COUR DES COMPTES

Summary

of the Public Thematic Report

January 2012

The costs of the nuclear power sector

Notice

This summary is designed to make the Cour des Comptes report easier to read and use.
The Cour des Comptes is responsible only for the content of the report.
Replies from government departments and entities concerned are appended to the report.

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Introduction

In a letter dated 17 May 2011, the French Prime Minister asked the Cour des Comptes to prepare, as part of its assignment to assist the French Government (now defined under Article L.132-4-1 of the Financial Courts Code) a report on "the costs of the nuclear power sector" to be submitted before 31 January 2012.

The resulting report brings together most of the factual data currently available on the past, present and future costs of generating nuclear electricity in France. It does not take a position as to the desirable level of this output or how it should be funded. The report can be seen as a "database" prepared to inform the public and promote transparency.

For the most part, the study focuses on the running costs of existing nuclear power plants as shown in operators' accounts. These costs can be investment expenditure (past), current expenditure (operating expenses) or future expenditure (dismantling and fuel and waste management).

The Cour des Comptes wishes to measure these costs "for society", not just for the operator. For this reason, it has also assessed expenditure funded by the public sector, which is not generally taken into account in energy costs, for want of precise figures. For the first time, an estimate was made of all French research expenditure relating to nuclear power generation since 1957. The Cour des Comptes also measured security and safety expenditure funded by the public sector in 2010.

Its analysis therefore excluded military nuclear expenditure and electricity transmission and distribution costs, focusing solely on the cost of generating nuclear electricity, which only accounts for some 40% of the price paid by the consumer.

The report does not compare the cost of different sources of energy or various energy mix scenarios. It does not compare costs to tariffs. The Cour des Comptes does not judge whether the public funds concerned are well or poorly managed. This is not an evaluation report.

In order to carry out this study, the Cour des Comptes organized a very broad consultation: a group of experts was set up to help steer this work and hearings were held not only with managers in the nuclear power sector, but also with representatives of trade unions and environmental protection NGOs. In addition, a written consultation of French embassies in key "nuclear power" countries was undertaken.

1 Power generating costs spread over a very long period

Generating nuclear electricity is a highly capital-intensive activity where costs are spread over a very long period of time. For this reason, in order to calculate the total generating cost of existing nuclear power plants from the operator's point of view, past investment costs, present operating costs and future costs, which concern both investment expenditure (for dismantling facilities) and operating expenses (for spent fuel and waste management) must all be added together.

It is generally considered that AREVA's costs (investments and operating expenses, including future costs) are incorporated in the fuel costs paid by EDF with regard to AREVA's involvement in French nuclear power generation. To avoid accounting for the same costs twice, calculations are thus based on EDF accounts only.

Past expenditure is reasonably well identified

Heavy initial investment

In all, it cost €121 billion$_{2010}$ to build the facilities required for nuclear power generation (excluding Superphénix). Of this, €96 billion$_{2010}$ represents the actual construction cost of the 58 existing reactors. This amount includes an "overnight"(2) cost of €83 billion$_{2010}$, which represents the initial investments made between 1973 and 2002, plus interest during construction. The latter is due to the fact that it takes several years to build nuclear power plants and was estimated at €13 billion$_{2010}$ by the Cour des Comptes.

These 58 reactors have a combined installed capacity of 62,510 MW.

(2)The "overnight" cost represents the initial construction cost (€72.9 billion$_{2010}$) plus engineering expenses (€6.9 billion$_{2010}$) plus pre-operating costs (€3.4 billion$_{2010}$).

Power generating costs spread over a very long period

The construction cost per megawatt (MW) has risen over time

The initial construction cost, including engineering (€79.751 million$_{2010}$), expressed in terms of reactor power, has risen over time, from €1.07 million$_{2010}$/MW in 1978 (Fessenheim) to €2.06 million$_{2010}$ in 2000 (Chooz 1 and 2) or €1.37 million$_{2010}$ in 2002 (Civaux), with an average of €1.25 million$_{2010/MW}$ for all 58 reactors. These rising costs can be largely explained by safety baselines, which have become increasingly stringent over time.

As the total final cost of the EPR is not yet known, no precise comparison can be made. Nevertheless, the Cour des Comptes observes that the construction cost per megawatt continues to rise with this new generation of reactors which must meet extremely strict safety requirements, right from the construction stage. With an estimated construction cost of €6 billion for the Flamanville EPR (a first of a kind) and 1,630 MW capacity, the cost per MW is €3.7 million. With an estimated cost of €5 billion for the standard EPR, the cost per MW works out at €3.1 million.

Clearly defined current operating expenses

EDF's annual operating expenses amounted to €8.9 billion$_{2010}$ for 407.9 TWh power output in 2010. These expenses are clearly identified and there is no particular difficulty involved in their calculation.

Operating expenses in current €	In €million 2010	Trend 2008-2010
Nuclear fuel	2 135	+ 5%
Staff costs	2 676	+ 5%
External charges	2 095	+ 19%
Taxes and duties	1 176	+ 15%
Central functions	872	+ 30%
Total operating expenses	8 954	+ 11%

Source: Cour des Comptes

Power generating costs spread over a very long period

Operating expenses represented a cost of €22/MWh in 2010. They rose by 11% between 2008 and 2010 (in current €), largely as a result of increased routine maintenance programmes and taxes and duties.

Staff costs look set to rise over the coming years as the recommendations of the Autorité de sûreté nucléaire (ASN, *French Nuclear Safety Authority*) following the Fukushima disaster are implemented (with, in particular, the creation of a nuclear rapid response force) and because of the need to renew the work force while maintaining operator skill levels.

Future costs are uncertain by their very nature

Precise estimates of dismantling costs cannot be obtained for want of genuinely comparable national or international experience

Dismantling costs, i.e. the "end-of-life" costs of nuclear power plants, are currently estimated at €18.4 billion $_{2010}$ in terms of gross expenditure for the 58 existing reactors.

Dismantling costs are calculated on an arbitrary historical cost basis, although the results are corroborated by much more elaborate methods. The technical parameters of these methods must nevertheless be validated by experts from outside the company.

Current estimated costs should not be taken at face value as experience in the field, whether for EDF with its first-generation plants, or the Commissariat à l'énergie atomique et énergies alternatives (CEA, *French Alternative Energies and Atomic Energy Commission*) or AREVA, shows that estimates have a general tendency to rise as operations take shape. Furthermore, international comparisons produce results that are generally higher than EDF estimations. Nevertheless, the results of such international comparisons vary widely, thus highlighting the uncertainty in this area.

The Cour des Comptes has therefore made two recommendations regarding dismantling costs:

- it wishes EDF to use the Dampierre 2009 method as a basis for calculating its dismantling provisions, rather than the historical method which does not enable sufficiently close monitoring of changes in provisions;
- it confirms the need to have technical audits performed by outside experts and firms to validate the technical parameters of the Dampierre 2009 method, as planned by the Direction générale de l'énergie et du climat (DGEC, *French General Directorate for Energy and Climate*).

Power generating costs spread over a very long period

The estimated cost of long-term radioactive waste management is yet to be stabilized

EDF's gross expenditure relating to long-term management of waste from nuclear power facilities currently totals €23 billion but is not yet stabilized. Since 2005, the share attributable to the management of high-level and intermediate-level long-lived waste has been based on an estimate (€16.5 billion$_{2010}$) of ANDRA's deep geological repository project, but this was subject to an in-depth review in 2009. The new figure of €36 billion$_{2010}$ is twice that of the initial estimate and is disputed by producers. The official estimation must be determined by a French ministerial order by 2015, based on which EDF, AREVA and the CEA may have to adjust their provisions.

As there is no management solution currently available for recycling the quantities of spent MOX and ERU (enriched recycled uranium) produced by nuclear power plants, EDF calculates its provisions for the long-term management of this material as if it were waste destined for the deep geological repository under the same conditions as high-level waste (HLW) and intermediate-level long-lived waste (ILW-LL). This method is consistent with the accounting conservatism principle but calls for a well "calibrated" provision, which is not the case today. In addition to the costing aspect, it would be more reassuring if this assumption could be properly demonstrated and, in the long term, possibly developed, should the Generation IV programme run into difficulties.

The Cour des Comptes has therefore made two recommendations regarding long-term waste management:

➔the new estimate regarding the cost of the deep geological repository should be prepared as rapidly and as realistically as possible and in accordance with the decisions made by the ASN, which is the only authority in a position to give a verdict on the safety level of this facility;

➔this new estimate should show the cost of direct disposal of MOX and ERU waste produced each year and this assumption should be taken into consideration in future design work on the deep geological repository.

Maintenance investments set to increase

Maintenance investments are aimed at guaranteeing reactor performance in terms of power generation, gradually enhancing security and safety and,

where desirable, extending plant service life.

Maintenance investments have been on a downward trend since 2000. This situation has drawn attention to their importance as the drop has had a negative impact on the nuclear fleet's unit capability factor and, consequently, led to a fall in power output. The need to improve safety at nuclear power plants is even greater than before, with the high standard set by the EPR and in light of the accident that occurred at Fukushima in March 2011.

The EDF maintenance investment programme for 2011-2025, which was prepared in 2010, amounted to €50 billion, or an average of €3.3 billion per year. This is nearly twice the amount invested in 2010 (€1.7 billion), a figure that was already up on previous years. The investments needed to meet ASN requirements under the complementary safety assessment initiative following the Fukushima disaster are currently estimated at around €10 billion, of which half was already accounted for in the initial €50 billion programme. Consequently, maintenance investments should reach a yearly average of €3.7 billion, for a programme in the region of €55 billion$_{2010}$ covering the period from 2011 to 2025.

Investments and maintenance

In €billion 2010	Annual amount
Average 2008-2010	€1.5 billion
In 2010	€1.75 billion
Average with a programme of €55 billion between now and 2025, including the impact of Fukushima	€3.7 billion

Source: Cour des Comptes

Power generating costs spread over a very long period

Overall generating costs to increase

A highly significant capital cost that may give rise to various estimations according to objective

Generating electricity from nuclear power is a long-cycle, capital-intensive industry in which the cost of capital is a variable – and one which has a highly significant impact when calculating the overall cost involved.

It is impossible to reconstruct the funding of these nuclear investments accurately for want of information and lack of a specific funding method for EDF activities. Furthermore, it is hard to determine the economic value of the existing fleet of nuclear power reactors in the absence of a second-hand plant market that is sufficiently "liquid" to calculate the market value of EDF's historical fleet. Stock market ratios are inoperative in that there are no purely nuclear listed operators and reactor fleets vary from a structural point of view. Lastly, a discounted cash flow approach would be handicapped by the considerable uncertainty regarding the future selling price of electricity and the number of years that the historical fleet will remain in service. For all the above reasons, capital cost is calculated on the basis of conventions.

Various approaches are therefore adopted to calculate capital cost and its share in the overall generating cost. This can be explained by the fact that several parameters depend on the variable being measured, and consequently the amount of capital whose cost is to be calculated, or even the distribution of this cost over time (constant or degressive annual cost). These approaches include:

- *full cost accounting for a given year*: this consists in considering the depreciation amount as the only factor in measuring the share of investments and capital in nuclear power generating costs. This method does not, however, take into account the cost of capital, i.e. the earned rate of return. Another point is that at the end of the period, total depreciation can only be used to reconstruct the amount of capital invested in the fleet at its initial value, making no allowance for inflation or changes in technological and safety baselines concerning nuclear reactors.

- *the Champsaur commission approach :* this approach is aimed at calculating the generating cost of the existing French nuclear reactor fleet over the next 15 years, taking into account the fact that the fleet was already 75% amortized in 2010, even though it had an average age of 25 years for a total amortization term of 40 years. This approach thus seeks to calculate a tariff at a given moment in time, taking into consideration the history of the fleet, focusing in particular on how it was financed and on past depreciation; the "rent", which is sup-

posed to measure capital cost, is calculated by applying an earned rate of return to the net book value of the fleet as of the calculation date (in this case, 2010).

- *the current economic cost (CEC):* this method is used to calculate the average overall generating cost of the nuclear reactor fleet throughout its service life, from the operators' point of view. It serves mainly to compare the generating cost of different energy sources. It measures the cost of return on and reconstitution of the capital invested through an economic rent paid in constant annual instalments throughout the service life of the reactor fleet. This rent is calculated to reimburse and pay an investor for his investment based on its readjusted value at maturity. This method makes no allowance for the historical conditions under which the construction of the fleet was financed and gives an indication of what it would cost to build the same fleet today.

In both the CEC and Champsaur commission methods, the selected rate of return on capital has an impact on results. The service life of the fleet, however, has relatively little impact on the calculated amount.

The approaches above do not have the same objective, so great care must be taken to ensure that identical calculation methods are employed when comparing the generating costs of different energy sources.

Costs that vary significantly according to the calculation method used

Although they treat investments and capital cost differently, the various methods for calculating nuclear electricity generating costs all take into account operators' past, present and future costs, with future dismantling costs and spent fuel and waste management costs being discounted at a nominal discount rate of 5% (2.94% actual rate, without inflation).

Calculations assuming a service life of 40 years for the existing fleet of 58 reactors and based on the depreciation and maintenance investment amounts for 2010, give the following results for the year 2010, when power output reached 407.9 TWh:

Power generating costs spread over a very long period

Results of the various calculations of generating cost per MWh according to objective	In $€_{2010}$
- Cost using the full cost accounting method, which takes into account the depreciation of the fleet but not the return on capital	€33.4/MWh
- Cost using the Champsaur commission approach, which takes into account the depreciation of the fleet and return on the capital that is not amortized (with the objective of calculating a tariff)	€33.1/MWh
- Current economic cost (CEC), which does not take into account fleet depreciation and which pays the capital originally invested, allowing for inflation (with the objective of calculating an average generating cost with no historical reference).	€49.5/MWh

Source: Cour des Comptes

This generating cost is not the cost currently calculated in some international comparisons, such as those made by the OECD Nuclear Energy Agency, or compared to that of other energy sources, such as in the reference costs of the DGEC. In both the above cases, in addition to the capital cost, which can be calculated using still other methods, the cost is calculated for an investor arriving on the market today with new nuclear power plants, such as the EPR in the case of France. This calculation, which simulates the fictitious cost of a fictitious fleet, is very theoretical. At the present time, the Cour des Comptes only knows the estimated construction cost of €6 billion for the Flamanville EPR, which gives a generating cost of at least €70 to €90/MWh, and bearing in mind that this is not the cost of a "standard" EPR. The Cour des Comptes is unable to validate these estimated costs while the site is still under construction. It is therefore far too early for it to calculate and validate a generating cost for an EPR fleet.

Power generating costs spread over a very long period

Results are relatively unaffected by provisions for future costs

Calculations of future dismantling and long-term waste management costs, which will only need to be paid in a few decades - or centuries in the case of waste disposal facility monitoring - are based on assumptions and often involve significant degrees of uncertainty. It is therefore important to measure the impact of the most uncertain cost items on the overall generating cost.

Simulations based on available accounting data have been carried out for 2010 conditions and using the current economic cost method as calculated by the Cour des Comptes, in other words on a total cost of €20 billion for a power output of 407.9 TWh. These simulations only measure the impact on generating cost.

Impact of variations in the discount rate

As gross charges will not be paid off until some point in the distant future, they must be discounted so that they can be booked in today's accounts. This is done by applying a 5% discount rate, which includes an inflation rate of 2% (actual rate is 2.94%). This reduces their overall calculated amount by 48%, bringing the total amount of gross charges for all operators from €79 billion$_{2010}$ to a €38 billion provision. This discount rate is roughly equivalent to that used in other countries.

Table of gross expenditure/provisions

In million € 2010	EDF	AREVA	CEA	Total
Gross expenditure	62.1	10.5	6.8	79.4
Provisions	28.3	5.6	4.5	38.4
Provisions/ gross expenditure	46%	54%	66%	48%

Source: Cour des Comptes

Power generating costs spread over a very long period

Reducing this rate by 1%, from 5% to 4%, would induce a 21% increase in EDF's provisions (i.e. €6 billion more than the current provisions of €28.3 billion). As a result, the annual nuclear power generating cost, calculated using the CEC method, would increase by €162 million per year, i.e. an increase of 0.8%.

Conversely, if the discount rate were raised from 5 % to 6%, the annual cost would fall by €131 million/year, which represents a 0.6% drop.

Impact of variations in end-of-cycle costs

Regarding end-of-cycle costs, the provisions calculated for spent fuel management seem adequate. The waste management provision, however, should be reviewed rapidly. The new estimate produced by the Agence nationale pour la gestion des déchets radioactifs (ANDRA, *French National Radioactive Waste Management Agency*), is slightly more than twice the amount currently used for calculating provisions. It would be worth measuring the impact of doubling this provision. A more accurate estimation of the impact of spent MOX and enriched recycled uranium waste disposal should also lead to an increase in the provision.

Based on a simplified simulation and ANDRA's latest assumptions for its estimate, the annual generating cost for nuclear electricity would increase by €200 million, which represents a 1% increase in the generating cost per MWh based on the CEC calculation.

Impact of variations in dismantling costs

Like those of AREVA and the CEA, EDF's dismantling costs are regularly calculated and monitored. This work shows that estimates have a general tendency to increase over time despite progress made in methodology, an increase which can be explained by the fact that this field is very new and by the lack of operating feedback. Secondly, operators periodically make allowance for these increases in their accounts, thus reducing any risk of significant misjudgement.

The simplified simulations carried out based on current economic cost and the same discount rate of 5% show that a 50% increase in the estimate of dismantling costs would cause a €505 million increase in the annual generating cost. This would, however, only represent a 2.5% increase in the generating cost per MWh.

The above tests carried out to measure the impact of variations in a number of parameters on future charges show that, while this impact should certainly not be overlooked, it remains relatively limited, bearing in mind the assumption of a 40-year reactor service life considered for these calculations.

Significant impact of changes in maintenance investments

While an increase in future dismantling and waste management costs have a relatively limited impact, increased maintenance investments have a much more significant impact.

Previous calculations are based on the maintenance investment amount for 2010, namely €1.747 billion. EDF has a projected investment programme of some €55 billion for the period 2011-2025, an amount which appears to include the investments induced by ASN work on complementary safety assessments. This means an average annual investment of €3.7 billion over the coming years.

This increase in investment expenditure induces a 10 to 15% increase in the generating cost per MWh, depending on the assessment method used, but in all cases it has a significant impact.

Impact of the €55 billion investment programme between now and 2025 on the generating cost per MWh

Maintenance investments	Full cost accounting	Champsaur approach	CEC
Value in 2010 €1,747 million	33.4	33.1	49.5
Average value of the €55 billion programme €3.7 billion	38.2	37.9	54.2
Percentage variation	+ 14.5%	+ 14.5%	+ 9.5%

Source: Cour des Comptes

Extending the service life of nuclear power plants affects their profitability

The effect of extending the service life of nuclear power plants cannot be measured by calculating its impact on measured costs using the approaches described above, except for the full cost accounting approach. Calculations carried out using the other two methods only take into account the initial investment value, not reactor service life.

If, however, it is assumed that the calculated costs are covered by revenue (prices, tariffs, etc.), it is clear that the longer the fleet remains in operation, the greater the return on the initial investment and the more profitable this initial investment is for its owner.

Furthermore, extending the service life of the reactor fleet postpones not only the payment of future dismantling costs, thereby reducing the amount of provisions, but also fleet renewal investments, which will call for considerable financial resources, especially since the new generations of nuclear power plants cost more to build than their predecessors.

2 Expenditure funded by the public sector

In order to calculate the cost of generating nuclear electricity "for society", then expenditure funded by the public sector must be added to the cost for the operator, as it does not appear in electric utility accounts. Expenditure funded by the public sector can be divided into two main categories: a) research and b) efforts to promote security, safety and transparency and information to the public. Five conclusions can be drawn from the figures calculated by the Cour des Comptes on these subjects.

In 2010, recurring expenditure funded by the pub-lic setor represented a limited amount, close to that of the tax on basic nuclear installations.

In 2010, expenditure funded by the public sector totalled an estimated €644 million (€414 million for public research and €230 million for security/safety/transparency). The analysis by the Cour des Comptes focuses on how these costs are determined and does not set out to judge whether the funds are adequate or put to effective use.

This expenditure only accounts for 5 to 6% of annual operating expenses (including provisions for spent fuel and waste management).

It represents roughly the same amount as the tax on basic nuclear installations (INBs), a special tax paid by plant operators (amounting to €580 million in 2010). Although it can be considered that it covers the related public expenditure, the INB tax and the charges that preceded it were originally designed to cover security and safety spending.

The development of nuclear energy relies on heavy research investment, mostly funded by the public sector

As part of its work on this report, the Cour des Comptes conducted a study of research trends from the mid-1950s up to the present day. The study shows that total research expenditure in the field of nuclear power can be estimated at €55 billion$_{2010}$, or in the region of €1 billion$_{2010}$ per year.

Of this amount, €38 billion$_{2010}$, (or an average of €690 million$_{2010}$ per year) was funded by the public sector, i.e. 70% of the total. This is a significantly higher percentage than that observed for

2010 and, more generally, over the past ten years, where the figure was only in the region of 40%.

It was not possible, however, to calculate past expenditure on security/safety/transparency, although it is probable that, unlike publicly funded research expenditure, spending in this area has tended to increase slightly over time with the creation and gradual reinforcement of the ASN and the Institut de radioprotection et de sûreté nucléaire (IRSN, *French National Institute for Radiological Protection and Nuclear Safety*) the organizations that account for most of the costs in this area.

Even without this information, it can be considered that a new situation has arisen with INB tax and expenditure funded by the public sector coming to roughly the same amount in 2010. This situation has been brought about by two opposite trends: a) the gradual drop in research expenditure funded by the public sector and b) the very significant increase in tax income, which was multiplied by 4.6 between the years 2000 and 2010 (in current euros).

In constant euros, actual income from the tax amounted to €3.3 billion over the past decade (2000 to 2010), while research expenditure funded by the public sector over the same period totalled €5.5 billion. Comparison of these two figures clearly shows that the previous situation was far less balanced than in 2010.

The State will have to fund the CEA's provisions

As at the end of 2010, the CEA faced future costs of €6.8 billion$_{2010}$, or a provision of €4.5 billion$_{2010}$ after discount. This breaks down into €2.9 billion for dismantling, €1.2 billion for long-term waste management and €0.3 billion for spent fuel management.

It is considered that €3.1 billion of this provision is covered by dedicated assets consisting for the most part of receivables from the State or AREVA securities. It is planned that the CEA can sell these to the State as needed.

The State therefore directly or indirectly finances these future costs, the amount of which remains uncertain based on dependable calculation methods. This is evidenced by the often considerable readjustments made to estimates of these future costs over the past ten years. The State will have to cover these costs when they fall due by means of budget appropriations.

The Generation IV programme significantly increases future research expenditure funded by the public sector

The "future nuclear" programme included in investments for the future provides funds of €650 million (between 2011 and 2017) for the detailed design of ASTRID, a demonstrator designed for the development of

Generation IV sodium-cooled fast reactors. If detailed design results encourage France to continue along this path, other forms of funding (probably public for the most part) will need to be sought to cover the cost of a) building ASTRID and b) financing other facilities, as the demonstrator will still be far from reaching industrial maturity. All these costs are unknown at the present time.

The State insures some of the "civil liability" risk in the event of a nuclear accident

The nuclear sector is in a very special situation as far as insurance is concerned. Although there is very little likelihood of a risk becoming reality, the consequences of a severe accident can be disastrous. The probability of an accident and the seriousness of its consequences are hard to estimate and are the subject of heated debate. It is nevertheless certain that in the event of a major accident, the upper ceiling for operator civil liability for nuclear damage, defined by international conventions, would be rapidly reached and probably exceeded.

According to current arrangements for civil liability for nuclear damage, the State could be obliged, in the event of a nuclear accident, no matter how unlikely, to pay damages above and beyond the liability ceilings defined in the legislation currently in force and to bear any economic consequences not covered by compensation mechanisms. Operators currently have this guarantee free of charge. The Cour des Comptes has demonstrated that the cost of this guarantee is very low in comparison with overall nuclear power generating costs. But costs in the event of a severe accident could be huge and weigh very heavily on the State's resources, bearing in mind that whatever happens, the State is ultimately liable for the cost of repairing nuclear damage and all the consequences.

The Cour des Comptes has therefore made two recommendations on this point:

- it recommends that France should make every effort to implement as rapidly as possible the amending protocols to the Paris and Brussels Conventions, signed in 2004, as they significantly raise the ceiling for operator liability, even if this ceiling remains limited;
- it also emphasizes the need for the provisions of current French substantive law to be rigorously applied, especially with regard to fixing the financial guarantee imposed on operators, which implies applying regulations in full.

3 Unresolved issues

Over and beyond the uncertainties identified above, and for which the Cour des Comptes has attempted to measure impacts on nuclear power generating costs, several issues which could have significant consequences require particularly close attention.

While costs are important, the positive and negative externalities of different energy sources must not be overlooked

The impact of nuclear power generation, particularly on health, the environment, the balance of payments and the economy is generally very difficult, if not impossible, to measure with currently available knowledge. These externalities should be taken into consideration when comparing different sources of energy.

The Cour des Comptes has nevertheless estimated the (low) cost of CO_2 emissions from nuclear power generation in 2010. The total cost was €90 million for an average cost of €15/teq CO_2 (average cost of CO_2 over the recent period) and €190 million for a cost of €32 €/tCO_2 (Quinet report reference).

The Cour des Comptes recommends encouraging and supporting research and studies on these issues, for other energy sources as well as nuclear energy. Although a monetary value cannot be calculated for many types of impact - at least not at the moment - knowledge of impacts is useful for comparing different energy sources.

Calculations concerning the cost of complementary safety assessments performed in the wake of the Fukushima disaster must be completed and refined

Following the Fukushima accident, the ASN initiated at the French Government's request an in-depth security and safety audit of existing nuclear facilities. Its report and opinion on "priority facilities" were published on 3 January 2012. Although they do not as yet allow a comprehensive and precise estimation of all the lessons to be learned from this accident, they do bring some details to light, taking into account the fact that EDF, AREVA and the CEA are not in the same situation.

EDF's situation

EDF is the most concerned by these issues. Two main types of cost can be distinguished, considering only the financial consequences:

- measures to "increase the resistance of facilities to extreme situations". EDF currently estimates that in terms of investments these measures will cost around ten billion euros over a period of a few years. Some of this amount is already included in EDF's provisional investment programmes. The costs induced by these measures will, however, also need to considered in terms of staff, especially for setting up a "rapid response force". According to EDF, this aspect represents a significant cost in the region of €300 million per year;

- social, organizational and human factors. These costs are even harder to determine today, though they will have an impact on staff numbers and the resulting payroll costs, as well as on the organization of subcontracting.

AREVA's situation

AREVA's facilities vary considerably and specifications, which were originally designed for power reactors, must now be adapted to the specific characteristics of each facility. As a result, AREVA's efforts are still in progress and the company must continue to work on safety improvements. By mid-2012, it must define concrete measures as part of its interdisciplinary emergency response studies.

As for EDF, the emphasis is on setting up a hard core for each AREVA "platform", together with supplementary measures for more robust pool filling. The creation of a rapid response force, however, seems less adapted to the smaller number of sites and greater diversity of activities. A more logical solution would be to reinforce emergency response organisation on each "platform".

AREVA's investments are set out in a five-year strategic plan and amount to €2 billion for the period concerned. At present, the company seems to consider that investments relating to complementary safety assessments should represent several hundred million euros of additional costs over the period, although the Cour des Comptes has no way of confirming these figures, especially because ASN recommendations are far from precise at the moment.

The CEA's situation

The CEA is in a rather similar situation to AREVA in terms of the diversity of its facilities, although this situation is made a little more exceptional in that most of its facilities will be examined in 2012 and that three of the five facilities examined during the first series of

assessments, namely Phénix, the Plutonium facility and Osiris, have now been shut down and are currently being dismantled. For this reason, it must specified in each case what investments are needed as risks continue to drop and dismantling work progresses.

Current CEA estimates concerning the possible financial impact of complementary safety assessments cover a relatively wide range, from €50 to €500 million over a period of three or four years.

It is therefore generally too early to calculate and verify the amount of investments and the costs in human terms induced by this first round of complementary safety assessments. Also, as the ASN mentions in its report, "feedback from the Fukushima accident could take some ten years to filter through. It appeared necessary to assess the resistance of facilities to extreme situations as rapidly as possible", although this is only the first step in what will be a long, drawn-out process of analysis and reflection.

The growing number of departures from the Act of 2006 and the impact of the financial crisis on dedicated assets management should lead to a review of the conditions for implementing this mechanism

Out of a total provision of €27.8 billion for end-of-cycle operations to be covered by dedicated assets, €18.2 billion was covered by listed financial securities, at as 31 December 2010, €2.7 billion was not supposed to be covered at that date and €6.9 billion consisted of mutual hedges between operators in the nuclear sector, including the State. In all, the State can be considered directly or indirectly liable for €4.6 billion, excluding RTE securities (€2.3 billion) accounted for in EDF's dedicated assets.

Several decisions have significantly modified the application of the initial Act of 2006 relative to Transparency and Security in the Nuclear Field: the date by which dedicated assets must cover provisions in full has been pushed back from June 2011 to June 2016; the liquidity of these assets has been impaired by the acceptance of securities issued by operators' subsidiaries and by "inter-operator" receivables; and, lastly, the very notion of dedicated assets has been dropped for the CEA.

At the same time, the financial crisis has increased uncertainties as to the medium- and long-term profitability of assets making up the portfolios and, therefore, raises doubts as to whether they are sufficient to cover future costs.

The mechanism underwent a number of changes before the commission that was supposed to structure its governance was set up. This is unfortunate. The CNEF(3) is now operational and in a position to give an opinion on the mechanism as it now stands and, if need be, on how it could be adapted to the present financial situation.

➔**The Cour des Comptes recommends** re-examining this issue. Each new difficulty is accompanied by a new dispensation, radically changing the structure and initial logic of the mechanism. This situation is unhealthy.

Power plant service life is a strategic variable that should be framed by explicit guidelines

The ASN performs a ten-yearly inspection to determine whether a nuclear power plant can be granted a licence to remain in service and under what conditions. So far, only two reactors (at the Tricastin and Fessenheim plants) have been licensed to operate for 40 years, subject to significant work to improve safety.

In accounting terms, however, EDF nuclear power plants have been depreciated over 40 years since 2003. Plant service life has a significant impact on the actual generating cost by allowing investments to be depreciated over a longer period of time. In addition, it postpones dismantling costs and the need to invest in new power facilities.

The Cour des Comptes observes that ten years from now (by the end of 2020), 22 out of 58 reactors will reach their fortieth year of operation. Consequently, assuming that nuclear reactors will have a 40-year service life and that nuclear power output will remain at its present level, eleven EPRs will have to be built by the end of 2022. This seems highly unlikely, if not impossible, including for industrial reasons.

This implies one of two things: a) either it is assumed that plants will operate for more than 40 years, as the "multi-year investment programme" (PPI) for electricity generation for 2009-2012 would seem to indicate, since it "favours the central scenario of extending the service life of nuclear power

(3) National Committee for the Evaluation of Funding for the costs of dismantling basic nuclear installations and spent fuel and radioactive waste management

plants beyond 40 years"; b) or the energy mix will move towards other energy sources. However, no clear public decision has been made concerning these major strategic issues, even though they call for short-term action and major investments.

Major investments required in the short or medium term will have a significant impact on the overall generating cost

In order to extend operating licences up to 40 years, make allowance for the consequences of safety assessments carried out following the Fukushima accident (ASN report) and maintain plant unit capability factor at an acceptable level (between 80 and 85%), the current rate of maintenance investments will have to be doubled. This represents an increase in generating costs of around 10% in terms of current economic cost.

In addition, if existing plants were to be replaced by EPRs, which have a much higher construction cost (at least €5 billion for a "standard" EPR) and assuming that the service life of existing plants is extended to 50 years, €55 billion (covering the cost of eleven EPRs) would need to be invested in the next twenty years.

The Cour des Comptes notes that, whatever the solutions found for these issues in the future, significant investment expenditure will be required in the short and medium term for both maintenance and new build purposes. This will be in addition to distribution grid and research investments if the authorities decide to move ahead with the Generation IV reactor development programme. This should entail a considerably higher level of investment than that currently observed in this area, although the exact amounts involved cannot be calculated as yet.

The strategic and financial impact of this situation must be analysed and taken into account in medium-term energy policy guidelines that are made public and accessible to all stakeholders in the nuclear sector. In the field of energy policy, it takes a long time for the effects of a decision to be felt. This time lag is particularly long in the nuclear sector, although it can be observed in all other sectors, too, including for energy saving initiatives. Not making a decision on this issue is the same as choosing to extend the service life of existing reactors beyond 40 years.

Cost calculations must be transparent and the data in this report regularly updated

Given the complexity of the subject, uncertainties concerning data and the many assumptions used in calculating the figures in the report, this work must be regularly reviewed and improved as part of a governance approach that takes into account the strategic aspects of the energy issue and the fact that public opinion is highly sensitive to this subject.

The Cour des Comptes therefore recommends that this survey should be regularly updated, adopting a transparent and objective approach, in order to:

- gradually specify the assessment methods required to evaluate decisions from an economic point of view in the event of uncertainty. In particular, the costs and probabilities of accidents should be investigated in greater depth;
- keep track of future trends in the various cost items analysed, drawing on available feedback and focusing in particular on the financial impact of complementary safety assessments following the Fukushima accident;
- capitalize on the contributions of the different parties involved and experts in the field.

The significance of externalities, the impact of which, particularly on the environment, health, employment and the trade balance, cannot be calculated except, perhaps, by comparison with other solutions, highlights the fact that costs are certainly not the only variables to be considered in decisions relating to nuclear power generation.