Economy

Twisting global economics

"The difficulties that France is facing to secure its energy supplies in a satisfying way could only be solved in the medium term through largely turning to nuclear power: it is the only energy that can bring timely responses to the problems of costs, commercial bill, security of supply and national independency."

D'Ornano Report (justifying the launching of the 1973 Messmer programme of new reactors), 1974

"The era of cheap oil is over. Nuclear power is more than ever an industry with a future and an indispensable energy. […] The EPR generates electricity which is 30 to 50% cheaper than that generated by a gas or coal fired thermal plant. One can become an electricity exporter although one has neither oil nor gas. This is an historical chance of development."

Nicolas Sarkozy, President of French Republic, Speech delivered in Creusot (France), announcing the decision to build a 2nd EPR, 3 July 2008

Nuclear power is claimed to be a key positive feature of the French economy, both contributing to national energy security and providing abundant and cheap energy for French industry and households. Though one can hardly pretend to grasp the full balance of the nuclear option's positive and negative impacts on the whole economy, basic facts are there to show the gap between the perpetual stream of rhetoric from the nuclear industry and reality.

No clear competitive breakthrough

The idea that France's nuclear choice is good for the national economy is deeply rooted in many people's minds – and a strong belief of most politicians and economic leaders in the country. But what clear advantage has it got? In brief, France's economy did not perform better than those of comparable countries, but rather below average for the European Union, where countries with no nuclear power enjoyed higher GDP growth rates.

The benefit, if any, could just not be seen at such a global level. So one might look for a more specific indicator. The ongoing use of "energy independence" as a key argument to promote the use of nuclear power in France points to the French energy bill, i.e. the commercial balance between French energy imports and exports, as the most relevant indicator.

Failed protection against imports at any cost

Avoiding costly imports of energy is a major goal for the nuclear programme. The development of a 58 reactor fleet seemingly eased the energy bill in a significant way, bringing it down from €28 billion in 1984, risen from just €3 billion in 1973, to €10 billion in 1988. But that is not in keeping with the fact that oil imports, the major contributor to the energy bill, have always been on the increase – and still are. In other words, the fall by 250 percent of oil prices in 1986 and their relative stability in the next years were the main reason for the drop in the energy bill.

Nuclear power's contribution appears very large, responsible for around 78 percent of the electricity produced in France in 2007. But in fact, electricity represented only 20.7 percent of the final energy consumption in France in 2007. And that is even though the French have the highest consumption of electricity per capita in the European Union. Taking into account the large share of nuclear power actually used for electricity exports, the overall share of nuclear power in the national consumption of final energy is rather more in the range of 14 percent, corresponding to 286 TWh.

No wonder then that France's final energy is provided over 70 percent by fossil fuels (oil, gas and coal), a situation which does not show much difference with comparative countries. If reducing oil dependence had been the real target, the development of nuclear power plainly failed. Already the largest consumer of oil in the early 1970s, the transport sector has developed to such an extent that its 70 percent increase in oil consumption largely outweighs the impact of nuclear substitution in the power sector.

The continuous increase in oil consumption, driven by the transport sector, brought French dependence on oil to a peak of 48 percent of final energy consumption in 2007. The limitation of nuclear power in face of this growing dependence on imports showed as early as the end of the 1990s in a jump in the energy bill. The current oil crisis further highlights the failure of nuclear power's promise to avoid a new shock like that of 1973 to the French economy, cruelly pushing up the energy bill to record levels close to €50 billion, a threshold most likely to be broken in 2008 (Figure 19.)[93] With €44.8 billion in 2007, the government recently noted, the energy bill brings down the overall commercial balance of France from a benefit of €5.6 billion without energy to a loss of €39.2 billion.[94]

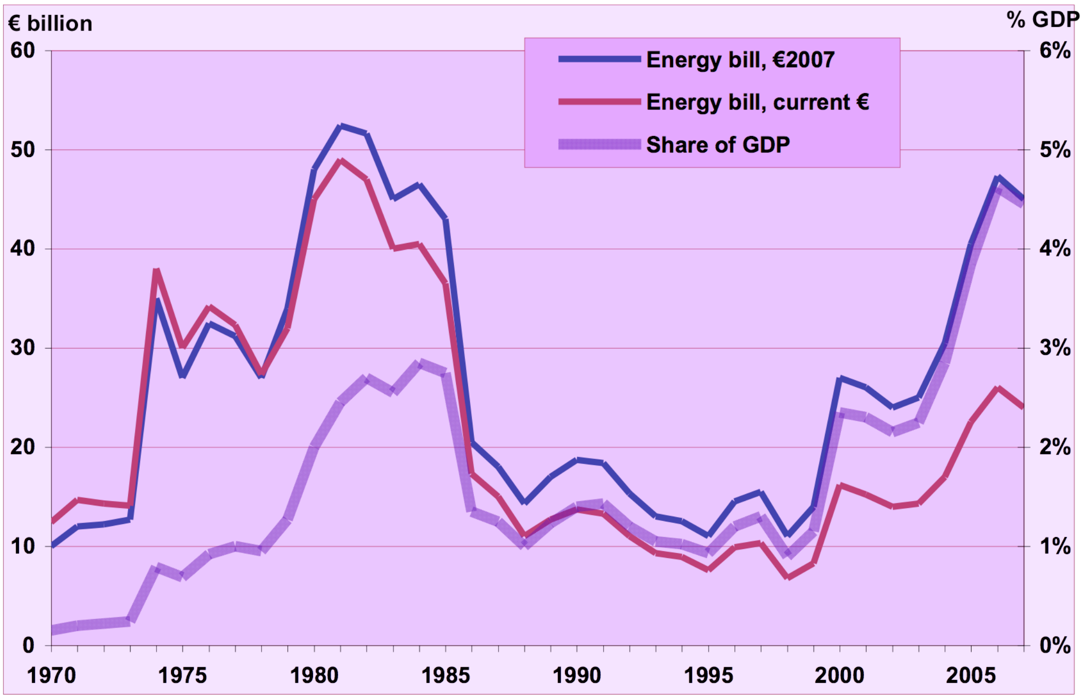
The impact of nuclear substitution, however, should be taken into account. This is obviously highly dependent on what one considers the nuclear reactors to be substitutes for. The French Ministry of Industry used to base any such calculation on a "substitution rule" where any nuclear generation would replace that of an oil-fired plant with a 38 percent efficiency ratio (corresponding to the old thermal plants of the 1970s). This method was used up until 2001, when France gave up this specific energy accounting and adopted the international IEA accountancy standards, to artificially increase the weight of nuclear substitution in the energy balance.

A more reasonable basis for comparison, as shown by the trends of generating capacity in the European Union, should be to consider the substitution of nuclear reactors to gas-fired power plants. The amount of natural gas needed to generate 310 TWh in order to deliver the equivalent 286 TWh of final electricity to French consumers that nuclear energy provides would amount to 47 Mtoe. This would represent an increase of € 10.7 billion of gas imports, based on the € 9 billion for the actual net import of 41.3 Mtoe of gas by France in 2007. However, this is an upper value for the need of gas in such a "what if" calculation. The French nuclear programme had a negative influence on other policies which could have been much more developed had another energy pathway been chosen as of the 1970s – renewable energies for heating and electricity, improved efficiency of buildings, etc. – reducing the final energy needs to provide the equivalent energy services to those provided by nuclear power. Also, the massive development of electric heating could have been avoided, and a significant part of that heating could have been much more efficiently provided by gas-based central heating systems instead of gas-fired stations and electric heating – again, reducing the amount of gas needed to provide the same service.

93 In particular, if the further increase of oil prices in the first half of 2008 is confirmed in the second half. The small decrease of the energy balance in 2007 as compared to 2006 is essentially due to the combined effects of a mild winter and a strong change of € against $.

94 Direction générale de l'énergie et des matières premières (DGEMP), *Facture énergétique de la France en 2007*, June 2008.

Figure 19 **French energy bill and its share of GDP, 1970-2007**



Source: DGEMP, 2008

Electricity exports: the soaring cost of overcapacity

So much for the protection provided by the use of nuclear power against rising imports of oil and gas at increasing costs. Yet another claimed line of contribution is the commercial benefit from electricity exports. France has always been since 1981 a net exporter of electricity, with a strong increase to reach 50 TWh by 1991 and a peak record of 77 TWh of net export in 2002. The average net exchange went down to 56.8 TWh in 2007 through the combined stabilisation of a small decrease of exports and increase of imports. This level is not matched by any country in Europe.

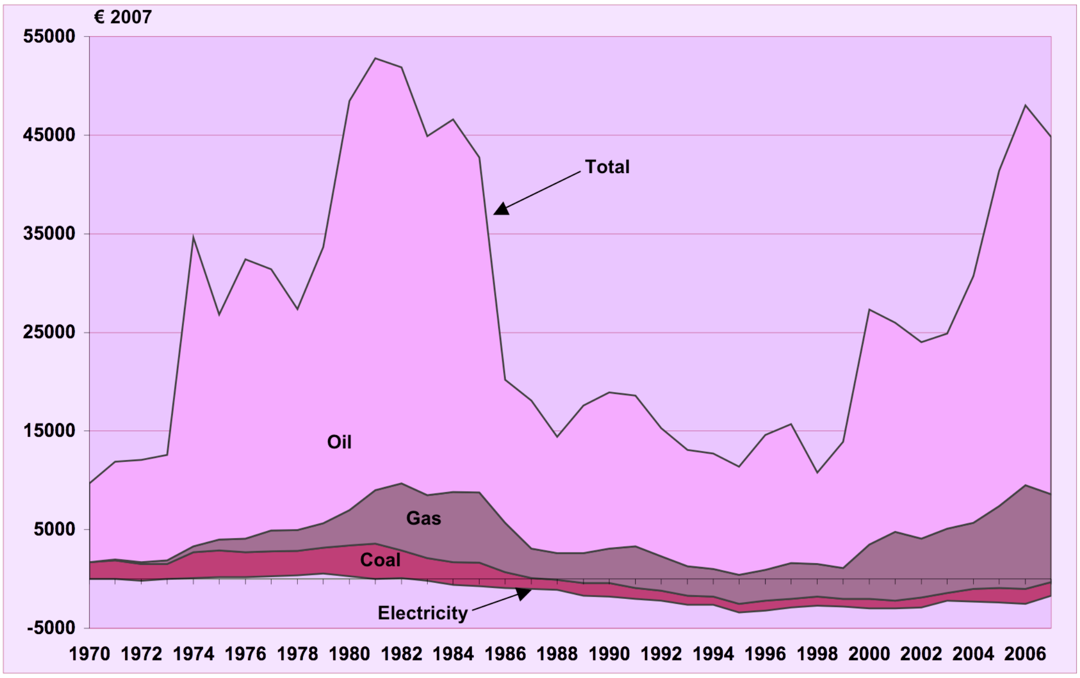
The electricity exchanges, accounting for a net export of 4.9 Mtoe, remain actually marginal compared to the oil and gas net imports of 130 Mtoe in 2007 (90 Mtoe of oil and 40 Mtoe of gas). This reflects in the breakdown of the French energy bill by source, which shows the very low contribution of electricity (Figure 20.) However, the pattern of electricity exports, as shown by the fact that they remain very high, even though the economic burden of oil and gas imports is rising, has nothing to do with energy security. Their driver is the overcapacity of French nuclear power plants.

Faulty forecasting of electricity consumption, which did not rise as sharply as promised, and the lack of timely adaptation of the planning of construction of nuclear power plants, resulted as early as the mid-1980s in a large overcapacity of the French nuclear fleet, which could be estimated at 12 to 16 nuclear reactors. The total installed power generating capacity reached 115,9 GWe as of the end of 2007, of which 63,3 GWe was nuclear power. This compares to a peak demand of 89,0 GWe in 2007, but also a minimum demand of 31,6 GWe, respectively in mid-December and mid-August, the main reason for this huge gap being the extensive use of electric heat in French buildings.

The technical and economical need for the nuclear reactors to operate as much on a base-load basis as possible implies that their production is in excess for large periods of time throughout the year. Exporting electricity was therefore a mean to use some part of the overcapacity and pay for the stranded investment costs. In the mid-1980s, EDF started long-term contracts of base-load electricity supply to foreign utilities in Belgium, Switzerland, Germany, Italy, Spain and the UK, offering very low prices and very high guarantees of supply. The profits claimed from those contracts by EDF and the government are doubtful and commercial data have never been provided to confirm them. On the contrary, independent assessments show that official income from exports remained below the official cost of nuclear generation, and suggest that power exports generated major losses estimated at €0.8 billion to €6 billion per year (through 1995-2001).[95]

Meanwhile, the continuous increase of peak demand brings some changes of priorities. Many of the long-term contracts were not renewed when they ended in 2005, and the need for imports linked to periods of high demand has increased. The electricity price can get much higher on the European market during such periods than it is when the French oversized nuclear plants have excess electricity to sell. The commercial balance of electricity exchanges remains positive but is evolving in a negative way. The mean prices of electricity exchanges for the years 2006-2007 show import prices between two and a half and three and one-tenth higher than export prices – a ratio to consider with some caution, as the range of prices from base-load to peak demand is much more extended and the physical exchanges seem to include the use of French lines for transit between neighbouring countries (mostly Germany to Switzerland).

Figure 20 **French energy bill broken down by energy source, 1970-2007**



Source: DGEMP, 2008

No clear pattern of electricity prices

Besides energy security issues, nuclear power was chosen on the grounds of its supposed competitiveness. Governmental estimates have regularly claimed that nuclear power plants were the cheapest available option for electricity generation in France, providing the country with the lowest electricity prices in Europe.

Prices of electricity for households are below the average prices in the European Union, but not the cheapest. Also, the price taken into account for France is that of the regulated market, excluding higher prices found on the small deregulated share of the market. For many reasons, this regulated tariff decided by the government does not necessarily reflect the full cost of nuclear power generation.

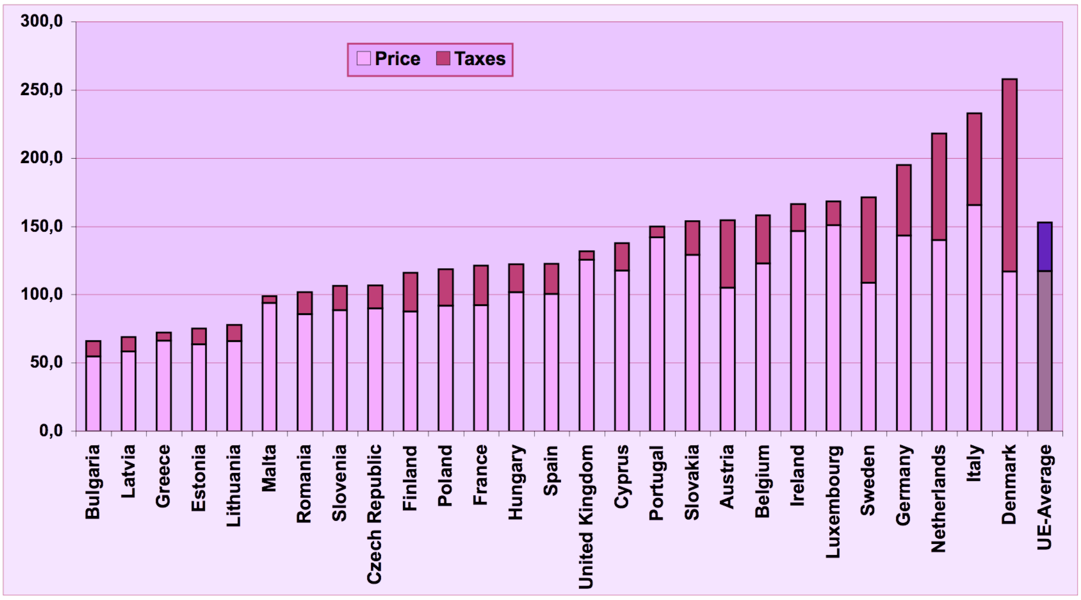
France comes third of EU-15 in the Eurostat comparison of electricity prices in the European Union, based on a standard household consumption of 3,500 kWh (Figure 21.) As for any comparison of that kind, the realness of assumptions behind the "normal" conditions considered in all countries is the key.

[95] A. Bonduelle, *Exportations de courant électrique : qui perd, qui gagne ?*, commissioned by Greenpeace France, Inestene, November 2002.

Another comparative study, by National Utility Service Consulting, ranked France sixth, with higher prices in 2006, and ninth in 2007 for industrial customers on the deregulated market – out of 14 countries, of which ten were European. Also, this study notes, "all European countries have reported their energy markets as being at their most volatile in several decades with this trend continuing in the future".

The good ranking of France is thus partly due to the predominance of a maintained regulated market, somehow disconnected from the real costs: energy planning, electricity generation and regulated tariffs are all managed by the state. Yet another factor should be taken into account when it comes to customers: how much one household has to pay depends on the price but also the amount it needs. One mean to improve the economics of French nuclear plants has been to develop the use of electricity, especially through a massive development of electric heating in the residential sector. With 145 TWh of electricity consumption in this sector, households use on average more than 7,000 kWh per year, or twice the "normal" condition considered for comparison in the Eurostat study.

Figure 21 Electricity prices for households in EU-25, as of 1st January 2007[a]



a. Prices in € per 100 kWh, for a yearly consumption of 3,500 kWh including 1,300 kWh at night.

Source: Observatoire de l'énegie, based on Eurostat, 2007

One key to nuclear economics is the higher share in the cost of nuclear power plants, as compared to other plants, of the investment. As both the regulator of electricity prices and the full owner of EDF, the French government could freely plan the rhythm of the return of capital costs, overcoming one of the main obstacles to the construction of nuclear reactors in deregulated economies. Moreover, this integrated framework, completed by the state ownership of the R&D body CEA and the operator Areva, allowed for large public funding in support of the nuclear industry in many ways, including very extensive R&D developments – up to the financing of industrial size prototype fuel cycle plants – ,costs linked to the electricity grid, adaptation of taxes, guaranteed loans with low rates, etc. This all points to the need to look for complete costs rather than drawing conclusions from prices…

Behind prices, the real costs

Government assessments of the projected costs of nuclear power plants started with the publication of the first report in 1964 by the PEON commission, followed by ten reports up to 1979 and replaced from 1981 on by the publications of the DIGEC, a department in the Directorate for Energy and Raw Materials (DGEMP) in the ministry in charge of energy [see Focus]. These official assessments have been regularly challenged on grounds of their methodological flaws and the oriented choice of hypothesis.

However, due to a lack of strong criticism of the nuclear option in the main government parties, it was not until 1997, almost 25 years after the choice in favour of a large number of pressurised water reactors had been made, that pursuing this option was challenged for the first time within the government after the victory of a left-wing alliance including the Green Party in general elections. This resulted in the first major attempt to draw a global public assessment of the economics of the nuclear option in France.

A report was thus commissioned, in May 1999, by the Prime Minister to Jean-Michel Charpin, Benjamin Dessus and René Pellat (then respectively Director of the General Planning Commission, director of a pluri-disciplinary programme on energy in the CNRS, and High Commissioner for Atomic Energy), to conduct "a study concerning the economic data of the entire nuclear industry" and "a comparative analysis of the various methods of generating electricity", taking the "full costs" into account for all options, including "all of the factors on which a public decision must be based: inherent competitiveness, externalities and long-term effects."

The report compiled data from the industry (EDF, Areva…) and had them analysed by experts inside and outside the industry to draw the economic balance of the existing nuclear fleet of 58 PWRs over its planned lifetime. The overall cost, not discounted, of investment (including specific R&D), operation and fuel (including front-end and back-end, up to final waste disposal) was estimated in the range of €418 to 446 billion (original costs are expressed in FrF of 1999), depending on assumptions on the reactors' lifetime and on the back-end. It showed the importance, in undiscounted calculations, of operation (€184 to €197 billion over 40 to 45 years) and fuel-chain costs (€124 to €144 billion) compared to the capital cost (€99 to €103), which is the dominant factor in discounted cost.

Finally, the report compared prospective scenarios up to 2050, introducing a mix of options on the demand side policy (high or low evolution of energy consumption) and on the supply side, from reinforcing the nuclear share in the energy mix to lowering it to a base-load level, or replacing out-of-date reactors with other sources of energy, mostly modern gas turbines. Calculations showed that economics could not strongly point to a cheaper option between pursuing the nuclear programme or replacing ageing reactors with alternative thermal power plants, e.g. gas-fired ones. How this result might differ if it took into account the changes in economic conditions since 2000 is not obvious. One might think at first that rocketing oil and gas prices would give a real advantage, in these official calculations, to the nuclear option, but large increases in reactors' costs or uranium prices could very well equalise the two options.

However, this growth of all energy costs reinforces what was already the main conclusion of the Charpin-Dessus-Pellat report. Low-demand scenarios appeared less costly in any case than high-demand scenarios, with the level of demand making a much higher economic difference than the energy mix for a given level of energy demand. Therefore – and even more so with today's cost conditions – energy efficiency should be a primary priority of any sustainable energy policy, while the choice of nuclear energy among alternatives for electricity generation should only be a secondary issue. Furthermore, the report concluded that the equivalent of the average difference between high- and low-demand scenarios, amounting to some €2 billion per year, could be spent on energy savings without losing any money. Again, a higher figure might be appropriate now, given today's energy costs.

Closing a vicious circle

The report was the first publication of its kind in the nuclear field to gain positive comments from most players, from the government to the industry, the political parties, trade unions and NGOs. At a time when no new reactor was on track, it gave a rare opportunity to review the priorities of the French energy policy. What happened next was the opposite: successive governments since 2001 have chosen to keep nuclear energy on the spot, and given priority to the construction of a new reactor, the first EPR. Although EDF insisted that its project was not driven by immediate priorities in energy needs but was reponding to its industrial strategic goal to maintain its capability to build nuclear reactors, and admitted that it might be a loss maker, the administrations advising the government produced reference reports to justify the need for an EPR on the energy side and to show that it would be competitive.

After more than 30 years of rhetoric, the myth of the nuclear role in French competitiveness has become stronger than reality. Policy makers and their official advisers appear caught in a vicious circle, where new official assessments must confirm the same results – even though they might be repeating previous mistakes – while their conclusions encourage decisions increasingly remote from reality. The announcement by President Nicolas Sarkozy, as of 3 July 2008, that a second EPR will be built in France in the future, as the best response to the shock of oil prices on the French economy, takes this surreal policy even further.

Focus 17 From "too cheap to meter" to too expensive to tell?

The forecast of American nuclear proponents in the 1950s – that nuclear power would be "too cheap to meter", in other words that the cost of metering would exceed the cost of production and delivery to the customers – demonstrates how confidence in the technology produced a skewed vision of its economic performance.

From the very beginning, the nuclear industry has always promoted itself as being one of the cheapest options for electricity. In fact, the planned costs have most of the time been unrealistically low, due to a series of repeated biases in economic assessments, including forecasting mistakes, over-optimistic technical assumptions, systematic use of the best suited economic values, extensive use of accounting methods favouring nuclear power, etc.

The French Consultative Commission for the Production of Electricity of Nuclear Origin (PEON), gathering 31 high-level experts from the administration and the industry, advised the government from the end of the 1950s to the end of the 1970s on the projected costs of new nuclear projects. It produced 11 reports from 1964 to 1979. Then the Department of Gas, Electricity and Coal (DIGEC) in the Ministry of Industry took over with a series of studies prepared with a working group of administration and industry experts on the "reference costs" of electric power. It produced eight reports from 1981 to 2004.

These reports invariably advised in favour of the nuclear option, and backed continuous support from the government to new reactor projects, from the launch of the PWR fleet with the Messmer programme in 1973-4 to the decision to build a first EPR in Flamanville in 2005-6. A quick historical glance shows how much this process has been flawed all the way along, and decisions made on a succession of unrealistic assessments.

To start with, PEON reports, which based their economic analysis of the need for new power capacities on forecasting of electricity consumption, have systematically overestimated the growth in demand. The 1973 report, which was key to the launching of the French nuclear programme as it stands now, overestimated electricity demand as close as in 1975 by 7.7 percent (real consumption reached 181 TWh instead of the forecasted 195 TWh), in 1985 by 32 percent (303 TWh real against 400 TWh planned) and in 2000 by 75 percent (430 TWh real against 750 TWh planned).

The same 1973 report, fifth in the PEON series, included for the first time in the cost calculation of new nuclear reactors the cost of nuclear waste management, neglected before. Yet it included neither the decommissioning costs, which were not taken into account until in the 1977 report, nor the R&D costs, which were considered for the first time in the 1993 DIGEC report.

It is also noteworthy that the investment cost assumed for a new PWR in the 1973 report was the lowest ever in the PEON-DIGEC series. The report used, based on the return of experience of the first generation of French reactors (natural uranium, graphite and gas, UNGG), an investment cost of 4,000 FrF96. After the construction of the first reactor in Fessenheim, which took two more years than expected to complete, the assumption used in the 1977 report rose to 5,200 FrF96. The investment costs used in the next reports increased, each time, to catch up with real costs that were invariably higher than the projected ones.

As the reports included the fuel costs and compared new nuclear reactors with other options, their assumptions about the prices of oil, gas or uranium played an important role. The PEON and DIGEC reports, like many others, constantly got it wrong when predicting the prices of primary energy materials, with all reports before 1973 forecasting low price rises, then all reports before 1986 forecasting high ones. More recently, 1997 and 2003 DIGEC reports have assumed high oil prices that nevertheless remain far off the actual increases.

Similar mistakes in forecasting uranium prices provided a faulty basis for very important decisions in the period 1975-85. The peaking of uranium prices in 1975-9 (from 25 \$2007/lbU_3O_8 in 1973 to more than 110 \$2007/ lbU_3O_8 in 1977) resulted in a forecast of high prices for the next decades that proved wrong, as prices on the uranium market fell as soon as 1980 to 40 \$2007/ lbU_3O_8 and remained very low for the next 20 years (below 20 \$2007/ lbU_3O_8 between 1988 and 2003), only climbing again in recent years to reach a new peak at 120 \$2007/ lbU_3O_8 in 2006, from which they went down to below 60 \$/ lbU_3O_8 in mid-2008. Meanwhile, the French government decided, based on projected prices for uranium more than twice those later realised, to launch the fast breeder reactor Superphénix in 1977, and the large-scale policy of spent fuel reprocessing and plutonium re-use as MOX for PWRs in 1985. The two-fold mistake on uranium prices, though, was key to giving PEON's and then DIGEC's own calculations a positive economic result instead of a negative one.[96]

Another regular bias is the systematic use of the best range of technical and economical hypotheses regarding the performance of new reactors. In its 1997 report, DIGEC concluded that new nuclear reactors would reach a better performance, by a narrow margin, than modern thermal plants using gas. However, this was only the case when piling up a series of assumptions on the economic conditions of investment and operation of a new reactor, each of them unlikely to be met in real conditions. For instance, the investment cost had to be scaled down by ordering ten reactors instead of one, an unrealistic assumption in the context of overcapacity of the French electric system. Also, the new reactor needed to reach a load factor of 85 percent, an unrealistic assumption given the fact that the French PWRs never exceeded an overall performance higher than 80 percent of load factor. Applying the more realistic assumptions of 20 percent higher investment cost for a single order instead of a series, and of a 75 percent load factor for a new reactor would wipe out the supposed competitiveness of a new nuclear reactor. Yet this is only shown in a table in an annex of the report, while the conclusions for the decision-makers are based on the over-optimistic scenario.

The last report of the series, published by DIGEC in 2003, proved even more controversial than its predecessors, mostly due to a lack of transparency in its preparation. Its calculation of the projected cost for a first EPR benefited from the usual kind of assumptions: investment cost based on a ten-series order, higher load factor of 90 percent, and even a fuel performance of 70 GW.d/t, although reaching this level is highly unlikely.[97] But the report went even further, introducing highly controversial unit costs by using the cover of industrial and commercial secrecy.(It argued that new competitiveness between industrial players required protection of their sensitive data. Accordingly, DIGEC proposed that the unit cost for each energy be discussed between DIGEC and each operator rather than in a working group.) Discussions between DIGEC and Areva provided unit costs for EPR construction and reprocessing far below those provided, only a few years before, by the same operator to the authors of the Charpin-Dessus-Pellat report: 1,043 €/kWe instead of 1,320 €/kWe for the construction cost, and 450 €/kg for reprocessing instead of 870 to 1,500 €/kg. Such hypotheses were highly criticised in the working group and outside it for lacking credibility and appearing "tailor-made" to respond to the political will of a positive result for nuclear competitiveness.

96 It can be added, regarding the decision to launch Superphénix, that the rationale for developing a plutonium-based industry was aimed at reducing the pressure on the natural resource of uranium, in the context of over-optimistic projected installed capacities. The 1974-6 PEON reports forecast 158 GWe of installed nuclear capacity in France by 2000, or more than two and a half times the actual capacity of 63 GWe.

97 The performance of fuel, expressed in burn-up of "power days per tonne" (GW.d/t), refers to the quantity of nuclear fuel needed to produce a given energy in the reactor. Increased performance means a decrease in the outage time for reloading the reactor, and a decrease in the quantity of nuclear material to handle, both described as favourable in terms of economics. 70 GW.d/t is well above the current 55 GW.d/t reached in the current fleet, and a number of technical and safety issues would have to be resolved before such a burn-up could be authorised and reached in a French reactor.

Focus 18 EPR costs: high and rising

> *"Olkiluoto is often presented as a showcase of an open process in a democratic country. The process might have been democratic, but the information that the democratic decisions were based on has turned out to be false and misleading."*
>
> **Greenpeace Finland, Olkiluoto-3 Factsheet, March 2008**

With one order placed in Finland and one in France, the EPR, a 1,600 MWe reactor based on French and German design, is the first reactor being built in Western Europe for more than 17 years (28 years outside France), and the first of the so-called "third generation" to be built in the world.

Olkiluoto-3 was predicted by the Finnish power company Teollisuuden Voima Oyj (TVO), in the early stages of licensing, to cost €2.5 billion and take four years to build. With the choice of EPR, a reactor with a higher capacity than that initially sought for, the contracted price went up to €3.2 billion, with a fixed price, and the agreed construction time became four and a half years. As of mid-2008, delays in the construction work, plus increased prices of raw materials and possibly other factors, led to estimates of cost overruns up to €1.5 billion, putting overall investment cost at around €5 billion. After two and a half years of construction, it is estimated that construction might actually take seven years. It is likely that French economic players, not Finnish ones, will have to pay for the direct cost increase. However, this delay in delivery will also hamper the whole electricity sector in Finland, resulting in higher prices for Finnish electricity consumers for a total cost that heavy industry in Finland (as a large consumer of electricity) estimated to reach about €3 billion in 2008-12. Moreover, though the Finnish EPR is presented as a truly market-financed private investment, the French export credit agency, Coface (usually covering export projects in countries presenting a financial risk) and a bunch of public banks ensure a very low interest rate, specific guarantees and favourable financial terms for the project.

The French EPR project is set in a different context. Its operator, the French utility EDF, has decided to develop it mostly for industrial – i.e., not energy – reasons linked to its strategic goal to keep the capability to build its own reactors in the future. On one occasion, during the national public debate that preceded the formal decision to build the reactor (although the political decision had already been made by the government and the parliament), EDF admitted that given the status of the electric system, this strategic industrial choice might represent a financial loss.

EDF forecast the generation cost of its new reactor to reach 43 €2004/MWh. In the document filed to the national debate, the utility insisted that this cost included the whole R&D cost for developing the EPR technology. This cost, presented to the public in 2005, was 44 percent higher than that published less than two years before by the DIGEC in its advisory report to the government on "reference costs", which underpinned the government decision to launch the project… EDF had to explain the difference between its cost estimate and the very low DIGEC estimate of 29.9 €2004/MWh (published as 28.4 €2001/MWh). The main difference came from the impact of a series (ten orders in DIGEC assumptions) compared to a single order, with EDF calculating that for ten EPR the cost would lower to 35 €2004/MWh. The remaining difference, still a 17 per cent increase, is explained by a series of favourable technical and financial hypotheses in the DIGEC report that EDF would not endorse, including: economic life of 60 years in DIGEC lowered to 40 years by EDF (although EDF aims for a technical lifetime of 60 years, never reached yet), assumptions more conservative and "in line with international accounting rules" by EDF than by DIGEC, etc.

Yet EDF's calculation still uses some assumptions pointed out as unrealistic or very uncertain by critics of the 2003 DIGEC report, such as the burn-up increase, the load factor (based on an availability factor of 91 percent) or the time of construction, 57 months (four years and three terms) – a figure already doubtful after the suspension for one month of on-site work by the nuclear safety authority ASN, due to problems very similar to those earlier experienced by the Finnish project. It is likely that reality won't justify the optimistic estimates, and the real cost of EPR will inevitably increase from the figures used in the licensing phase. In the press release announcing the formal launching of the EPR project in May 2006, EDF mentioned that the complete cost of the EPR might rise to 46 €2005/MWh, due to changes in context like the price of steel, setting the construction cost at $3.3 billion, i.e. 10 percent more than the figure of "around €3 billion" presented by EDF in 2005 to the public debate. The latest figure published by the economic press, as of July 2008, sets the construction cost estimate at €3.4 billion.

Side economics: downplaying associated costs

"Compared to other energy sources, nuclear power is behind in the trend towards the liberalization of energy markets. The heavy investment and research costs, the long time lag before payback, the uncertain evolution of technologies, the problem of reprocessing and waste, and the sensitivity of public opinion on security issues, all point to high industrial and financial risks that require some State involvement. […] The State control over the public industrial players in [French] nuclear industry is key to guarantee the competitiveness of nuclear power, notably through public R&D financing."

Report of the Seminar "Energy and Society", Ecole nationale d'administration (ENA), Promotion Copernic, 2002

The cost of a nuclear reactor, as discussed in the case of the EPR, includes the investment cost and the operation cost but also many associated costs in the front-end or the back-end of its construction and operation. These include direct costs, like R&D costs, the costs linked to the fuel chain, and the costs raising from the inheritance of nuclear power – radioactive waste management and decommissioning. There are also indirect costs which might be significant, especially those arising from implementing the appropriate technical and organisational framework, like the costs of the high-voltage electric grid or the costs of assessment and control of safety and security. Official estimates usually neglect or downplay such costs.

R&D costs

The total R&D costs in public support of the nuclear industry in France can hardly be calculated due to a lack of sufficient data and the difficulty of separating out costs regarding the overlap between civil and military applications, or the share of fundamental research in CEA later used for nuclear developments. It proves even harder to identify the respective R&D costs associated with the various technologies developed in nuclear generation and the fuel chain.

Altogether, at least half of the costs of nuclear power R&D have been covered by CEA public funding. The total R&D expenditures of CEA for the civilian nuclear programme since its creation in 1946 were estimated for the Charpin-Dessus-Pellat report as €24.7 billion (FrF 162 billion) as of the end of 1998.

Economic Costs of Reprocessing in France

In France, the costs associated with the fuel chain are framed by the structural choice to reprocess – at least partly – spent nuclear fuel. The strategic decision to launch the large scale reprocessing of spent fuel from PWR reactors was taken at the end of the 1970s, at a time when uranium spot prices reached a peak that was not reached again until the end of 2006, with the price already down to half that record level as of the mid-2008. The assumption that uranium prices would, contrary to what actually happened later, remain high and rising justified a fleet of fast breeder reactors, with Superphénix as the first order, then the construction of a reprocessing plant and later a MOX fuel fabrication plant to separate and re-use the plutonium from PWRs in PWRs.

The decisions have been made, and Superphénix, La Hague UP2-800 and UP3 and Marcoule MELOX have been built, although the economic rationale, as in the terms set out by the industry and government themselves at the time of high uranium prices, had disappeared with the end of that uranium peak.

Superphénix undoubtedly proved a big loss. Ordered in 1976, the 1,200 MWe reactor was connected to the grid in 1986. It experienced various technical and administrative problems until it was permanently shut down from 1996 and its decommissioning decided in 1998, eventually achieving no more than a 7 percent load factor, with a mere gross production of 8.6 TWh over its short lifetime. The overall cost of Superphénix has been estimated as €9.7 billion (FrF 64 billion) by the Court of Auditors (Cour des Comptes) in 1996, very close to the estimate provided by its operator, the European consortium NERSA, in 1998, at €9.8 billion (FrF 65 billion, of which FrF 38 billion being paid for by EDF). Yet this does not include the stranded R&D cost and a potential rise in the future costs for decommissioning and waste management, including the storage and future disposal or reprocessing of the two cores fabricated for the reactor, one irradiated and one non-irradiated.

The case for reprocessing and MOX fabrication could be laid out just as clearly, if the global economics of the plutonium industry were discussed in an open way. The Charpin-Dessus-Pellat report commissioned by the prime minister in 1999-2000 offered a rare occasion to do so. Using real and projected costs provided by the industry, the report compared the global costs of the current nuclear fleet under various assumptions, including the status quo on reprocessing and MOX on one hand, and the theoretical scenario of a choice for direct disposal of spent fuel from the beginning of the French PWR programme. Although embedding favourable assumptions on future costs linked to reprocessing, like those of La Hague decommissioning, the report concluded that the choice of the French government in favour of reprocessing represented an increase in average generation cost of about 5.5 percent per installed GWe over the reactors' lifetime. In other words, not developing reprocessing from the start would have provided total savings of €25 billion (FrF 164 billion).

In 2003, the official DIGEC report on reference power costs acknowledged, that "for the time being, the low prices in the front-end of the fuel cycle (natural uranium and enrichment services) do not justify the reprocessing of spent fuel on purely economic grounds." But while it recognised the conclusions of the Charpin-Dessus-Pellat report as "representative of the current economics of the fuel cycle", the DIGEC used instead projected costs for the period 2025-85 (corresponding to the reprocessing of the spent fuel of a future EPR reactor). The assumptions, based on confidential discussions between Areva and DIGEC, proved less than half the costs calculated in Charpin-Dessus-Pellat (450 €/kg of reprocessed fuel instead of 1,000 €/kg or more under various assumptions). No explanation was given for cutting by half the investment and operation costs of a future reprocessing plant as compared to La Hague, apart from a clear statement on its political origin by DIGEC: "the cost of reprocessing used in the study is the cost objective needed to guarantee the competitiveness of reprocessing compared to the direct disposal option."

This fools' game of using unrealistic assumptions to preserve the appearance of an equivalence of costs between reprocessing and direct disposal might not be played for long by EDF. With more than 8,000 tHM of spent fuel stored at La Hague, representing 99.8 percent of the material stored in advance of reprocessing as of 31 December 2007, the French utility is faced with financing most of reprocessing costs. In 2007, in the first phase of working discussions preparing an update of DIGEC's 2003 report, EDF explained in a working document that it "expects the new [reprocessing] facilities to allow for some gains in productivity," but that "one must remain cautious about the final impact on reprocessing costs" and therefore, "EDF regards the values used in the report as a low estimate."

Since 1995, EDF has assigned in its accounts a zero value to its stocks of separated plutonium – as well as to its stocks of reprocessed uranium – and made it publicly clear that, if a market existed for separated plutonium from PWR fuel, "the price would be negative". EDF is for instance charging the Dutch utility EPZ (which has its fuel reprocessed in La Hague but no means to reuse the plutonium) for taking its plutonium – rather than paying for it. The liberalisation of the electricity sector presses EDF to lower its costs, including those linked to the plutonium industry. While the reprocessing and MOX contract signed for seven years in 2001 had already included an option for 2008-15, EDF only signed on to a provisional one-year follow-up agreement with Areva in April 2008.

Decommissioning and Waste Management

The reprocessing option has a strong impact on waste management policy and costs estimates. The key issue in cost calculations is the burden of final disposal of very long-lived and highly radioactive waste, set to be a geological repository by the 2006 law on radioactive waste management. Although large uncertainties prevail in this matter, refining the design is not necessarily bringing the costs down, as illustrated by projected costs published by Andra. Its estimates of the total cost of a geological disposal rose from €14.7 billion in 1996 to a range of €15.9 billion to €58.0 billion in 2003.

This 2003 estimate conveniently concluded, in line with the claim that reprocessing is reducing waste volumes, that ending reprocessing in 2010 would more than double the cost of final disposal as compared to reprocessing all spent fuel. The bias was however obvious: in the first case, the cost accounts for the disposal of all nuclear material discharged from the reactors; in the second case, on the contrary, more than half of the total plutonium and uranium inventories are transferred to an hypothetical next generation of reactors, and none of the cost arising from the management of the waste this will produce in the future is accounted for.

As the 2006 law would require dedicated funds from the operators to cover long-term costs of waste management, the Ministry of Industry set up a group with the operators to reduce the range of uncertainties in Andra's estimates. The group concluded with lower-cost estimates for the total reprocessing scenario, in the range of €11.5 to €12.9 billion. The Cour des Comptes stressed in a subsequent report that the study failed to deal with major uncertainties on the waste site, its design and inventory or size, as some of the main cost factors remained very high. It insisted that the reduced costs displayed were caused by an announced strategy that had yet to demonstrate its technical and political feasibility.

Many factors have still to be taken into account that will lead to higher costs of disposal than the current estimate. Calculation is based on the availability of a repository by 2020, but the programme is already some years behind schedule. The final conditioning of some categories of waste, representing some of the largest volumes has yet to be designed, as well as some concepts of galleries. Finally, some of the separated nuclear materials assumed to undergo indefinite reuse will eventually go to final disposal.

Long-term liabilities also include the decommissioning of one of the world's largest infrastructure of nuclear power plants, research centres and facilities of all kinds. The Court des Comptes has calculated liabilities pending on the three main operators (EDF, Areva and CEA) to a total of €65 billion (undiscounted) as of the end of 2004. This includes the decommissioning of PWRs, for which a provisional estimate of 15 percent of the investment cost is used, but also the huge costs of decommissioning reprocessing plants. However, a part of this cost might be lifted from the operators and transferred to public funding. In 2004, the provisions calculated by Areva for the decommissioning of its facilities dropped from a total of €12.2 billion to €8.0 billion thanks to a bailout agreement with CEA transferring to the state the decommissioning responsibility for the Marcoule reprocessing site in exchange for a lump sum payment by Areva of €427 million plus a commitment to a future payment of €158 million.

Structural costs

To estimate structural costs linked to the development of nuclear energy is out of reach of a simple independent analysis, for obvious methodological reasons including the difficulty of setting a limit to costs attributable to the nuclear industry and the lack of data on structural costs in general. Nevertheless, nuclear energy generates some specific infrastructural needs that can be identified and discussed on the basis of a few examples.

One obvious need linked to nuclear power is that of the appopriate electric grid to transport and distribute the electricity generated by nuclear power plants. Of course, an electric grid would be needed in any case to distribute electricity to consumers, yet the highly centralised repartition on the territory of nuclear power casts some specific needs. This is illustrated by the case of the EPR project in Flamanville, where the introduction of a third massive unit producing electricity on the site requires an additional high-voltage line to help evacuate energy from the site and transport it to areas of consumption. Although the projected line would provide a larger benefit to consumers than the evacuation of the EPR production, these benefits could be obtained through other options, some of them at a lower cost. A large part of the investment cost to build this 150 km, 400 kV line, estimated at €240 million, is therefore directly attributable to the EPR project.

The global investment costs for the development of the electricity grid (transport and distribution) from the 1970s up to 1997 has been estimated by a working group for the Charpin-Dessus-Pellat report to reach more thant €75 billion, of which more than 10 percent is for the very high voltage grid. By the turn of the century, around €2.9 billion was spent each year for developing the grid, of which 0.5 billion was for the very high voltage grid. Based on those costs, the report introduced a difference of €6.8 billion over the period 2000-2050 in a low-electricity-demand scenario, in favour of a non-nuclear, decentralised power system compared to a status quo nuclear fleet.

Structural costs such as those arising from the organisation of safety and security are even more difficult to assess. These cover, for instance, a large part of the IRSN budget – amounting to €276 million in 2006 – dedicated to public expertise and advisory work on radiation protection, nuclear safety and security issues. Or that, of course, of the nuclear safety authority, ASN and its decentralised control means in the French regions, around €50 million. The specific activities of security forces to protect nuclear facilities and transports should also be included.