INSTITUT D'ECONOMIE ET
DE POLITIQUE DE L'ENERGIE

The mitigation of the French nuclear option
New industrial realism
and technical democracy learning

Dominique Finon

2002

A paraître dans *Energy and Environment*
Special Issue on "National nuclear policies in Europe"

Unité mixte de recherche du Centre National de la Recherche Scientifique
et de l'Université Pierre Mendès France (UFR DGES) - UMR 5111

IEPE, BP 47, 38040 Grenoble Cedex 09, France
Tél : +33 (0)4 76 51 42 40 ; Fax :+33 (0)4 76 51 45 27
Mél : iepe@upmf-grenoble.fr ; URL : http://www.upmf-grenoble.fr/iepe

Abstract

Nuclear phase-out policies and the European obligation to liberalise electricity markets could put dramatically at odds the French nuclear option by influencing social preferences or by constraining power producers' investment choices in the future. In reality the particular institutional set-up which has allowed the efficient build-up and operation of several series of standardised reactors preserves the stability of the main elements of the option.
However important adaptations to the evolving industrial and political environment occur and contribute to mitigate the option. Some institutional changes (such as local public inquiry, creation of a Parliamentary committee, independence of safety authorities) and divergence between industrial interests allow debates on internal options such as reprocessing, type of waste management deposits, ordering of an advanced PWR. These changes improve the cost transparency, even if internalisation of nuclear externalities (cost of insurance, provisions for waste management) is still uncomplete. However, when effective, this internalisation would not affect definitively the competitive position of the nuclear production because of the parallel internalisation of CO_2 externalities from fossil fuel power generation in the official rationale. Consequently the real issue for the future of the nuclear option in France remains the preservation of social acceptability in the perception of nuclear risks.

Keywords: Nuclear energy, policy process, cost, externality, technological risk

Introduction

The development of nuclear production has been the main aim of French energy policy since the seventies. The installation of a nuclear capacity of nearly 60 GW and a complete fuel cycle infrastructure between 1971 and 1995 has been dealt with by a close network of public organisations and firms backed by strong political support with a closed decision-making process and centralised institutions. This institutional set up preserved its high level of legitimacy, even during the period when it faced public controversy and opposition on the siting of nuclear plants. Whatever their political leanings, successive governments have sided with the nuclear industry and the national utility, heavily involved in this equipment option.

Since 1990, however, both changes from inside and shocks from outside have affected the nuclear option in France. Vested industrial interests have progressively diverged, while technological democracy and institutional control have increased in consistency. The involvement of the Green Party (Les Verts) in the left-wing governmental coalition since 1997 has had some significant impact: the symbolic closure of the controversial SuperPhenix fast breeder demo-plant, the postponement of the order for an advanced PWR prototype, developments in the nuclear safety institutions, the first official questioning of the plutonium option, etc.). Coming from supranational institutions the European obligation to liberalise electricity markets should put at odds the chance of replacement of the French nuclear reactors in the future if this obligation is totally fulfilled. Changes abroad have also affected the justification of these elements in the nuclear option: the continuation of poor prospects in the worldwide nuclear market with the deregulation of the electricity markets, and the persistent problem of public acceptance, and the policies of nuclear phase-out in Western Europe, leading to a degree of insularity in the French nuclear option.

This paper analyses the adaptation of the French nuclear option to these changes in its environment. The industrial and technological choices have been shaped by specific centralist institutions which remain a constitute strong elements of path-dependency (as understood by North, 1988). However, it is now curving, with mitigation of industrial and technological choices and adoption of more flexible options, reflecting a more complex set of social preferences than before. After a survey of the institutional and industrial status of nuclear power in France the paper identifies new developments in the industrial and policy-making dimensions: the institutional adaptation that have been made in the power sector and the nuclear industry with a view to protecting the nuclear option in the long term in the newly liberalised power market, the effects of learning in industrial democracy on moderation of technological choices. Finally we analyse how the new institutional context that favours greater cost transparency and tends to reduce the doctrinal side of the nuclear policy has effects on rationale by considering environmental externalities and risks. Argument of collective efficiency of nuclear option has henceforth to be back on climate change risk.

The institutional and industrial basis of nuclear option in France

The network of actors responsible for developing nuclear energy is a close-knit one, and was closed to government for a considerable time, being managed on a centralised basis and insulated from the political arena. This has had a considerable influence on the implementation of a major public policy programme in an area fraught with controversy and public opposition. Since 1975, the four main actors have been Electricité de France (EDF), the public electricity company which owns important engineering resources, Framatome, the reactor seller whose stock was mostly controlled by public players[1], the Atomic Energy Commission (CEA), the nuclear research and development agency closely linked with COGEMA, the public nuclear fuel company. The Ministry of Industry played a role in co-ordinating and taking decisions on most industrial structuring aspects.

The safety regulation has been shaped by the administrative culture, in keeping with the specific sociology of the "Ingénieurs d'État", which allowed technology promotion and regulation functions to be kept together. Until 1992, the nuclear safety regulations were monitored by a department of the Ministry of Industry (SCSIN), which relied on the expertise of a division of the CEA (the IPSN)[2]. This allowed a pragmatic approach to licensing procedures, and to the development and monitoring of the safety rules. Since 1979, nuclear waste management has been developed under the auspices of ANDRA, an agency responsible for the management of storage sites and the setting-up of repository sites, which was a semi-autonomous CEA's department until 1991 when it becomes fully independent[3] .

This institutional set-up allowed the effective implementation of a nuclear programme based on a few contracts for a series of standardised PWR reactors under the Westinghouse licence (the CP1 series of 18 900-MW reactors, the CP2 series of 10 900-MW reactors, the P4 series of 8 1,300-MW reactors, and the P4 series of 12 1300-MW reactors). The last four orders in the N4 series of 1450 MW-reactors, which were based on a "frenchified" PWR design and ordered between 1984 and 1993, were not followed up in this series. The total production of the fifty-nine reactors accounts for 80% of French electricity production. Overcapacity,

[1] In the nineties until 1999, Framatome's shares were divided between Alcatel (44%), CEA-Industrie (36 %), EDF (10 %), Framatome's employees (3%) and a public bank the Crédit Lyonnais (5%).
[2] The SCSIN is the Service Central de Sûreté des Installations Nucléaires, the IPSN is the Institut de Sûreté et de Protection Nucléaire.
[3] ANDRA means Agence Nationale pour la gestion des Déchets Radioactifs.

estimated to be 10 GW, has offset the efficiency of the implementation of the nuclear crash program; but it has been partly compensated by long-term contractual exports of totalling around 70 TWh, i.e.15% of nuclear production).

This industrial organisation has allowed efficient control of investment costs (Thomas, 1988). Their advantage of 50-100% over the reference investment costs in other industrial countries is explained by this particular institutional and organisational set-up (OECD-NEA, 1992 & 1998). Some unavoidable learning costs for the first reactors in each series, and the regular appearance of generic faults and their significant costs, have offset this standardisation[4]. The adoption of the “frenchified” N4 design has also incurred considerable learning costs, with low records in terms of construction costs and the utilisation factor[5].

The development of the complete closed fuel cycle (enrichment, reprocessing etc.) has also been facilitated by the institutional set up. The development of the end-of-fuel cycle has been backed by strong belief in the imminent requirement for the FBR and commercial interests in selling reprocessing services to foreign utilities. Consequently, LWR fuel reprocessing was mostly developed during the 80's with the construction of two plants (each of 800 t/year), commissioned in 1989 and 1994 respectively, one for EDF’s nuclear fuels and one for foreign fuels under contracts mainly with Germany and Japan[6]. After the *sine die* postponing of commercial FBR introduction in the mid-eighties, the substitutive option of plutonium recycling in PWR with MOx fuel maintains apparent rationale for reprocessing. Development of geological waste repository and search of sites have begin to be explored lately at the end of the eighties, but siting met strong local opposition, that obliged to open decision-making process on this issue (see below)

The conservationist answer to power market liberalisation and industrial globalisation

As the European legislation to liberalise national electricity markets carries the risk of reduced potential for reinvestment in new nuclear plants in the future, defending the nuclear option leads to institutional conservatism in the recent electricity reforms. Meanwhile, with the tight concentration of the worldwide equipment industry and the lack of good prospects for nuclear equipment sales in France and in the world, the institutional answer has been the recent total re-concentration of the French nuclear industry inside the public sector (Finon, 2001).

The institutional requirements of the nuclear option with regard to electricity competition

Nuclear equipment is very capital intensive with long lead-times for construction. As such it is not an attractive technology for private investors in a competitive electricity industry (OECD-NEA, 2000), and the vested interests in the nuclear policy are aware of that. Two solutions are possible for maintaining the nuclear option when new investment is needed for replacement or extension. The first solution consists of maintaining vertical companies while allowing only third-party access to the network and preserving a significant legal captive

---

[4] The appearance of generic faults, which on each occasion affected up to twelve reactors, required costly and programmed repairs (such as the replacement programmes for the steam generators in 24 reactors between 1988 and 1992 and the covering of pressure vessels in 15 reactors between 1992 and 1995).

[5] The four N4-reactors suffered delays in commissioning (from three to six years) and numerous shutdowns because of the novelty of their overall design, electronic control and components.

[6] The construction of the UP3 plant was pre-financed by contracts with utilities from Japan, Germany, Belgium, Netherlands and Switzerland

market, and creates a strong dominant position in the competitive sector. The second solution consists of separating nuclear generation from the power market by creating a regulatory niche managed with tenders for long-term contracts.

In France, conservatism has mitigated in favour of a mix of the two solutions. The introduction of effective competition at generation level, which would require divestiture and privatisation of nuclear assets in a way similar to that followed by the British ESI, would presuppose huge changes in the technocratic and political culture.

Therefore, the reform in transcription of the European Directive on electricity deregulation, voted in late 2000, has been designed mostly to preserve the role of the state-owned monopoly as an instrument of energy policy based on the nuclear option (Assemblée Nationale, 2000). France opted for institutional conservatism without radical restructuring or the creation of any kind of market pool. It chose to limit competition to bilateral contracts between producers and industrial consumers (one third of the retail market) through the third-party access provision to the national utility's transmission network. EDF therefore retains its over-dominant position, thus dissuading potential entries and limiting the entrants' market share in the eligible consumers' segment to a low level (around 10% in 2001).

Moreover, the reform creates legal grounds for creating a market-niche for new nuclear equipment. The Law contains articles giving the government the power to control the development of the overall electric production capacity and its technology mix. Indeed, it sets up a five-year programming procedure that has to be debated (and voted**)** by the Parliament. The law also allows the government to tender for the construction and operation of specific additional generating capacities with clearly specified technology, long-term guaranteed outlets and bid-price payment for the winners. It also creates a general interest fund financed by a tax on every kWh generated, aimed at bearing all the costs incurred in paying for general interest missions. It could therefore be used in the future to finance the additional cost of producing electricity by new nuclear units in the market-niche.

The public re-concentration of the nuclear industry

Despite the preservation of the integrated public utility as a national champion, relationships between participants of the French nuclear system have been affected by European economic integration, globalisation and increasing concentration of electric equipment supplies at the worldwide level. During the nineties the first answer was to abandon technological nationalism by establishing a partnership with Siemens for developing a new advanced PWR, the European Pressurised water Reactor or EPR. Meanwhile Framatome, which concentrates on the nuclear reactor business, developed a second core business in electronics (in the connector industry).

However, the increased concentration of the international electromechanical industry, the protracted slump in the international nuclear market and the subsequent sales by some major companies of their nuclear divisions (namely Westinghouse and ABB), requires the French nuclear industry to be restructured. The traditional nationalist and technocratic logic behind the increasing nuclear momentum has recently induced a separation between the nuclear industry, which has once again become confined to the statist industrial area, and the equipment supply industry –Alcatel-Alstom- which is fully involved within the global electric equipment market. Reinforcement of the financial and strategic links between the public comppanies involved in the nuclear industry within the public sphere has proved the answer to future uncertainties.

Alcatel, which owned 44% of Framatome shares without having full control, decided in 1999 to get out of nuclear activity by selling its capital share. Framatome has been replaced in the public area, help ed by Alcatel's withdrawal : it resulted in a situation where both COGEMA and the CEA were given control of Framatome, which has been obliged to cease its activities in electronics. The definitive structure defined in September 2001 is a public holding known as AREVA and owned by the CEA (79% of shares)[7]: Areva owns public shares of Framatome ANP (66%) in partnership with Siemens, of COGEMA (80 %) and STM Electronics, which has taken over Framatome's electronic activities (FCI).

This corresponds to a take-back from the State, aimed at protecting French technological and industrial resources in the nuclear activities for preparing a strong position for the anticipated take-off of the worldwide nuclear market.

The mitigation of the nuclear option: the easing of relations between EDF and the nuclear industry

The content of the French nuclear option is currently being redefined on a number of items on which the different industrial interests oppose each other. The adaptation of EDF to competition and its strategy of internationalisation is opposed to the preservation of its unconditional support for the reactor and nuclear fuel industry by its procurements. The aim of the electricity utility is to reduce its operating and maintenance costs by 20-30% and to limit its investments in production (OPECST, 2001, p. 5). As the previous close-knit of industrial interests is therefore less, some aims of nuclear policy are becoming vulnerable as their justification in an environment that is more open to decision making becomes less.

Therefore, in 1998, despite nuclear industry's resistance, the new coalition government decided in 1998 to shut down the expensive FBR prototype SuperPhenix, which had continually encountered technical problems since it was commissioned in 1984[8], knowing that there was definitely no commercial future for this type of reactor. The current agenda contains three sources of tension : extending the lifetime of nuclear reactors, the undertaking to build the prototype EPR in preparation for renewing the early reactors, and continuing with the option of reprocessing and recycling plutonium.

Extending the lifetime of the reactors

Extending the lifetime of the reactors will affect the horizon of replacement of the existing reactors, especially the 900-MW reactors, whose operational lifetime was originally defined 30 years. In consequence, replacement of this generation of reactors should begin with orders in the period 2003-2005 (CGP, 1998). However, since 1995, the prospective technical lifetime of the materials and components in the respect for the bounds established by the safety

[7] The other shares are owned directly by the State (4%), a public holding ERAP (3.2%), EDF (2.4%), Alcatel (2.2%), Framatome's employees (1.6%), a public bank CDC (1.3%), and TotalFinaElf (1%).
[8] This decision was based on the compromise drawn up between the Greens and the Socialists in the Government's progamme.

authority have been the subject of major studies aimed at assessing the possibility of extending life times, after replacement of components and treatment of reactor vessels. At present (2001), although no official decisions have yet been taken, the lifetime will be probably authorized to be extended to 40 years, with a possibility of extension to 45 and even 50 years for some of the reactors.

Postponing the development of the EPR reactor

The EPR project was commenced in 1991 by Framatome, in association with Siemens and aimed to the modernisation of the PWR design with respect for the stricter safety standards raised to the German levels[9] and with a better economic performance. To do this, the design of the EPR was simplified, the size of the components increased and their number reduced, and the unit power raised; in addition, research was carried out into improving the fuel use rates by increasing the burning time in the reactor and by making the components more accessible for maintenance purposes.

The aim of this project was twofold: to prepare the technological base for renewing the reactors with a horizon of 2000-2005 for the first orders, and to place Framatome in the forefront of the future competition between world actors by offering an advanced LWR reactor in its catalogue. For these reasons, an order for a 1,500-MW prototype EPR was planned for 1998-1999. Producing a series of 8-10 reactors of standardised design should reduce the cost of kWh production to c€2.5 /kWh instead of c€3 /kWh for a N4 reactor in a series of 12 reactors (OFECST, 1998). This official prediction supposes that all the problems of technical learning have been resolved, recent experience with the N4 design having shown the importance of such learning and that the promises of lower costs will be effectively reached. (The four N4 reactors have encountered many problems of design, which delayed their industrial commissioning by several years and affected dramatically their performance). As usual, in France, the costs of learning, in this case the extra cost of the prototype EPR and the initial reactors and the loss of earnings linked to interruptions in production during the first years, have not been taken into account when assessing the options for nuclear policy. Consequently official rationale could justify the EPR option by the need to modernise the PWR technology for future reactors during the first half of the 21th century, without the cost of modernisation being taken into account[10].

However, despite the interests of Framatome and the nuclear industry, the beginning of the order renewal period has been put back ten years to 2010-2015 in the official forecasts made by EDF and the Government (CGP, 1998) because of the tacit decision to extend the life span of the reactors. Therefore, when the question of ordering the EPR prototype was broached in 1998 by the reactor construction industry, EDF and the majority of the coalition government that favoured the nuclear option did not seek to introduce it in the light of fierce opposition from the Greens. The bleak prospects in the world reactor market and the absence of new investments in nuclear energy in almost every OECD country, was further basis for putting off the project, as was the absence of commercial outlets for the German partner in the light of Germany’s nuclear phase-out policy. The decision to adopt the EPR prototype has been put

---

[9] Reducing the probability of an accident by a factor of 10 ; independence of the four systems dedicated to safety functions, increased prevention of core fusion accidents, and reinforcing the confinement system.

[10] This need to modernise is also justified by the opportunities which would be created by the relaunching of the world reactors market, which could only be seized using an advanced a technique that carries improved safety and reduced costs.

off until after the 2002 presidential elections. It will depend on EDF's perception of its interests, in the light of the additional costs that it will have to bear.

The progressive change of doctrine on closing the fuel cycle

In the past, the technological push was based on the doctrine of the fast breeder reactor necessity in view of autarky based on an evolutive nuclear system with two stages, LWR (thermal neutrons) and Breeders (fast neutrons). The key to the whole system was closing the LWR cycle by reprocessing in order to extract the plutonium (Finon, 1989). However after 1985, during the construction of the two reprocessing plants at The Hague (UP2-800 for foreign fuel and UP3 for EDF fuel), the *sine die* report on the commercial development of fast-breeder reactors led EDF to accept the development of plutonium recycling and the use of MOx fuel in PWR reactors in 1987, this alternative option being proposed by COGEMA and the CEA after having considered it as a technological heresy compared to the FBR.

No in-depth assessment or Parliamentary enquiry accompanied the decision. Nevertheless the economic argument in favour of the choice was weak, as with the plutonium (Pu) having no price as a fatal product of reprocessing, the savings made on natural uranium and the enrichment allowed by the Pu recycling would not compensate for the additional cost of producing the MOx in relation to the normal UOx fuel (€1100 / kg of MOx instead of €200 / kg of UOx). Strangely, EDF always doubted unofficially whether it was economic. The main reason for this game was the investment made in the UP3 reprocessing plant (€2,000 million), in relation to the services of which EDF signed a reprocessing contract for 8,000 tonnes of irradiated fuel with COGEMA. Engineers rationality dictated that the extracted plutonium should not be left on the shelf, as one of the rules of the game of politics was that it should never be admitted that the expensive choice was not worthwhile. At the same time the choice of reprocessing was strengthened by the argument, rarely discussed in France, that the volumes of long-lived waste should be reduced with a view to managing it properly in the interest of future generations (see below). COGEMA therefore built a plant that produced MOx fuel at 120 tonnes per year - the MELOX plant. EDF, meanwhile, altered 20 on the 28 reactors in the 900-MW series that one third of their cores was loaded with MOx fuel (110 tonnes per year in total)[11].

The lack of potential for renewing the foreign reprocessing contracts, because of the German nuclear phase-out (which implied the cessation of irradiated fuel deliveries to COGEMA in 2005), and the building of a reprocessing plant in Japan, has created a whole new international background for the commercial potential of reprocessing. At present, a reduced undertaking by EDF would not undermine the credibility of the reprocessing option in the eyes of COGEMA's clients, as would have been the case before.

Although EDF finally renewed the contract in September 2001, it was for a period of six years only, and a unit price reduction of 50% was obtained[12]; only the quantities necessary for loading the twenty reactors adapted for the MOx use were taken into account. EDF is currently refusing to adapt any more reactors, so as not to have to reprocess higher quantities of UOx fuel. The policy of "total reprocessing" has therefore been officially abandoned. Only

[11] In 2000, 17 900-MW reactors were one-third loaded with MOx fuel. It should be noted that the neutron profile of the 1,300-MW reactors is much less favourable to plutonium recycling.
[12] The contract relates to 5,250 tonnes over 8 years for a total of €4,000 million (that is, €760 / kg), Source: *Enerpresse*, 4 September 2001.

850 tonnes will be reprocessed annually, out of the 1200 tonnes discharged[13]. The non-commitment on the remaining quantities weakened the argument in favour of reprocessing as the ideal way to manage nuclear waste. Although the decision appeared yet to be backed up by choices made previously (it refers to a so-called "deferred reprocessing" for this remaining quantities), it is really indicative of the divergence in interests between COGEMA and EDF and marks a key stage in the progressive change of official thought. It could mean that towards 2010, EDF will probably abandon its policy of reprocessing and recycling plutonium in order to pursue its policy of cost reduction. Significant in this regard is an official report on the cost of nuclear policy (Charpin et al., 2000), which "dared" to study the option of ceasing to reprocess and abandoning MOx[14].

Changes in the institutional control of nuclear risks

Regulation of nuclear safety and radiation protection began to evolve after 1986 and the Chernobyl accident. The objective was to preserve the nuclear technology acceptability at a time when the installation of the reactor fleet was nearly complete. At the same time the management of nuclear waste, which was beginning to become a major issue, could not rely on the same decisional forcing as before, as the search for repository sites met with fierce opposition between 1987 and 1990. The changes that followed in the early 1990s (increased independence of the safety authorities and institutionalisation of participation in the management of waste) have gradually been consolidated since 1997 under pressure from the Greens in the government coalition[15].

The slow increase in independence of nuclear safety authorities

The organisation and style of nuclear regulation is a determining factor in the collective management of nuclear risks and its effect on the cost of investing in and operating nuclear equipment. Up until the end of the 1980s, the French nuclear regulatory authorities remained closely linked with the nuclear energy promoters, taking the form of a small department of the Ministry for Industry called the SCISN, which relied heavily on the expertise of a division of the CEA known as the IPSN (see above). In addition, these authorities were managed by State engineers from the same body of civil servants as the directors of EDF, FRAMATOME, COGEMA and the CEA or from the ministerial divisions concerned. The result, in the past, was a style of regulation that was flexible and not greatly procedural. The opacity of decision-making and the proximity of controller and controlled agent led to frequent judgements in favour of the builder and the operator of nuclear equipment. After 1980 the safety regulation became much stricter as in other industrialised countries. But on one hand they were

[13] This choice was announced by EDF in 1996, but was not officially endorsed until 2001. COGEMA and the CEA wanted to maintain the idea of "total reprocessing" in order to justify the strategy of developing second and third generation reactors (EPR and HTR) and commissioning the whole of the MOx fuel chain. They also planned on reprocessing all of the MOx fuel, although studies showed that this was of no economic interest.

[14] The report calculated that abandonment from 2010 onwards would allow a clear non discounted saving of F50 billion between 2010 and 2050 for existing reactors until the last of these is closed in 2040, and 164 billion for the whole of the future nuclear fleet (OPECST, 2001, p. 21), that is, F4 billion per year.

[15] We must also underline the importance progressively taken by the control by the Parliamentary Office for Evaluation of Scientific and Technological Choices (OPECST), created in 1984. It oversees nuclear choices and safety questions on a regular basis, thus giving them a level of transparency, even though its opinions often appear to be dominated by the nuclear establishment.

somewhat less restrictive[16] ; and on the other hand they were applied so as not to hinder the construction of reactors by "back-fitting", and the standardisation of technology. Operation was also further facilitated by not imposing shut-downs in series in the event of a generic fault on group of reactors.

This organisation of the control was altered progressively from 1986 onwards, following the Chernobyl accident. To ensure that the technology remained acceptable, the nuclear safety authority tightened its controls and increased the caution with which its decisions were taken (for example, the decision to replace the steam generators in all 900-MW reactors in 1988, and the successive decisions to stop the SuperPhenix FBR for long periods between 1986 and 1998). In 1990 the nuclear safety authority changed its administrative status, becoming a ministerial division under the joint supervision of the Ministry for Industry and the Ministry for Environment[17]. This change granted it further independence, but it did not gain total independence, such as the creation of an independent nuclear safety agency would have given. It still allowed allegiance to the interests of the nuclear industry, by playing the Ministry for Industry off against the Ministry for the Environment.

After 1997, the left wing coalition government has looked to increase the independence of the safety authority under pressure from the Greens, whose plan was to create a completely independent authority holding both expertise and decision-making power. However, because of divisions in the coalition government and administrative resistance, the compromise was not reached until 2001, with a decrete making the IPSN independent from the CEA[18]. A general law concerning security and nuclear transparency, to be probably passed in 2002, will complete the reform process. These successive institutional developments, although heavily shaped in the French culture of centralisation, reflect nevertheless a progressive alignment with the dominant model of independent control of nuclear safety, which goes hand in hand with existence of technical democracy channels.

Nuclear waste repository : an uncertain decision-making process

The French approach to the management of nuclear waste has been conditioned by the technological push of the nuclear establishment. Firstly, the option of irreversible geological storage of high-activity vitrified wastes was the only solution envisaged in consistency with the reprocessing of irradiated fuels; the separation of the long-life products (transuranic elements and actinides), would reduce the volume of such waste in comparison to the volume of irradiated fuel[19]. Next, the search for sites for setting up long-life waste repositories did

---

[16] On the first series only one water reservoir and a dual safety system is used in French PWR reactors, compared to four reservoirs and four redundant safety systems in German reactors. The level of the reference accident probability was ten times higher

[17] It was named the Nuclear Installations Safety Directorate (DSIN).

[18] At the same time the IPSN merges with the Office of Protection from Ionising Radiation, formerly under the authority of the Ministry of Health. The new body, the Institute of Nuclear Safety and Protection against Radiation (IRSN) is placed under the supervision of five ministries: Industry, Environment, Defence, Health and Research.

[19] For a review of the different options of waste management and official programmes in OECD, see OECD-NEA (1997)

Without going into detail, focusing on volumes of long-life waste alone has the effect of eclipsing the consequences of reprocessing fuel: risks specific to the activity, dissipation of alpha emitters into others wastes, in particular the technological wastes (the B-waste in the French classification) requiring monitoring for several centuries.

not start until after 1985. Since then, the requirement to keep nuclear power socially acceptable has led successive governments and the Parliament to look closely at the question of waste without leaving it to the discretion of the principal actors[20]. After some local opposition to the choice of sites in 1988 and 1989, a special law was voted in 1991 concerning a fifteen-year period of organising choices for the storage of long-term nuclear waste.

The law of 1991 set out the following principles as guidelines for a decision to be taken by the Parliament in 2006:

– scientific research into a number of options for long-term waste management: geological storage, surface storage and transmutation of long-term waste;
– the construction of two underground laboratories for testing the viability of two types of geological configuration (granite and clay);
– an association of the parties involved (local communities, populations) in the choice of installation sites, to investigate their acceptability;
– the creation of an evaluation committee responsible for monitoring the advancement of the studies.

The law gives also full independence to the ANDRA from the CEA. Since then, progress has been erratic, with occasional controversy, and has not been sufficient to allow a decision to be taken in 2006. After 1997 it was made more complicated by certain demands from the Greens In terms of the options to be compared[21], the surface storage study was disregarded by the CEA until 1998, as this option was considered to be a means of delaying the development of a permanent geological storage solution. Since 1998 it has been studied again, as a compromise with the Greens who in the context of the coalition government have campaigned strongly for the study of a reversible sub-surface storage option (less than 100 m). In addition, the surface storage argument was strengthened in 2001 following the abandonment of the “full reprocessing” policy, and is now considered to be a complement to the geological storage option (OPECST, 2001).

The study of the geological storage option has been delayed by disputes over setting up the laboratories. The choice of laboratory sites as probable locations for future high-activity waste storage centres was blocked by local opposition to the two sites selected. Only the construction of the laboratory for storage in layers of clay, was decided on in December 1998 after a delay of four years[22]. Meanwhile, the granite zone laboratory project in the Gard was abandoned in 2000 after encountering stiff local opposition[23].

The third option, that of transmutation of long-term waste, is way behind the other two in terms of the cost and time required for experiments and development[24]. It is used by the CEA to maintain the justification for research into new types of reactor and nuclear fuel, although a long-term programme cannot be drawn up.

---

[20] Six reports by the Parliamentary Office (OPECST) have been produced on this question.
[21] In 2001, about €220 million was set aside for studying the three options, with equal allocation between each.
[22] The cost of this type of laboratory is estimated at euros 230 millions.
[23] Nominated by the Government in December 1998, the committee responsible for holding dialogue at the proposed granite sites, “Mission Granit”, had to stop work in July 2000 because of stiff local opposition.
[24] There is in fact a need to develop new stages in reprocessing process to separate the fission products, and new types of reactors. In other words, an additional nuclear system is required in addition to the conventional nuclear system.

The political powers and safety authorities are resigned to postponing the choice of waste management methods beyond the 2006 deadline. The most important aspect, however, is the interest in the procedure itself: the accumulation of scientific information on options on one side, and the opening of decision-making process at local and national level on the other, are the best way of confirming one of the options in future and getting the local population to agree to the setting-up of a long-lived waste repository.

More recently, the public authorities have started to concern themselves with the continuity of institutional device for financing the storage of long-lived wastes. As with the dismantling of nuclear reactors, the presence of a single reactor operator with a monopoly over the reactors has up until now allowed a simple solution to be used: a system of internal provision within EDF balance sheets for financing the future costs of long-term storage. An average levy of 0.4 c/kWh is therefore made, together with a levy of 1 c/kWh for dismantling[25]. The problem, however, is how to ensure the continuity of finance for storage of waste and for dismantling if the organisation of the French electricity institution changes radically in the future. Such continuity is subject to uncertainty over the intermediary use of these resources by the public operator (they are currently being used to finance EDF's international expansion), and these uncertainties are bound to increase if the operator is privatised or some nuclear assets divested. A report by the Accounting Court in 1999 drew attention to the issue, and a number of public authorities were made very much aware of it (Cour des Comptes, 1999). As ANDRA and the Parliamentary Office proposed (OPECST, 2001), a special public fund will most probably be created in the next reform of the electricity industry, to be kept supplied by a fee payable by the nuclear electricity producers.

Economic and political justification in transition: the welcome support of the greenhouse effect

Changes in the institutions organised around the nuclear option have made improvement in transparency of costs easier. However, the taking into account of remaining environmental externalities in the comparison of power generation options – climate change risk on one hand, nuclear risks on the other hand - allow official justification of the nuclear option to be renewed.

Improvement in transparency of costs

The mobilisation of the institutions around the setting up of the nuclear system has long since relied on rough economic justifications based on information that cannot be verified. Since 1990, with the slow but real opening of the French society to technical democracy, economic arguments are less simplistic. The report by the Ministry for Industry on reference costs of power generation in 1997 therefore takes account of the significant effect of technical progress on gas turbines and modern coal-fired power stations and considers less optimistic serial effects on reactors than before, (Ministry for the Industry, 1997). It establishes that the

[25] In 1997, the accumulated sum for financing the long-term storage of waste by EDF was €4.73 billion (OPECST, 1999). The sum accumulated for dismantling was €6.71 billion at the same date, while the cost of dismantling all of EDF's reactors was estimated at €15.24 billion based on a figure of 15% of investment costs.

cost price of a nuclear kWh and that of a gas kWh or a coal kWh are very similar, using the hypothesis of moderate development in coal and gas prices (see table 1)[26].

Another example, the energy prospects report published in 1998 by the Plan Commissariat (CGP, 1998), stresses the risk of having the national electricity system too dependent on the nuclear power. It predicts a fall in the proportion of nuclear energy from 80% to 60% with both independent producers entries and promotion of co-generation and renewable sources. The last convincing example appeared in July 2000, in an evaluation of the cost of options in nuclear policy, ordered by the Prime Minister from three experts with varying opinion (Charpin et al., 2000). This report "dares" to anticipate different and contrasting nuclear policy options: cessation of reprocessing in 2010, progressive withdrawal from nuclear power and a moderate nuclear option (50% of electrical production and 60 GW operating in 2050), alongside a high development option (70% of production and 85 GW operating in 2050), this being in two different electricity demand management scenarios with identical economic growth (25% of reduction of electrical requirements in 2050 in the lowest scenario). The results of the exercise, which calculates the total costs for each scenario, show the possible room for manoeuvre. For the option of slow withdrawal from nuclear power (closure of reactors after 40 years), it calculates a total expenditure for 2000-2050 that is similar to the expenditure for maintaining the nuclear option in a context of stable gas prices ($3.2 / Mbtu). If gas prices tend to rise ($4.7 in 2020, $6 in 2050), the strong nuclear option will cost 11% less than the nuclear withdrawal option without a policy of demand side management (DSM), but only 7% less if the option is accompanied by a policy of DSM. Between the two nuclear options, the differences in total expenditure are only significant if gas prices are higher: the difference is 9%, but reduces to a mere 3% if a DSM policy is present.

Table 1: Official comparison of the costs of electrical production means in 1997 by the Ministry for Industry (c€/kWh)

	Nuclear kWh	Gas kWh	Coal kWh
Hypotheses	Series of 4-12 reactors	Price: $2.7-3 / Mbtu	Price: $40-50 / tonne
Total cost	3.16 – 3.52	2.94– 4.15	2.97 – 3.61

Source: Ministry for the Industry, 1997

Maintaining the nuclear option is given further justification when the externalities are taken into account. This reckoning, when it does not include CO_2, already significantly altered the respective positions of total gas and coal kWh costs in comparison with nuclear kWh cost (see table 2). Adding the cost of CO_2 emissions gives a new significant advantage to nuclear production in the complete cost comparison. The ExternE-France study, used in a recent Parliamentary report (OPECST, 1999), shows environmental costs of 0.33 cF / nuclear kWh compared with c€ 2.5 / gas kWh, of which c€ 1.3 relates to the cost of CO_2 emissions.

[26] These similar estimates are for stable anticipation of fuel prices in the long run ($2.7-3 / Mbtu for gas and $40-50 / tonne for coal).

Table 2: External costs relating to electrical production (c€/kWh)

	Coal kWh	Gas kWh	Fuel kWh	Nuclear kWh
External costs, exc. CO_2	5.24	1.30	3.14	0.05*
CO_2 external costs **	2.74	1.25	1.81	0

* Include social cost associated with a nuclear accident (0.02 c€)
** Cost of the effects of CO_2
Source: Rabl A. and Sparado J.V., ExternE-France Study,1998, quoted in OPECST (1999)

We will not discuss at this point how the validity of the assessment and the comparison of the differing types of impacts and risks[27]. The most important factor is the role played by the externalities when justifying the nuclear option.

Support from national commitment relating to climate change policy

The risk posed by the greenhouse effect have undoubtedly the effect of continuing to justify the nuclear option in the political process. The moderate level of greenhouse gases emissions by France in 1990 (6.6 tonnes of CO_2 per capita to compare to 12,4 t/cap in Germany or 10,1 t/cap in the UK), which is due to nuclear power development between 1970 and 1990, meant that France's commitment to reduce emissions (stability between 1990 and 2010) should have to be low compared with other European countries (especially Germany and Great Britain). France does not get the room for manoeuvre offered in other countries by electricity production based on coal or other fossil fuels. Consequently, the successive governments have never lost sight of the stake of the nuclear capacity replacement after 2020, in view of the risk of a substantial increase in CO_2 emissions, although nuclear capacity could decline under the influence of the competition logic that provides disincentive to invest in capital-intensive units. This concern has led to limitations in the liberalisation reform of the electricity industry voted in 2000 (see above)[28].

With this logic, the public authorities are ensuring that any tool used for internalising C02 environmental costs respects the differences in contributions of each electrical production resources to greenhouse effect. In this way, in 1994-5, the French government campaigned at European level against an energy ecotax that would have been payable at half rate on non-fossil-fuel kWh, including nuclear fuel. In early 2001, the Constitutional Court rejected an environmental tax prepared under pressure from the Greens in the framework of the National Plan against the greenhouse effect. One of the two reasons given was that electrical energy was required to be taxed when 95% of its production, namely nuclear and hydroelectric, did not produce any greenhouse gases.

---

[27] For a critique, see for example A. Stirling, 1994; Eyre, 1997.
[28] It will be noted in the passage that setting up an emissions permit market at European level, or indeed at international level, will reduce the political requirements to renew all nuclear capacities.

The insufficient level of internalisation of the nuclear risk

Internalisation of the various social costs of nuclear electricity remains uncomplete. The accident risk is clearly underestimated in the cost of the nuclear kWh. In fact, the compensation system produces an operator liability limited to €91 million, for which the operator takes out a reduced insurance policy. A second source of compensation is insured by the State up to a level of 220 million, and a third by a Pool of States (between 220 and 380 million) according to the Brussels Convention; beyond this, the liability reverts to the State. The low total insurance paid for the sixty reactors (€6.3 million in 1997, that is, about m€0.015 per kWh) is low and much less than the actuarial estimate of the total nuclear risk. For information, the ExternE-France study estimates the actuarial cost at m€0.2 per reactor per year, that is, m€0.03 per kWh). Adjusted by a risk aversion coefficient of 20, the study re-estimates the value of the risk at €4 million, that is, m €0.6 per kWh (OPECST, 1999).

The re-assessment of the operator's total nuclear liability, and the adjustment for internalising the value of the risk, are not on the political agenda, as is the case in other countries. It is known that in Germany a re-evaluation after 1998 raised the liability of the operators from 75 million euros to 750 million euros, the tenfold increase leading to a tenfold increase in insurance premiums (Mez & Piening, 2001). In the same way Sweden, where the Prudential Plan entrusted the State with liability for damages beginning at €380 million, a high tax of m€2,8 per nuclear kWh was imposed on the operators in order to finance this liability. The lack of internalisation in France can also be found in other costs that are currently uncertain, such as end of life costs (dismantling and management of waste). These costs could have to be socialised by financing in the public budget in future if the funds accumulated for the purpose prove to be insufficient.

Conclusion

The magnitude of the French nuclear system installed in the 70's and the 80's has created a strong social momentum. The nuclear option has been shaped by the particular institutional set-up which exists in France within the State-industrial sectors considered as a key sectors for the national interest. Because of this particular situation, the possibility of nuclear phase-out policies influencing the French policy is narrow. But the content of the French nuclear option is evolving under the influence of two factors : the divergence between industrial interests in the new competitive environment on one hand-side and the rising requirements from nascent industrial democracy in the French society on the other side. This creates new channels of social internalisation of safety and environmental costs.

Even if the existence of a number of operating reactors and their chance of replacement are not at present questioned, each technological and industrial choice in the nuclear option is henceforth debatable in some arenas (parliamentary committee, public inquiry, expert committees, etc.). The electronuclear industry could not impose any more their preferences as evidence for governmental decisions. It results that less opacity in costs has already been reached. But new internalisation of some environmental costs in electricity generation, in particular with carbon value, tends to renew the rationale for nuclear policy by charging significantly the cost of fossil fuel power generation. A rebalancing by extensive social cost internalisation in the nuclear option, in particular insurance costs and nuclear waste management provisions, would not affect dramatically the competitiveness of the nuclear generation. Therefore the real issue for the future of nuclear option in France appears to be the preservation of the social acceptability, beginning with the issue of the nuclear waste management.

References

Assemblée Nationale (2000) *Loi relative à la modernisation et au développement du service public de l'électricité (Loi n°2000-108)* Paris, Assemblée Nationale.

CGP (Commissariat Général du Plan) (1998) *Energie 2010-2020. Les chemins d'une croissance sobre* (P. Boisson président) Paris, La Documentation Française.

Charpin, J.M., Dessus, B. and Pellat R. (2000) *Etude économique prospective de la filière nucléaire (Rapport au premier Ministre*) Paris, La Documentation Française.

Cour des Comptes (1998) *Rapport sur les comptes de la Nation 1998, Chapitre Observations concernant les entreprises publiques (Chapiter 5)* Paris, Cour des Comptes.

DIGEC (Ministère de l'Industrie) (1993) *Les "coûts de référence" de la production électrique* Paris, Ministère de l'industrie.

DIGEC (Ministère de l'Industrie) (1997) *Les "coûts de référence" de la production électrique* Paris, Ministère de l'industrie.

Eyre N. (1997) “External costs: what do they mean for energy policy?” *Energy Policy*, Vol. 15, n°5, p. 517

Finon, D. (1989) *Autopsie d'un grand programme: l'échec des surgénérateurs* Grenoble, Presses Universitaires de Grenoble.

Finon, D. (2001) "French electricity reform: from weak contestability to effective competition?" *Energy Policy*, Vol. 29, n°7.

Finon, D. and Staropoli, S. (2001) "Institutional and' technological coevolution in the French electronuclear industry", *Industry and Innovation*, Vol. 8, n° 2, August 2001, pp. 179-199.

Mez L. and Piening A. (2002) “Phasing-out Nuclear Power Generation in Germany. Policies, Actors, Issues and Non-issues” (in this issue)

North, D.C. (1991) *Institutions, Institutional Change and Economic Performance,* Cambridge, Cambridge University Press.

OECD-NEA (1992) *Projected costs of generating electricity* Paris, OECD.

OECD-NEA (1997) *Waste management programmes in OECD-NEA countries* Paris, OECD.

OECD-NEA (1998) *Projected costs of generating electricity* Paris, OECD.

OECD-NEA (2000) *Nuclear power in competitive electricity markets* Paris, OECD.

OPECST (1998) *Rapport sur le projet de réacteur franco-allemand EPR* Paris, Assemblée Nationale.

OPECST (1999) *Rapport sur l'aval du cycle nucléaire. Les coûts de production de l'électricité (Christian Bataille et Robert Galley rapporteurs*) Tome II Paris, Assemblée Nationale n° 1359.

OPECST (1999) *Rapport sur le contrôle de la sûreté et de la sécurité des installations nucléaires* Paris, Assemblée Nationale, n° 1496.

OPECST[*](2001) *Rapport sur les possibilités d'entreposage des combustibles nucléaires irradiés (Christian Bataille rapporteur)* Paris, Assemblée Nationale.

Rabl A. and Sparado J.V. (1998) *Coûts externes et décisions à long terme des électriciens* (Etude ExternE 1998) Paris, Ecole des Mines.

Stirling A. (1997) "Limits to the value of external costs" *Energy Policy* Vol. 25, n° 5, pp. 517-540.

Thomas, S. (1988) *The Realities of Nuclear Power: International Economic and Regulatory Experience* Cambridge, Cambridge University Press.

[*] Office Parlementaire d'Evaluation des Choix Scientifiques et Technologiques.