, known as the "reactor line war", is for instance documented in successive reports by the French Consultative Commission for the Production of Electricity of Nuclear Origin (PEON), adviser to the government on the competitiveness of proposed nuclear power stations.

A first report in 1964 put UNGG reactors, which were assumed to produce electricity at the same cost as oil-fired plants (but expected to gain in competitiveness), at the core of a nuclear programme. The report estimated that LWRs would have lower investment costs but these would be levelled out by higher fuel costs, therefore "nothing allows [us] to conclude that the kWh costs would be more economic using US techniques." The main problem with LWRs was that the French industry would have to rely on US technology for both the reactors and uranium enrichment.

The government decided in 1967 to pursue the UNGG programme, with an order to be passed for two units at Fessenheim. The 1968 PEON report took note of that decision, but insisted on the need to wait for feedback on the first large units, and noted how economical the LWR designs were, although it pointed out yet again their tie to the US monopoly on uranium enrichment at that time. The report advised the development of studies to build an enrichment plant for French and European needs.

The 1969 PEON report took note of the decision to postpone UNGG orders and proposed the launching of a programme of five LWR units of 700 to 900 MWe, through buying licences of foreign designs. UNGG had become uneconomic in comparison. By the way, an inter-ministerial committee in January 1969 had decided on the launching of a "diversification programme" through a series of low-enriched uranium reactors. The report also recommended the construction of an enrichment plant, based on gaseous diffusion technology. Finally, the 1973 and 1974 reports were centred on LWR technology, in order to be consistent with the government decision to launch a massive programme of pressurised water reactors (PWRs) by the turn of 1973-4.

The final decision was therefore contrary to the will of the CEA, which had argued as long as it could against the change to a foreign technology – and almost won the case in favour of pursuing the UNGG programme. Nevertheless EDF's preference proved right, put in the perspective of today's status of nuclear reactors worldwide, where LWRs clearly dominate the fleet with 88 percent of the total installed capacity,[46] and natural uranium-based designs are largely on the decline and outdated.

Yet one interesting result of the CEA's blindness to LWR technology is that the French programme launched in 1974 had to be developed based on the Westinghouse licence, which had been granted to the French reactor constructor Framatome. It was 1982 before the franchise ended and Framatome was commercially regarded as the genuine designer of the reactors it built. By that time, 50 of the 58 units operated by EDF had been constructed or were still under construction... under a US licence.

Uranium enrichment: dead-end choices

This is not the only time the industry branch of the CEA, later Cogema in 1976, and Areva in 2001, developed technological options that had to be reviewed. Some choices that it made on the front-end

[45] This does not include two reactors operated by CEA in Marcoule, G2 and G3 (43 MWe each), started for plutonium production and later used also by EDF to produce electricity.

[46] As of the end of 2006, the world installed capacity totalled 368.8 MWe, and included 242.3 MWe of pressurised water reactors and 83.9 MWe of boiling water reactors (BWR), or 326.2 MWe for the two categories of LWRs together.

of the fuel chain also proved erroneous. When the decision to base a large nuclear programme on LWRs emerged, the need to be independent of the then US monopoly on low enrichment of uranium triggered plans for a French uranium enrichment plant that could also serve the whole European nuclear industry.

The US had developed uranium enrichment on the basis of a gaseous diffusion technology for isotopic separation. The French plant, operated by the Eurodif consortium, was designed and built to start operation in 1979 on the same technology, which CEA had already developed for a first plant operating for the military programme. An alternative technology, based on ultra centrifugation, had been developed after the war and was implemented at the same time in other European countries by the Urenco company, as well as in the then Soviet Union. This technology proved robust and effective, and much less energy-intensive. (The Eurodif plant consumes up to 15 TWh of electricity per year, a centrifugation plant of the same size would use around 50 less times less.) It also has lower construction times and investment costs and is more easily adaptable to enrichment needs. It can also be used to re-enrich reprocessed uranium if needed, which gaseous diffusion plants could not do without technological problems.[47] It is overall more competitive, and has clearly become the leading technology on the enrichment market.

The CEA had planned to replace the gaseous diffusion plant by a very advanced technology of enrichment by laser. The process, called SILVA in France, was also developed under the name AVLIS in the US (atomic vapor laser isotope separation), where the corresponding R&D programme was abandoned in 1999. The CEA, on the contrary, further developed it and still claimed in the early 2000s that the process would be ready to replace the Eurodif plant when needed and would come at a lower cost than other enrichment technologies. The official plan remained to use either gaseous diffusion or laser technology for a new plant.

The plan failed. In 2004, Areva launched the process to license and build a new enrichment plant at Tricastin to gradually replace, as of 2012, the existing Eurodif plant. This plant is to be based not on renewed gaseous diffusion or on a new laser process, but on the centrifugation technology that, turning its back on everything it had said up to then, Areva noted as "currently considered by every expert as the best performing technology for uranium enrichment", pointing out the huge difference in energy consumption as a clear advantage.[48] The laser process, it also said, "has proved a theoretical capacity to enrich uranium, but using it on an industrial scale brings unavoidable costs given the current status of technology and available materials."

As France never developed a R&D programme on centrifugation, choosing this technology means Areva has to buy it from its designer, Urenco. Areva bought 5 percent of ETC, the Enrichment Technology Company, the Urenco subsidiary which owns the design and sells centrifuges. However, because of the highly sensitive status of this technology regarding proliferation risks, Areva did not get access to the design. In other words, 30 years of industrial development of French-owned enrichment technologies came to an end to use Urenco's black boxes, like anyone else.

A reality systematically short of projected targets

The French nuclear industry has thus a fairly faulty record when it comes to the technologies it chooses to develop. Another regular pattern has been the failure of new equipment to match planned performance. New plans for reactors or fuel-chain plants have usually been promoted through economic justification based on highly optimistic assumptions – sometimes necessary to win the case – that could not be met in reality.

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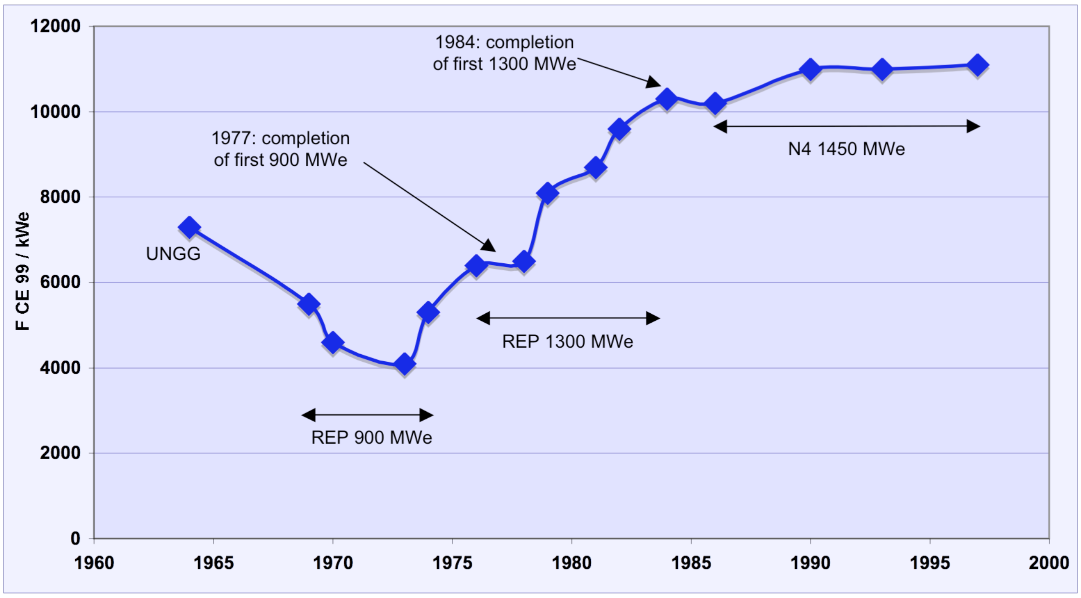
[47] The choice of gaseous diffusion for Eurodif therefore appears to run counter to the reprocessing plans developed at the same time in France.

[48] The huge electricity consumption of the gaseous diffusion process has not been a problem as long as EDF, with its excess nuclear capacity, could provide cheap electricity in exchange for some enriched uranium – a sort of mutual dumping allowed by the state. It is likely that diverging interests causing this agreement to end have played a role in Areva's decision.

Although the phenomenon surely started from the beginning of the military-civilian programme, it only became apparent as new projects started to be discussed in public reports as industrial options. The PEON reports are among the first documents to trace the gaps between paper projects and reality. The evolution of the investment costs for new reactors, for instance, shows an escalation, with each report taking feedback into account – and the reason why real costs were actually higher than projected. Altogether, projected investment costs have gone up 3.3 percent per year over the period, when the 1968 PEON report projected a decrease of 3 percent per year (Figure 11.)

Figure 11 Investment costs considered in PEON and DIGEC reports, 1964-97



Source: CDP, 2000

It all started with the construction of the first reactor of the 58 LWR series, Fessenheim, which took two more years than planned. The PEON report noted in 1977, the year of its start-up, that "the norms currently used in terms of a period of construction, determined before the real start of the nuclear programme, at a time when the regulatory context and the quality processes were strongly different, are very tight"… This brought the financial burden of interest payments from 23 percent up to 32 percent of the total investment cost. The same report noted that Fessenheim and Tricastin real construction costs had actually gone up 7 percent and 13 percent compared to projected costs.

The series also demonstrate the failure of the projected decrease in investment costs as was expected with the increased scale of the reactors. The 1976 report, for instance, expected a 24 percent decrease in the investment cost for 1,300 MWe reactors compared to the 900 MWe of the first series. The average costs used throughout the PEON series, incorporating the return of experience of real costs, actually went the opposite way, with the cost for 1,300 MWe around 68 percent higher than that for 900 MWe reactors. The increase also applied to the next series of 1,450 MWe, with a further 25 percent.[49]

The problems did not decrease with experience. Construction of the four last reactors entered in service, of the 1,450 MWe type, also called N4 series, started between 1984 and 1991 (two units in Chooz and two units in Civaux). Yet they were connected only between 1996 and 1999, or after an average of 10.5 years. Moreover, safety problems forced them to an early shut-down and their official industrial service only started in 2000 (Chooz) and 2002 (Civaux), that is respectively 15.5 and 12.5 years after their construction started!

[49] The average costs used in PEON and DIGEC reports are respectively, converted in 1999 FRF then in Euros, 777 €/kWe for 900 MWe, 1.311 €/kWe for 1,300 MWe, and 1.646 €/kWe for 1,450 MWe.

Construction times and investment costs are not the only problems experienced with reactors. Another big difference between projected calculations and real operation comes from the load factor of EDF's reactors. Due to the excess capacity created by the planning mistakes of the 1970s and 1980s, the reactors cannot be used as much as they are technically available. While their full capacity cannot cope with the high peaks of demand linked to electric heating at some times in winter, it is largely in excess for long periods of time throughout the year. The average load factor of EDF's reactors is in the range of 75 to 80 percent, compared with load factors of 85 percent or even 90 percent reached by reactors in some countries – in other words, EDF looses 10 percent profitability by comparison. Nevertheless, EDF has constantly presented projections of a load factor above 80 percent, especially for new reactors, whose competitiveness is calculated using such optimistic figures.

Another area of failure has been the export of nuclear reactors. The high figures detailing planned development of nuclear capacity in France were assumed to be part of a similar development worldwide which did not happen. The projections almost got to a ten-fold order of error, with André Giraud's forecast, as CEA chairman in 1976, of 4,000 reactors operating worldwide by 2000 – against a real figure of 440 units. France's nuclear technology was to be involved in this international development – and the industry spoke of a massive potential for exports. When the French programme of LWR was launched, the manufacturing capacity for the large components of nuclear reactors was based on the assumption that France would export, on average, one unit for each unit built at home. In real terms, before the EPR order by Finland in 2005, the French industry eventually exported only nine units to four countries (Belgium, South Africa, China and South Korea), all based on its oldest 900 MWe design.

The lack of a comprehensive public assessment of projects has allowed the industry to produce over-optimistic justifications of its plans in a very systematic manner. Furthermore, the lack of reassessment procedures to compare implemented projects with their targets has prevented any learning process. The industry's promises, no matter how unrealistic, are still the basis for public discussion of its projects. Based on controversial hypotheses regarding key factors such as its planned lifetime (60 years) or its fuel performance well above the current licensed levels, the European Pressurised Reactor (EPR) project provides the most recent example.

The choice of this 'evolutionary' design is constrained by structural factors related to maintaining the competencies and motivation of the French nuclear industry while managing the time gap between the past programme of reactors and their potential renewal.

In the end of 2003, a French government's White Book on energy policy outlined four options, with no given preference order, to manage the replacement of nuclear reactors. These included the anticipation of the need for a first EPR; the potential to extend current reactors' lifetime while waiting for the next 'generation' of reactors; the acceleration of development of this new generation; and finally the possibility of waiting until when new reactors would really be needed and buying the best technology on the international market. In particular, there was concern over the EPR's large capacity – not fit for the smaller electricity grids of new countries – and its evolutionary design, less innovative yet more complex than some of its current competitors. Also, new reactors could emerge in the next 15 years that would definitely make the EPR outdated.

The first option has been chosen two years later without any comparative assessment being presented. Therefore, instead of the visionary cliché promoted by the French industry and government, constraints inherited from past mistakes have been decisive in the choice to anticipate the building of a first-of-its kind French EPR, rather than there being any analysis of the potentially negative impact of that structuring decision.

Focus 03 From planning to structural mishap

Some key decisions about the evolution of the French nuclear programme were based on dramatically faulty forecasting. The main example is the development of a large fleet of light water reactors (LWRs) decided in 1973-4. Based on unrealistic previsions of electricity demand, these decisions have had the strongest and most long-lasting impact on the national nuclear and energy policies.

The PEON reports series documents the projection of electricity consumption, showing how the forecast for any given year evolved from one report to the next (Table 10). In fact, France's official experts, like those in most western countries at the same time, based any planning on a forecast of very high increase, roughly based on a doubling of the electricity consumption every ten years. In 1964, they forecast 103 TWh in 1965, thus 205 in 1975 and 410 in 1985. What happened instead was a significant slowing in the rate of electricity demand compared to economic growth. The projection for 1985 was not less than 33 percent higher than the eventual real consumption, at 303 TWh. The decisive report for the launching of the "Messmer programmes" (from the name of the then prime minister), published in 1973, forecast 750 TWh of electric demand in 2000, an overestimate by 75 percent of the real demand, set around 430 TWh.

The divergence between this "rule" and the real evolution of demand was plain as early as the end of the 1970s. Yet the last reports of the PEON series still projected the building of a huge nuclear capacity, to reach 158 GWe by 2000 (of which around 40 GWe of FBR reactors of the Superphénix type…). And a corresponding rhythm of construction was maintained all through the first half of the 1980s, only coming almost to a halt by 1985, when 54 reactors of the 58 LWRs now in operation (totalling 63.8 GWe) had already been built or at least ordered.

In fact, while some countries gave up parts of their programmes and cancelled some projected reactors,[50] EDF did not abandon a single order. As a result, France is marked by a structural overcapacity of nuclear power that is still in effect, impacting on nuclear economics and preventing demand-side management and development of renewables in the electricity sector.

Table 10 Electricity consumption forecasted in PEON reports, 1964-79

Year of prevision	Electric consumption in France – forecast (TWh)							
	1960	**1965**	**1970**	**1975**	**1980**	**1985**	**1990**	**2000**
1964	72	103	150	205	290	410		
1968				210	300	400		
1970				200	285	400		
1973				195	280	400		750
1974						355-420		
1976						365		
1978							350-450	
1979							400-450	530-700
Real	**72**	**102**	**140**	**181**	**249**	**303**	**349**	**430**

Source: CDP, 2000

[50] For instance, no less than 138 reactor units were cancelled in various stages of planning and construction in the US, compared with 103 reactors in operation.

Focus 04 The loss of competencies

"The whole point in anticipating the building of a 'first-of-a-kind' is to bring the industrial system back with the capacity and competence."

Head of Nuclear Engineering Dept, EDF, about the EPR in Flamanville, in a public meeting of the national debate on the project, Paris, 29 November 2005

The national public debate that preceded the licensing of the French EPR project in Flamanville shed light on the main reason for building it at a period when, as opponents pointed out, no additional nuclear production was needed. EDF made it very clear through public meetings that, although the company forecast no problem in selling the new reactor's electricity, production of energy was not the main rationale behind the project. On one occasion, a high representative of EDF's engineering department even acknowledged that the EPR project might turn into a negative financial balance in the short and mid-term, but claimed it was still a decisive step in EDF's industrial strategy for the longer term.

The main reason why EDF is building the EPR is the desperate need to maintain industrial, organisational and engineering competences that widely erode. The company intends to pursue its singular strategy and remain the only nuclear operator with the ability to build its own reactors. The international window provided by the building of an EPR in France is also said to be vital for Areva, which warned during the public debate that "in the absence of new orders, the French nuclear engineering community would lack the critical size, the necessary means and mobilisation to maintain its technological superiority"…

The competency issue is mostly one of human resources. The pyramid of ages of the French nuclear workforce is strongly influenced by the history of the nuclear programme, with large numbers hired in the fast growth phase and then a standby phase. This results in a generational gap between the skilled scientists, engineers and technicians that developed the French nuclear fleet into its current status, and the new workforce that will have to build and operate reactors to replace the existing ones. (And which will also, to make things more complicated, have to manage their inheritance in terms of waste disposal and decommissioning…) On the one hand, about 40 percent of EDF's current staff in reactors will retire by 2015; on the other, there is a lack of graduates with the relevant qualifications following years of reduction in the number of students interested in nuclear studies.

Encouraging large numbers of new engineers and technicians to embrace a career in the nuclear industry would not solve the problem, as they would need to be trained and learn from operational experience. Already, operational problems arising from the shortage of competence renewal, which EDF's Inspector General for Nuclear Safety pointed out in his annual report for 2007 as "the first management concern", are apparent at all management levels and all sites in the whole nuclear sector (and not only in EDF).

Finally, the issue extends to organisational and industrial considerations, such as the capacity to cast the largest pieces of the reactor vessel of an EPR. The only plant, owned by Japan Steel Works, that could forge ingots of the needed size (450 tonnes) up to now will provide components for the Finnish and French EPRs. Only in July 2008 Areva announced that it would proceed with the investment needed to upgrade its Chalon forgery to produce components for future EPR orders.

Focus 05 The problems of EPR projects

"It is difficult to build a nuclear power plant."

François Fillon, French Prime Minister, 30 May 2008

The problems experienced on both the EPR construction sites of Olkiluoto in Finland (OL3) and Flamanville in France show how difficult the building of a nuclear power plant can be, given the level of specification to meet and the skills required. In both cases problems have started at early and supposedly less complex stages of construction such as the pouring of concrete and the welding of steel. Yet the companies involved – Areva as supplier, Bouygues as subcontractor for construction works, EDF – are considered among the best in the field. Nuclear reactor construction proves hard to manage even for the cream of the French nuclear and construction industry.

The construction of the first EPR started in October 2005 in Finland, and problems began very soon. Two and a half years later, the project is at least two years behind schedule. The Finnish nuclear safety authority STUK made clear, highly critical statements about the supplier's responsibility for the delay. In a report published in July 2006, STUK considered that "the time and resources needed for the detail design of the OL3 unit were clearly underestimated when the overall schedule was agreed upon", and that "major problems involved project management", pointing to the insufficient guidance of subcontractors with no prior experience in nuclear power construction. STUK also comments that "the incompetence in the constructor role becomes obvious in the preparations for concreting of the base slabs."

In early 2007, STUK had listed 1,500 safety and quality problems with the project, including critical ones, and considered it possible that all the problems had not been detected. Most pieces of the pressure vessel, the pressuriser and steam generators had been badly manufactured. The future operator, TVO, has also complained, its project manager recalling in February 2008 that at the time, Areva had submitted only half the plans for the EPR.

The work building the second EPR started two years later in Flamanville. There again, problems were evident from the beginning. On 3 December 2007, on the very first day of concrete pouring on the site, an inspection carried by the French nuclear safety authority, ASN, concluded that the quality control procedures for the base slab concrete were "unsatisfactory". Some basic specifications had not been respected and the right procedures had not been followed for concrete mixing, pouring, and test sample filing. Another inspection, ten days later, showed erroneous assumptions and violations of regulations as regards the potential interaction of the building works with the two operating units, suggesting a deeper lack of basic safety culture.

Further inspections carried on during the first half of 2008 found a series of anomalies that led ASN to point to "a lack of rigor in the construction of the building site, difficulties in the management of external subcontractors and organisational deficiencies." Finally, on 23 May 2008 ASN took the very unusual decision to stop the concreting of all safety relevant parts of the plant. A long series of inspection reports listed very serious errors affecting the quality of concrete – too porous in some parts; the quality of repair of subsequent cracks; the incorrect following of specifications in welding etc. On 17 June 2008, ASN authorised a conditional restart of the concrete work, based on a commitment by EDF to upgrade quality control and organisation.