The costs of the nuclear power sector

Thematic public report

January 2012
II - Spent fuel management ................................................................. 116
   A - EDF spent fuel management ..................................................... 117
   B - CEA fuel management costs .................................................... 127

III - Radioactive waste management .................................................. 132
   A - Types of waste and management methods ............................... 132
   B - Waste which currently has an ultimate destination .................. 134
   C - Waste without an ultimate destination ..................................... 137
   D - Recovery and conditioning of old waste (RCD) ......................... 152
   E - Unresolved issues ................................................................. 154
   F - Summary of gross waste management costs in the operators’ accounts ................................................................. 159

CHAPTER IV PROVISIONS AND DISCOUNTING .................................. 163
I - Balance sheet provisions .............................................................. 163

II - Provision discounting .................................................................. 166
   A - The principle of discounting .................................................... 166
   B - Discount rate used ................................................................. 168
   C - Operator provision sensitivity to the discount rate ................. 175

III - Profit & Loss Account provisions ............................................... 177
   A - EDF provisions for existing plants ........................................... 177
   B - Provisions of other sector players .......................................... 179

CHAPTER V DEDICATED ASSETS .................................................. 181
I - The regulatory and legislative framework ...................................... 181
   A - Assets dedicated to hedging part of the future costs of the nuclear sector .................................................. 181
   B - Characteristics of the French system of securing future nuclear costs .................................................. 183

II - Different and evolving application procedures ............................. 185
   A - Management of EDF’s dedicated assets ................................. 185
   B - Management of AREVA’s dedicated assets ........................... 192
   C - Management of CEA’s dedicated assets ............................... 196

III - Thoughts on the current situation .............................................. 198
   A - Moving away from the initial goal ........................................ 199
   B - The financial crisis reveals the weaknesses of the system ......... 201
   C - An imperfect system of governance ....................................... 203
CHAPTER VI POSSIBLE DEVELOPMENTS IN FUTURE EXPENDITURE ................................................................. 207

I - Two major factors in expenditure development ......................... 207
   A - Plant service life ................................................................................ 207
   B - Future research .................................................................................. 220

II - Costs of the EPR .................................................................................. 224

III - The variants ....................................................................................... 226
   A - The baseline situation ...................................................................... 226
   B - Variant: service life of 50 years ....................................................... 227
   C - Variant: “discontinuing reprocessing” ............................................. 229
   D - Variant: “without any fourth generation” ........................................ 230

CHAPTER VII COSTS WHICH ARE DIFFICULT TO QUANTIFY 233

I - Externalities .......................................................................................... 233
   A - Impacts on the environment ............................................................. 234
   B - Impacts on human health ................................................................. 237
   C - Other externalities ............................................................................ 238

II - Nuclear risk and insurance ................................................................. 240
   A - Nuclear risk ...................................................................................... 240
   B - International conventions on civil liability for nuclear damage ...... 245
   C - Positive French law .......................................................................... 253

CHAPTER VIII GENERAL CONCLUSION .................................................. 265

I - Costs counted by operators ................................................................. 265
   A - Investment and capital ..................................................................... 266
   B - Operating expenses .......................................................................... 275
   C - Generation cost calculations and their sensitivity to changes in different parameters .................................................. 278

II - Expenditure funded by the public sector ........................................... 284

III - Unresolved issues .............................................................................. 288

ANNEXES .................................................................................................. 295

RESPONSES FROM THE GOVERNMENT DEPARTMENTS & AGENCIES AND OTHER STAKEHOLDERS ........................................ 375

GLOSSARY .................................................................................................. 437
Public reports of the Cour des Comptes
- production and publication -

The Cour des Comptes publishes one annual public report as well as thematic public reports.

This report is a thematic public report. It covers the results of an investigation carried out by the Cour des Comptes at the request of the Prime Minister (a procedure now governed by Article L. 132-5-1, Financial Courts Code1).

Public reports by the Cour des Comptes are based on audits, investigations and assessments conducted by the Cour des Comptes or regional audit divisions and, in certain cases, jointly by the Cour des Comptes and regional divisions or between divisions themselves. Outside consultants assist whenever necessary, and consultations and hearings are arranged to obtain broad and varied clarification.

The work of the Cour des Comptes and related issues, including preparation of draft documents for a public report, are carried out by one of the seven divisions or by an inter-divisional group.

Three fundamental principles govern the organization and activity of the Cour des Comptes and regional audit divisions, and therefore not only the conduct of their audits and investigations but also the production of public reports: independence, the inter partes principle and collegiality.

Institutional independence of financial courts and statutory independence of their members guarantee that they have complete freedom in their work and findings. The Cour des Comptes and each regional or territorial audit division may also freely choose the scheduling of their work.

The inter partes principle means that all findings and assessments resulting from an audit, investigation or assessment, and all observations and recommendations made subsequently, are routinely submitted to the heads of the authority or agency concerned; they may only be made final after consideration of the responses received and, where appropriate, after hearing the officials concerned.

1 Article L. 132-5-1 was inserted into the Financial Courts Code by Act No. 2011-1862 of 13 December 2011 on allocation of litigation and simplification of certain proceedings.
Publication in a public report is necessarily preceded by provision of the draft which the Cour des Comptes proposes to publish to ministers and the directors of the bodies concerned, and also to any individual or entity directly concerned. Their responses are always included with the text in the published report.

Collegiality applies in completing the main stages of preparation, audit or assessment and publication.

All audits, investigations or assessments are assigned to one or more rapporteurs. Their investigation reports, and any subsequent provisional and final draft observations and recommendations, are considered and studied collectively by one division or another bench with at least three judges, one of whom has the role of shadow-rapporteur, responsible for monitoring the quality of audits. The same applies to draft public reports.

The content of draft public reports is decided, and their preparation supervised by the public report and programmes committee, comprising the First President, the Public Prosecutor and the Presidents of Chamber of the Cour des Comptes, one of whom acts as Rapporteur-general.

Finally, the draft public reports are submitted for adoption to the Court in chambers, under the chairmanship of the First President and with the attendance of the Public Prosecutor, the Presidents of Chamber of the Cour des Comptes, the conseillers maitres (Audit Managers) and the conseillers maitres en service extraordinaire.

Judges who are obliged to disqualify themselves due to their present or former duties or for any other ethical reason may not participate in the decisions of collegial benches.

* The public reports of the Cour des Comptes may be consulted on the website of the Cour des Comptes and the regional and territorial audit divisions: www.ccomptes.fr. They are published by La Documentation Française.
Report and participants

The Cour des Comptes, having deliberated in closed session, has adopted this report on "The costs of the nuclear power sector".

The report was finalized after the draft was provided to the authorities and agencies concerned, and after their responses to the Cour des Comptes.

The responses are published at the end of the report. Responsibility for those responses is confined exclusively to their authors.

Discussion participants: Mr. Migaud, First President, Messrs. Babusiaux, Descheemaeker, Bayle replaced by Mr. Cazanave, conseiller maître (Audit Manager), Mr. Bertrand, Mme Froment-Meurice, Messrs. Durrleman, Lévy, Lefas, Presidents of Chamber, Messrs. Pichon, Picq, Mme Cornette, Mr. Hespel, co-opted President of Chamber, Messrs. Richard, Devaux, Rémon, Gillette, Monier, Troesch, Beaud de Brive, Moreau, Mme Lévy-Rosenwald, Mme Pappalardo, Messrs. Brun-Buisson, Cazala, Andréani, Dupuy, Mme Morell, Mr. Braunstein, Mmes Saliou, Dayries, Mr. Phéline, Mmes Ratte, Ulmann, Messrs. Barbé, Jean Gautier, Vermeulen, Mmes Darragon, Seyvet, Messrs. Bonin, Vachia, Vivet, Mme Moati, Messrs. Charpy, Davy de Virville, Petel, Mme Trupin, Mr. Corbin, Mme Froment-Védrine, Messrs. Rigaudiat, de Gaulle, Guibert, Piolé, Prat, Guédon, Claude Martin, the Méne, Baccou, Sépulchre, Arnauld d’Andilly, Mousson, Mmes Malgorn, Bouygard, Vergnet, Mr. Chouvet, Mme Démier, Mr. Clément, Mme Cordier, Messrs. Le Mer, Léna, Migus, Rousselot, Mme Esparre, Messrs. Geoffroy, Lambert, de Nicolay, de la Guéronnière, Guillot, Messrs. Duwoye, Aulin, Senhaji, Audit Managers, Messrs. Schott, Klinger, Gros, Carpentier, Schmitt, conseils maîtres en service extraordinaire.

Mr. Bénard, Public Prosecutor, attended and participated in the hearings but not in the deliberation.

Mr. Bertrand, Rapporteur-general, gave his report assisted by Mme Pappalardo and Mr. Dupuy, both Audit Managers.

***

Mr. Terrien, Secretary-general, provided secretarial services to the deliberation chamber.

Signed in the Court on 27 January 2012
The draft report submitted to the deliberation chamber was prepared then deliberated, on 19 January 2012, by an inter-divisional bench of the Cour des Comptes, chaired by Mr. Levy, President of Chamber, and comprising Messrs. Camoin, Monier, Morceau, Mme Seyvet, Messrs. Vivet, Cossin, Rigaudiat, de Gaulle, Claude Martin and Migus, conseillers maitres (Audit Managers), Mr. Schott, conseiller maître en service extraordinaire, with Mme Pappalardo, Audit Manager, Rapporteur-general, and Mr. Dupuy, Audit Manager, Shadow Rapporteur.

Messrs. Camoin, Vivet, de Gaulle, Audit Managers, Mme Mondoloni, Messrs. Meddah, Michelet, Babeau, Fourrier, conseillers référendaires (Senior Auditors), Messrs. Imbert, Jourdan and Picard, auditeurs (Junior Auditors), Mme Kabylo, Messrs. Janin, Pinon and Olivier Robert, outside rapporteurs, acted as rapporteurs in assisting Mme Pappalardo, Audit Manager, in her duties as Rapporteur-general for the interdivisional bench.

The draft report was examined and approved on 6 December 2011 by the public reports and programmes committee of the Cour des Comptes, comprising Messrs. Migaud, First President, Bénard, Public Prosecutor, Descheemaeker, Bayle, Bertrand, Rapporteur-general for the committee, Mme Froment-Meurice, Messrs. Durleman, Levy and Lefas, Presidents of Chamber, Mr. Beysson, Audit Manager.
Introduction

By letter dated 17 May 2011 (Annex 1), the Prime Minister requested the Cour des Comptes, as advisor to the Government, to report on "the costs of the nuclear power sector, including the cost of dismantling facilities and site safety", stating that he wished to "have this report before 31 January 2012". In his reply of 8 June (Annex 2), the First President stated that "given the general interest in the topic", he had "decided to include it in the Cour des Comptes' programme" and specified the organizational arrangements he had made to ensure that the investigation would be carried out "pursuant to the usual procedures of the Cour des Comptes". This report is the result of that approach.

Unlike the usual work of the Cour des Comptes, the primary objective of this investigation is neither to audit accounts nor to give an opinion on the effectiveness or efficiency of energy policy. The sole objective of the report is to assess costs without commenting on their amount, which was not possible in any event within the timescale. It concentrates therefore on identifying and assessing the various costs associated with producing nuclear power in France and explaining the calculation methods and hypotheses adopted for each; the investigation nonetheless enabled some recommendations to be made, which are to be found in the general conclusion at the end of this report.

As this report concerns only the "cost" of nuclear power production, it contains no analysis of the "price" of such electricity, or of the tariffs which finance the cost. It does not broach the increase in demand for electricity nor the energy "mix", unlike predictive analyses conducted in other forums.

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2 Article 47-2 of the Constitution provides inter alia that the Cour des Comptes "assists Parliament and the Government in auditing enforcement of Finance Acts and application of laws for funding social security and in assessing public policy.".
Assisting the Government: Article 132-5-1, Financial Courts Code, provides that: "The Prime Minister may request the Cour des Comptes to conduct any investigation into the enforcement of Finance Acts and the application of laws for funding social security, and any enquiry into the management of departments or agencies under its control or that of regional or territorial audit divisions." (article incorporated into the Financial Courts Code by Act No. 2011-1862 of 13 December 2011 concerning allocation of litigation and simplification of certain proceedings).
Working organization and methods

The usual procedures of the Cour des Comptes have been applied, including collegiality and the inter partes principle, but special organization was arranged so as to meet the deadline and assemble the necessary skills to handle a technical subject covering science, finance and accounting. In addition to a team of fifteen rapporteurs, each of whom devoted about 4 months to this report, a dedicated interdivisional bench was formed to monitor this work. It received opinions from a group of experts (listed in Annex 3) who were attached neither to the existing French nuclear authorities nor to the companies or operators concerned, but who understand the subject thoroughly and have a wide range of skills (scientists, economists, engineers, etc.) and points of view. The observations of the members of this group greatly assisted the Cour des Comptes in defining the subject, avoiding technical errors and verifying the correct interpretation of its conclusions.

The interdivisional bench also conducted hearings (Annex 4) to ensure input from all stakeholders and to clarify the relevance of the questions, as suggested in the Prime Minister’s letter. For this reason, hearings were organized with environmental NGOs and trade unions. Other hearings concerned government officials and the operators and research agencies concerned.

Methodological principles

The long-standing argument over the issue of the "cost of nuclear energy" demonstrates the need to define precisely the scope of the study and the methods used to define each part of the cost.

Defining the investigation scope

The investigation covers exclusively the cost of producing nuclear energy in France:

− it therefore excludes costs associated with nuclear weapons;
− in the civil nuclear sector, only activities concerning electricity have been examined, any industrial or medical use being excluded;
− in the electricity sector, only production has been covered, thereby excluding both transport and distribution of electricity, necessary activities whatever the type of production, even though the method of producing electricity affects transport and distribution networks.
Production costs in the French nuclear energy sector have been assessed from the viewpoint of a French citizen who finances the cost via tariffs, rates and taxes, either directly as a consumer or indirectly as a taxpayer, as the State was first the owner and now the majority shareholder in EDF, the sole producer of nuclear energy on French soil. The cost "for EDF" or for other industrialists has not therefore been calculated; this difference in perspective explains the various methods used to calculate part of the component costs.

Identification of all cost components: 
past, present and future

Taking a didactic approach, the cost involved in producing one nuclear kWh in France has been calculated using time slicing, enabling an explanation of how an overall cost can be assessed via different successive sequences. Accordingly, there are:

- past costs, principally investment in the construction of nuclear plants and also research and development;
- current costs, split into two categories: the current operating costs of power plants (personnel, fuel, external expenses, etc.) part of which is directly linked to the quantity of electricity produced; the "attendant" costs of nuclear power production, including not only research, but also supervision, safety and transparency;
- future costs including firstly costs associated with the consequences of current production, but which will only come into play later (decommissioning power plants, spent fuel management and long-term management of waste), and secondly investment and research costs for future production (continued power plant operation, adapting to new safety requirements, new Generation IV power plants).

The report is principally concerned with determining the production cost of existing plants by quantifying past costs and "committed costs", i.e., all costs arising from a decision already taken, even if they have not yet been paid out. It also enables certain "future decisions" to be clarified, and sometimes quantified, distinguishing them from those already taken.

Varied nature of costs included

This time slicing enables the difference in nature of the costs included to be highlighted and the sources of information used:
past costs are taken from various sources of recorded costs, whether
related to plant construction investment or R&D expenditure; how ever, these records, covering expenditure made sometimes 40 or
50 years ago, are not always complete nor prepared using the same
methods over time. It was often necessary to ignore them and use
estimates;
− current costs are generally easier to assess, especially from operators’
accounts or governmental budgets;
− future costs must be assessed as they have not yet been expended.
They require the use of numerous hypotheses which must be clearly
explained. The report presents a critical analysis of the quantification
of these future costs as they appear in the accounts of operators, tests
alternative solutions or decisions and measures the sensitivity of the
costs according to the value retained for the relevant parameters,
including the discount rate;
− certain components are not currently quantifiable in monetary terms
but it is nonetheless important to identify them and consider how they
should be included. These are positive or negative external factors of
nuclear power production, and analysis of the current system of
public liability insurance.

Reference year 2010

In general, figures are shown both in the adjusted value for the
year in which they appear, and updated to their 2010 Euro value, the latter
year being the latest for which operators’ accounts were available at the
time of the investigation.

Data prior to 2010 has been converted into the "2010 value" by
applying the INSEE gross domestic product index (Annex 5).

The discount rate retained for future costs is analysed and the
sensitivity of results to the rate used is assessed.
International comparisons

Comparisons with experiences and costs in other countries appear in several chapters and in Appendices 15, 16 and 17 according to available and relevant information on each subject; Annex 14 also shows general data on several countries in very summarized form.

These international comparisons are based on studies conducted for the International Energy Agency (IEA), the Nuclear Energy Agency (NEA) or the European Commission, and on information provided by the French embassies in Japan, Great Britain, Belgium, Sweden, Finland, Germany and the United States. A special effort has been made to try to explain any differences which may appear between the French figures and those from other sources; however, it is generally very difficult to be certain of the consistency of the figures so compared.
Chapter I

Past costs

Current nuclear power production is the result of past investment, both in constructing nuclear plants and in developing research and development expertise. The cost of this investment is included in the costs of the nuclear power industry. Given the age of some of this investment, it has sometimes only been possible to provide estimates whose accuracy the Cour des Comptes has endorsed.

I - Total physical investment

On 31 December 2010, 147 operative and inoperative plants amounted, in legal terms, to 126 basic nuclear installations (INBs)
Distribution of civil plants per operator

<table>
<thead>
<tr>
<th>31 December 2010</th>
<th>EDF</th>
<th>CEA</th>
<th>AREVA</th>
<th>ANDRA</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operative</td>
<td>62</td>
<td>22</td>
<td>10(1)</td>
<td>2</td>
<td>10</td>
<td>106</td>
</tr>
<tr>
<td>Being decommissioned (+associated plants)</td>
<td>12</td>
<td>21</td>
<td>7</td>
<td>1</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>Total plants</td>
<td>74</td>
<td>43</td>
<td>17</td>
<td>2</td>
<td>11</td>
<td>147</td>
</tr>
</tbody>
</table>

Source: Cour des Comptes, based on ASN 2010 report
(1) not including two Cadarache plants operated by CEA (included in those of CEA) for which AREVA is liable for dismantling costs

EDF Group plants, mainly comprising 58 operative reactors, account for half of the total, CEA being in second position with a range of widely different facilities from research reactors to laboratories researching spent fuel. AREVA is in third position. "Others" includes CNRS facilities and private companies.

Most of the past physical investment for producing nuclear power in France may be divided into four categories: operative or inoperative EDF nuclear power plants, AREVA fuel cycle facilities, the waste disposal facilities of the Agence Nationale pour la gestion des Déchets Radioactifs (ANDRA; French National Radioactive Waste Management Agency) and CEA research facilities. Part I of this chapter quantifies the investment made for the first two categories; the ANDRA investment and the cost of facilities constructed and used for research, mainly by CEA, are included in the costs of research considered in II.

EDF nuclear power plants are classed according to "generation". "1st generation" power plants include those built prior to the existing plants, launched in 1978. They are currently inoperative. The "2nd generation", 58 pressurized water reactors (PWRs), comprises the existing plants. The third generation so far only includes the EPR (European Pressurized Reactor) under construction in Flamanville.
A - 1st generation inoperative power plants

The first generation comprises 8 reactors with different technologies\(^3\). The first power plants built in France used a CEA-refined technology called "graphite-gas" (GCR). These were the 6 reactors commissioned between 1963 and 1972 in Chinon, Saint Laurent and Bugey. This group of 1st generation power plants also included that in Brennilis, a heavy water reactor, and the Chooz A power plant, a light water reactor which is a PWR like the current power plants but much smaller in size.

All these power plants are now inoperative but are included in the EDF accounts under provision for decommissioning which still has to be done.

The initial investment cost for these power plants, the sum of construction, engineering and pre-operating costs, plus capitalized interest, amounts to €6 billion\(^{2010}\).

**First generation reactors (excluding Superphénix)**

<table>
<thead>
<tr>
<th>Reactors</th>
<th>Type</th>
<th>Commissioned</th>
<th>Adjusted £ million</th>
<th>€million 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinon A1</td>
<td>GCR</td>
<td>1963</td>
<td>54</td>
<td>500</td>
</tr>
<tr>
<td>Chinon A2</td>
<td>GCR</td>
<td>1965</td>
<td>91</td>
<td>775</td>
</tr>
<tr>
<td>Chinon A3</td>
<td>GCR</td>
<td>1967</td>
<td>128</td>
<td>1 011</td>
</tr>
<tr>
<td>Brennilis</td>
<td>Heavy water</td>
<td>1967</td>
<td>33</td>
<td>249</td>
</tr>
<tr>
<td>Chooz A</td>
<td>PWR</td>
<td>1967</td>
<td>75</td>
<td>582</td>
</tr>
<tr>
<td>Saint Laurent A1</td>
<td>GCR</td>
<td>1969</td>
<td>142</td>
<td>1 047</td>
</tr>
<tr>
<td>Saint Laurent A2</td>
<td>GCR</td>
<td>1971</td>
<td>107</td>
<td>733</td>
</tr>
<tr>
<td>Bugey 1</td>
<td>GCR</td>
<td>1972</td>
<td>183</td>
<td>1 200</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>813</strong></td>
<td><strong>6 097</strong></td>
</tr>
</tbody>
</table>

*Source: EDF*

\(^3\) Excluding Superphénix, treated below (II, page 35).
B - The 58 currently operative nuclear units

1 - Composition and age of current plants

A current nuclear production site generally comprises several nuclear "units", which are all functional units connected to the grid. One unit principally comprises a reactor, a building for fuel, a machine room where electricity is generated from steam produced by nuclear reaction and a cooling system. Most units have been built in pairs: they are now grouped in pairs, with each pair being given a mean industrial commissioning date.

Commissioning was staggered between 1978 (Fessenheim 1-2) and 2002 (Civaux 1-2). As 1985 is the mean year of commissioning, the average age of plants in 2010 was 25 years. The graph below illustrates the intensity of investment made in unit construction, with a peak in the early 1980s.

Costs of construction in adjusted Euros

Source: EDF

The units currently operative in France, i.e., the second generation French power plants, all belong to the pressurized water reactor category (PWRs). In this respect, French plants are more homogeneous than those in other countries which makes maintenance easier but may also have a negative impact on output in the event of technical breakdown.

4 The weighted calculation according to unit output gives 24 as the average age of plants in 2010.
Currently operative units are divided into several "levels" according to their technical features and output. The initial 900 MW units were succeeded by 1 300 MW units from 1985 then by four 1 450 MW units in 2000. In addition to its nominal output, each pair of units has a "net continuous output", i.e., the maximum stable electrical output.

2 - Initial plant investment cost

Apart from the actual construction costs, initial expenditure associated with industrial commissioning of a pair of nuclear units includes engineering and labour costs and pre-operating charges for progressive "rigging" of the power plant before its industrial use. These are called "overnight costs".

Construction costs

Construction costs are estimated from the historical cost of power plant construction, calculated by EDF at €36.9 billion adjusted Euros (cf. table below), spread between 1969 and 2004, i.e., €72.9 billion2010.

These costs cannot be reconciled in financial accounting as the accounting bases used by EDF have changed significantly during the relevant period from a mostly budgetary approach5 to accounting under IFRS standards, via French accounting law. However, they are consistent with EDF internal archived documents; in the absence of other usable methods, the figure of €72.9 billion2010 is the best available assessment of the historical construction cost of the nuclear plant stock6.

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5 Historically, the principal accounting document has for a long time, taken the form of a "provisional income and expenditure statement".

6 In practice, 5 percent of investment in current plants (the equivalent of 2.7 units) has been financed by contributions from external operators: in return, they receive a portion of the corresponding electricity invoiced at the appropriate production cost: the operation has not had a significant impact on EDF production costs.
### Construction cost of existing nuclear plants

<table>
<thead>
<tr>
<th>Pair of units</th>
<th>Net continuous output</th>
<th>Mean industrial commissioning date</th>
<th>Construction cost (Adjusted €million)</th>
<th>Construction cost (€million 2010)</th>
<th>Cost per MW (in € 2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>900 MW Level</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fessenheim 1.2</td>
<td>1 780 MW</td>
<td>February 1978</td>
<td>348</td>
<td>1 488</td>
<td>835 955</td>
</tr>
<tr>
<td>Bugey 2.3</td>
<td>1 840 MW</td>
<td>March 1979</td>
<td>423</td>
<td>1 630</td>
<td>885 869</td>
</tr>
<tr>
<td>Bugey 4.5</td>
<td>1 800 MW</td>
<td>October 1979</td>
<td>474</td>
<td>1 619</td>
<td>899 444</td>
</tr>
<tr>
<td>Tricastin 1.2</td>
<td>1 840 MW</td>
<td>December 1980</td>
<td>754</td>
<td>2 191</td>
<td>1 190 760</td>
</tr>
<tr>
<td>Tricastin 3.4</td>
<td>1 840 MW</td>
<td>August 1981</td>
<td>523</td>
<td>1 512</td>
<td>821 739</td>
</tr>
<tr>
<td>Blayais 1.2</td>
<td>1 830 MW</td>
<td>July 1982</td>
<td>824</td>
<td>2 185</td>
<td>1 194 535</td>
</tr>
<tr>
<td>Blayais 3.4</td>
<td>1 820 MW</td>
<td>October 1983</td>
<td>845</td>
<td>2 032</td>
<td>1 116 483</td>
</tr>
<tr>
<td>Dampierre 1.2</td>
<td>1 800 MW</td>
<td>November 1980</td>
<td>702</td>
<td>2 109</td>
<td>1 171 667</td>
</tr>
<tr>
<td>Dampierre 3.4</td>
<td>1 800 MW</td>
<td>August 1981</td>
<td>560</td>
<td>1 575</td>
<td>875 000</td>
</tr>
<tr>
<td>Gravelines 1.2</td>
<td>1 840 MW</td>
<td>December 1980</td>
<td>759</td>
<td>2 294</td>
<td>1 246 739</td>
</tr>
<tr>
<td>Gravelines 3.4</td>
<td>1 840 MW</td>
<td>August 1981</td>
<td>572</td>
<td>1 620</td>
<td>880 435</td>
</tr>
<tr>
<td>Gravelines 5.6</td>
<td>1 820 MW</td>
<td>June 1985</td>
<td>1 017</td>
<td>1 989</td>
<td>1 092 857</td>
</tr>
<tr>
<td>St Laurent 1.2</td>
<td>1 760 MW</td>
<td>August 1983</td>
<td>723</td>
<td>1 972</td>
<td>1 120 455</td>
</tr>
<tr>
<td>Chinon 1.2</td>
<td>1 740 MW</td>
<td>May 1984</td>
<td>787</td>
<td>1 997</td>
<td>1 147 701</td>
</tr>
<tr>
<td>Chinon 3.4</td>
<td>1 760 MW</td>
<td>September 1987</td>
<td>1 115</td>
<td>1 969</td>
<td>1 118 750</td>
</tr>
<tr>
<td>Cruas 1.2</td>
<td>1 760 MW</td>
<td>October 1984</td>
<td>994</td>
<td>2 206</td>
<td>1 253 409</td>
</tr>
<tr>
<td>Cruas 3.4</td>
<td>1 760 MW</td>
<td>November 1984</td>
<td>837</td>
<td>1 722</td>
<td>978 409</td>
</tr>
</tbody>
</table>
### Past Costs

#### 1300 MW Level

<table>
<thead>
<tr>
<th>Location</th>
<th>Capacity (MW)</th>
<th>Month/Year</th>
<th>Cost 1 (€)</th>
<th>Cost 2 (€)</th>
<th>Cost 3 (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paluel 1.2</td>
<td>2600</td>
<td>December 1985</td>
<td>1,743</td>
<td>3,950</td>
<td>1,531,008</td>
</tr>
<tr>
<td>Paluel 3.4</td>
<td>2600</td>
<td>April 1986</td>
<td>1,555</td>
<td>2,985</td>
<td>1,156,977</td>
</tr>
<tr>
<td>St Alban 1.2</td>
<td>2600</td>
<td>September 1986</td>
<td>1,519</td>
<td>2,935</td>
<td>1,128,846</td>
</tr>
<tr>
<td>Flamanville 1.2</td>
<td>2600</td>
<td>January 1987</td>
<td>1,727</td>
<td>3,320</td>
<td>1,286,822</td>
</tr>
<tr>
<td>Cattenom 1.2</td>
<td>2565</td>
<td>September 1987</td>
<td>1,933</td>
<td>3,484</td>
<td>1,358,285</td>
</tr>
<tr>
<td>Cattenom 3.4</td>
<td>2600</td>
<td>July 1991</td>
<td>1,836</td>
<td>3,092</td>
<td>1,091,154</td>
</tr>
<tr>
<td>Belleville 1.2</td>
<td>2620</td>
<td>September 1988</td>
<td>1,735</td>
<td>2,987</td>
<td>1,140,076</td>
</tr>
<tr>
<td>Nogent 1.2</td>
<td>2620</td>
<td>September 1988</td>
<td>1,881</td>
<td>3,128</td>
<td>1,193,893</td>
</tr>
<tr>
<td>Penly 1.2</td>
<td>2660</td>
<td>November 1991</td>
<td>2,223</td>
<td>3,420</td>
<td>1,285,714</td>
</tr>
<tr>
<td>Golfech 1.2</td>
<td>2620</td>
<td>August 1992</td>
<td>2,193</td>
<td>2,657</td>
<td>1,246,183</td>
</tr>
</tbody>
</table>

#### 1450 MW Level

<table>
<thead>
<tr>
<th>Location</th>
<th>Capacity (MW)</th>
<th>Month/Year</th>
<th>Cost 1 (€)</th>
<th>Cost 2 (€)</th>
<th>Cost 3 (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chooz 1.2</td>
<td>2910</td>
<td>July 2000</td>
<td>3,450</td>
<td>4,758</td>
<td>1,635,052</td>
</tr>
<tr>
<td>Civaux 1.2</td>
<td>2945</td>
<td>May 2002</td>
<td>2,895</td>
<td>3,683</td>
<td>1,250,594</td>
</tr>
</tbody>
</table>

**Total** |

<table>
<thead>
<tr>
<th>Level</th>
<th>Capacity (MW)</th>
<th>Cost 1 (€)</th>
<th>Cost 2 (€)</th>
<th>Cost 3 (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>62510</td>
<td>36,948</td>
<td>72,862</td>
<td>1,165,605</td>
<td></td>
</tr>
</tbody>
</table>

Source: EDF
Installed MW costs increase gradually but irregularly over time, due \textit{inter alia} to more stringent regulations. The initial production units are also more expensive to build as are the first units on each site, due to economies of scale achieved by sharing certain facilities. The average cost is \textbf{€1.17 million\textsubscript{2010} per MW}.

\textit{Engineering and labour costs}

Engineering and labour costs incurred by EDF for project construction and management are calculated from recorded annual engineering hours, i.e., a total of 78.15 million hours for constructing all nuclear plants. Identified adjusted costs for this volume of hours amount to €3,063 million (€6,888 million\textsubscript{2010}), representing an implied hourly rate for engineers of €88\textsubscript{2010}, which is consistent with actual rates.

\textit{Pre-operating charges}

Pre-operating charges represent the costs incurred by the future operator, before industrial commissioning of power plants, for nuclear licences, testing the various systems and training personnel. They have been quantified at €3,488 million\textsubscript{2010}, using approximate round figures which only give an overall idea of the past costs actually incurred but which cannot be precisely calculated.

\"Overnight cost\"

The "overnight" cost of the first investment in the existing facilities - construction, engineering and labour costs and pre-operating charges - can therefore be assessed overall at \textbf{€83.2 billion\textsubscript{2010}}, despite the uncertainty surrounding some of its components.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|}
\hline
\textbf{Overnight cost breakdown} & \textbf{€ 2010} \\
\hline
Construction costs & €72 862 million \\
Engineering and labour costs & €6 888 million \\
Pre-operating charges & €3 488 million \\
\hline
\textbf{Total} & \textbf{€83 238 million} \\
\hline
\end{tabular}
\end{table}

\textit{Source: EDF.}
3 - Depreciation of investment in existing plants

Existing nuclear production plants have largely been written down in accounting terms:

- currently operative nuclear units were initially depreciated on a declining balance basis over 30 years pursuant to French standards. This method enables higher depreciation allowances in earlier years, sharply and progressively reducing thereafter;

- on 1 January 2003, after introduction of the IFRS accounting standards⁷, depreciation was retrospectively recalculated by the straight-line method, resulting in adjustments to the amount of shareholder equity in the EDF balance sheet and in a correlative reassessment of tied-up assets (the gross value remained unchanged but accumulated depreciation was reduced);

- in parallel and since the same date, EDF has depreciated power plants over an operating period of 40 years, taking the view that this probable operating period better fulfils the requirements of accounting rules⁸, even though legally the decision to extend the operating period of each power plant by an extra 10 years can only be taken by the government following each ten-year safety assessment by the Autorité de Sûreté Nucléaire (ASN, French Nuclear Safety Authority) which specifies the conditions for any such extension. The remaining available depreciation for each power plant in 2003 was therefore recalculated using the straight-line method over an operating period of 40 years.

Due to the average age of plants and initial depreciation being calculated over a period of 30 years, existing nuclear plants have mostly been written down: by the end of 2010, the first investment costs had been depreciated by about 75 percent. Given the history of unit commissioning, most of the depreciation occurred in the financial years of the late 1980s and early 1990s.

Given these changes in depreciation calculation and the fact that EDF accounts do not enable tracing of depreciation of the initial investment but only that of total investment, including the capitalized cost of maintenance carried out on the plants since their construction (see

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⁸ Pursuant to IFRS rules, the depreciation period must correspond to the "probable useful life".
below), total annual depreciation in 2010 was **€1,352 million**, an increase of 19 percent, adjusted € value, since 2005.

**EDF depreciation provision for nuclear activity**

<table>
<thead>
<tr>
<th>Adjusted €million</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depreciation</td>
<td>1 137</td>
<td>1 131</td>
<td>1 236</td>
<td>1 232</td>
<td>1 272</td>
<td>1 352</td>
</tr>
</tbody>
</table>

*Source: EDF*

As a guide, the cost of the first investment (€83,238 million) can be divided by various possible operating periods to assess the resulting average annual investment; the figure varies according to the lifespan used, as shown in the table below.

**Initial investment according to plant lifespan (€2010)**

<table>
<thead>
<tr>
<th>Assumed plant operating period</th>
<th>30 years</th>
<th>40 years</th>
<th>50 years</th>
<th>60 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average annual investment €million</td>
<td>2 775</td>
<td>2 081</td>
<td>1 665</td>
<td>1 387</td>
</tr>
</tbody>
</table>

*Source: Cour des Comptes*

### 4 - Maintenance investment

The initial investment for power plant construction was supplemented by further investment, either to maintain plants in their original operating condition or to improve output or safety. These maintenance costs are entered in two different ways: as operating charges if they are "normal" maintenance costs (see Chapter II) or fixed assets, as accounting rules - which distinguish entries in charges from those in tied-up assets - have evolved over time.

It is impossible to know the total amount of maintenance investment in plants since their construction for the accounting reasons stated above. The table below shows the total of these tied-up costs since 2003. They relate to modifications made as a result of ten-year inspections required by law under the supervision of the French Nuclear Safety Authority (ASN), investment to comply with new safety regulations, costs required to run the power plants over a 40-year operating period and major preventive maintenance projects to correct the main defects which reduce power plant availability.
The table below shows that this investment almost tripled, in 2010 unadjusted Euro value, between 2003 and 2010, and increased by 61 percent between 2007 and 2010.

**Maintenance investment in existing plants**

<table>
<thead>
<tr>
<th>Maintenance investment</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjusted € million</td>
<td>518</td>
<td>568</td>
<td>664</td>
<td>790</td>
<td>1027</td>
<td>1221</td>
<td>1476</td>
<td>1748</td>
</tr>
<tr>
<td>€ million</td>
<td>584</td>
<td>630</td>
<td>723</td>
<td>842</td>
<td>1067</td>
<td>1237</td>
<td>1488</td>
<td>1748</td>
</tr>
<tr>
<td>Source: EDF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

There was a slowdown in this maintenance investment in the first few years of the new millennium when power plants started to reach an operating period of fifteen or twenty years. An insufficient level of maintenance investment at the start of the century led to defects and lowered performance⁹. EDF is now endeavouring to catch up and stop the reduction in plant availability rates, which diminished between 2006 and 2009, as shown in the table below.

**Changes in nuclear power plant availability rate**

<table>
<thead>
<tr>
<th>Year</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>%</td>
<td>83.6</td>
<td>80.2</td>
<td>79.2</td>
<td>78 (1)</td>
<td>78.5</td>
<td>80.7 forecast</td>
</tr>
<tr>
<td>Source: EDF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) 75 percent if the consequences of industrial unrest are included

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⁹ Statement by the Chairman of EDF before the Economic Affairs Committee of the French National Assembly on 26 January 2011: "The plants are entering a key phase: the majority of units will soon cross the decisive age threshold of thirty years which, in a heavy industry such as ours, means replacement of major components. A period of "major overhaul" has begun, meaning that major equipment such as steam generators, alternators and transformers must be replaced, as our American and European colleagues have done. We have fallen behind in this area. It has no impact on safety but causes severe damage and reduces our performance."
The low availability rate in recent years is partly explained by exceptional damage caused by insufficient maintenance investment to prevent unscheduled stoppages which reduce the plant availability rate. Maintenance investment has since risen regularly, particularly due to the accelerated programme to change the 900 MW steam generators.

EDF envisages that these costs will continue to increase significantly in the near future (+50 percent between 2010 and 2013) to restore its availability rate and bring it up to 85 percent. (See Chapter III-II-A-1: extension of power plant operating periods).

It should be pointed out that during the maintenance period, lengthy in certain cases, the availability rate may reduce again. Investment will prevent further worsening of this rate but will not immediately improve it.

### Availability rate of pressurized water reactors worldwide

<table>
<thead>
<tr>
<th>Year</th>
<th>United States</th>
<th>Spain</th>
<th>Belgium</th>
<th>Germany</th>
<th>United Kingdom</th>
<th>Japan</th>
<th>China</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>89.5</td>
<td>76.8</td>
<td>87.6</td>
<td>80.2</td>
<td>87.4</td>
<td>82.4</td>
<td>87.4</td>
</tr>
<tr>
<td>2010</td>
<td>90.4</td>
<td>89.7</td>
<td>88.0</td>
<td>86.4</td>
<td>45.6 (1)</td>
<td>77.3</td>
<td>87.9</td>
</tr>
</tbody>
</table>

*Source: CEA Elecnuc (information and statistics on nuclear power plants in the world)*

(1): pressurizer failure at Sizewell (British Energy)

### 5 - Book value of existing plants

The previous sections show that the EDF accounts do not enable a precise year-by-year reconstitution of the total initial and maintenance investment made since the plants started.

However, after extracting all things nuclear, the company accounts enable calculation of the net book value of nuclear power plants. This net book value is the sum of the remaining non-depreciated initial investment (very low for the oldest units, higher for recent units) and the non-depreciated portion of tied-up maintenance investment.
The gross value in the table below (€54.6 billion), the aggregated historical value, represents the cost of assets of the first investment in the plants, adjusted value (mainly the €36.9 billion construction costs, as shown in the table on pages 18 and 19), increased by tied-up maintenance investment and reduced by replaced assets, expressed in adjusted value.

### Book value of nuclear plants on 31/12/10
(under French standards)

<table>
<thead>
<tr>
<th>€million</th>
<th>Gross book value</th>
<th>Depreciation</th>
<th>Net book value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land and buildings</td>
<td>6 968</td>
<td>- 4 405</td>
<td>2 563</td>
</tr>
<tr>
<td>Nuclear production units</td>
<td>46 129</td>
<td>- 31 201</td>
<td>14 928</td>
</tr>
<tr>
<td>Non-network plant and tools</td>
<td>1 121</td>
<td>- 793</td>
<td>328</td>
</tr>
<tr>
<td>Other tangible fixed assets</td>
<td>424</td>
<td>- 334</td>
<td>90</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>54 642</strong></td>
<td><strong>- 36 733</strong></td>
<td><strong>17 909</strong></td>
</tr>
</tbody>
</table>

*Source: EDF*

The high depreciation calculated on historical costs in adjusted Euros explains the low **net book value** of the existing nuclear plants in the EDF accounts (€17.9 billion), a value which differs only slightly from the data calculated under IFRS standards, which results in a net book value of €18 billion.

### 6 - Precommissioning interest

The cost of constructing a power plant is incurred long before it begins to produce electricity; throughout the period, the company must cover the construction costs while income is nil. The current IFRS accounting standards allow the cost of precommissioning interest to be capitalized in the balance sheet enabling costs during construction to be financed, rather than allocating them to financial year charges, and to write them down over the same period as the construction itself. As such, they can be considered as part of the initial investment.

The construction cost records enable calculation of the average cash advance period for power plant construction. Two dates mark the start of production: the date of "first coupling" (first injection of electricity into the grid), and "industrial commissioning" (the contractual date for the end of construction, triggering the start of book depreciation). Actual electricity production regularly increases between these two dates which are several months and sometimes years apart.
By using the mean date between the first coupling and industrial commissioning as the reference for the start of electricity production, the average cash advance period is calculated as 3.24 years (the gap between the "mean" construction date and the "mean" production date). This calculation takes into account not only the power plant construction period but also the regulation policy under which EDF deliberately deferred industrial commissioning of a large number of units, especially to avoid excess capacity: in 1983 and then in 1986, "regulation" led to commissioning of the last Chinon units and all 1300 MW units being postponed for several months. EDF has also anticipated civil engineering work on some sites. The average cash advance period for the most recent units at Chooz and Civaux is particularly long (10 and 7.6 years respectively) due to industrial difficulties (design fault in the new instrumentation and control model) and also to a deliberate major delay in commissioning those units whose output would have caused excess capacity.

Precommissioning interest represents increased cash requirement, usually covered by short-term interest rate instruments under the borrowing terms prevailing at the time of construction. As a guide, the long series of average rates for public bond issues may be adopted, deducting the effect of inflation, i.e., for the 1977-2022 period an average actual cash rate of 4.5 percent per annum.

Using the adjusted rate of 4.5 percent and an average cash advance period of 3.24 years, total precommissioning interest amounts to €12.78 billion2010.

7 - Power plant financing

In addition to the investment itself, financing has a cost which is impossible to calculate directly via the EDF accounts as investment in nuclear power plants has not been separated from the company’s other investment and financing requirement. However, given the weight of nuclear investment, it has probably had a significant impact on the financing requirement of EDF.

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10 To assess the adjusted financial cost, EDF calculates precommissioning interest by applying an interest rate of 7.8 percent, giving a total of €23 billion2010.
The table below shows how the financial structure of the company has evolved, particularly as regards its capital and indebtedness. EDF shareholder equity was consolidated by regular injections of capital by the State until the end of the 1970s. The company capital increased significantly between 1975 and 1980 when it was engaged in nuclear plant construction. From 1981, the State stopped its capital investment and the accounts showed a significant negative carry-forward balance and a sharp increase in debt.

**Evolution of EDF shareholder equity and debt during the main nuclear plant construction phase**

<table>
<thead>
<tr>
<th>Year</th>
<th>Shareholder equity*</th>
<th>Carried forward</th>
<th>Debts</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>3 151</td>
<td>-279</td>
<td>7 681</td>
</tr>
<tr>
<td>1980</td>
<td>10 434</td>
<td>-682</td>
<td>17 823</td>
</tr>
<tr>
<td>1985</td>
<td>9 241</td>
<td>-3 480</td>
<td>42 133</td>
</tr>
<tr>
<td>1990</td>
<td>6 374</td>
<td>-4 280</td>
<td>46 321</td>
</tr>
<tr>
<td>1996</td>
<td>6 163</td>
<td>-2 798</td>
<td>31 337</td>
</tr>
<tr>
<td>1997</td>
<td>11 597</td>
<td>235</td>
<td>29 532</td>
</tr>
<tr>
<td>2000</td>
<td>12 961</td>
<td>327</td>
<td>28 682</td>
</tr>
</tbody>
</table>

*Source: EDF, statistical yearbook, financial situation*

11 This debt data covers a wider area than the debt data in the Bataille report (€33.9 billion adjusted in 1990), which only concerns medium- and long-term debt.
The significant reduction in the negative carry-forward balance and indebtedness at the beginning of the 1990s coincided with industrial commissioning of a large number of units at the end of the 1980s. In 1997, financial recovery was accompanied by balance sheet restructuring which enabled the carry-forward balance to be cleared and reserves to be bolstered.

As the Cour des Comptes stated in a previous report in that same period, price reductions had been scheduled in contracts between the State and the company so as to "bring cost and sale price closer by passing on the reduction in financial charges and productivity gains to the customer". The price reduction was 22 percent in unadjusted Francs over the 1985-1995 decade, while the company contract for 1997-2000 provided for a further reduction of 14 percent.

While the previous table concerns EDF as a whole and not exclusively the nuclear sector, it suggests that nuclear plants were financed, like other assets, both by State capital injections and by company debt, culminating in 1990 just after the period of very high investment. EDF estimated in 1996 that the nuclear programme had been 50 percent funded by self-financing, 8 percent by State capital injections and the remaining 42 percent by debt. However, it is difficult to see the specific consequences of those figures in terms of the cost of this financing.

* As for State funding, a system of interest on capital injections enabled the funds to be remunerated even in the event of a loss. From 1984, extra remuneration was provided, based on results. After the 1997 restructuring, remuneration on capital injections was reduced from 5 to 3 percent, while a ceiling was put on the extra remuneration so that total State remuneration could not exceed 6 percent of capital funding.

The statistical yearbook established by the company at that time reveals annual State remuneration of about 1 billion Francs in the 1970s, 2 billion Francs in the 1980s and 3 billion Francs in the 1990s. Taking inflation into account, remuneration of State capital injections, 3 to 6 percent, represents low real income, significantly lower than the theoretical rates of 8 or 9 percent, excluding inflation, provided at the time by the Commissariat général au Plan pour les entreprises publiques (General Plan Commission for Public-sector Companies).

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As for indebtedness, EDF as a State operator has traditionally had advantageous terms due to backing, and therefore guarantee, by the State, so has been able to borrow at interest rates comparable with those of the State while not having to finance the cost of guarantees.

Moreover, the peak of investment in nuclear production plants coincided with a period of high inflation which contributed to reducing the financial charges borne by the company. In 1979 for example, the average rate for public issue bonds over 7+ years was 10.63 percent, while the GDP inflation rate was 10.26 percent, representing an actual cash rate of 0.34 percent. Throughout the 1977-2002 period, the actual cash rate based on these two indices was 4.5 percent\(^\text{13}\). This average, calculated on the actual yield of State bonds, provides the historical costs borne by EDF for the portion of historical investment financed by debt.

**C - AREVA facilities**

The parliamentary report by Messrs. Bataille and Galley on the back end of the fuel cycle, published on 2 February 1999, shows in the graph below the sequence of costs for investment in the fuel cycle.

Total investment over the period\(^\text{14}\) amounts to 114 billion adjusted Francs, including 19 billion Francs for enrichment and 95 billion Francs for reprocessing, i.e., €30 billion\(^\text{2010}\), including €8 billion\(^\text{2010}\) for enrichment and €22 billion\(^\text{2010}\) for reprocessing.

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\(^{13}\) Average geometric annual rates after neutralization of inflation.

\(^{14}\) The report states that the three Tricastin reactors specifically for supply of electrical current to the Georges Besse 1 enrichment plant are not included in this total as they were counted among the investments of EDF, which is consistent with the approach of the Cour des Comptes in this report.
Investment by the COGEMA Group in the fuel cycle (adjusted kFF)

Source: Parliamentary report by Messrs. Bataille and Galley on the back end of the fuel cycle—2 February 1999

The report states that 50 percent of investment in enrichment and reprocessing capacity has been financed by foreign customers for their own requirements. The Cour des Comptes has therefore adopted, as total investment in the Cogema cycle, half the investment as described in the Bataille and Galley report, i.e., €15 billion2010, including €4 billion2010 for enrichment and €11 billion2010 for reprocessing15.

These investments represent "overnight" costs (construction, engineering, commissioning) and do not include associated financial costs (pre-commissioning interest).

AREVA invested about €10 billion2010 to renew its industrial tools (excluding its mining investment) between 2001 and 2010. As a result of the obsolescence of some of its facilities, this investment enabled it to develop its production capacity and use different technologies. The new Georges Besse 2 enrichment plant, inaugurated at the end of 2010, uses centrifuge technology, which consumes 50 times less electricity than the gas diffusion used formerly.

Only 40 percent of this investment (€4 billion out of €10 billion) is retained in the remainder of this report, to reflect the fact that France contributes only about 40 percent of the group’s current turnover.

15 This is reinforced by information provided by AREVA relating solely to the total construction cost (overnight cost excluding precommissioning interest) of Eurodif (€7 billion 2010) and of the two most recent plants at La Hague (UP3 and UP2 800 totalling €19.5 billion 2010).
II - Research costs

Deployment of the existing nuclear power plants was preceded and supported by major research programmes which may be regarded as part of the investment in and cost of the sector\textsuperscript{16}. Given the time scale chosen, from the end of the 1950s to the present day, the number of research organizations involved and variations in scope, the data is neither completely homogeneous nor wholly reliable. However, this uncertainty does not affect the consistency of all the following calculations.

To facilitate analysis, nuclear fission research has been split into two major segments:

• the existing nuclear power industry, covering research into:
  • reactors: 1\textsuperscript{st} generation (graphite-gas, heavy water), 2\textsuperscript{nd} generation boiling and light water (optimization) and 3\textsuperscript{rd} generation (EPR);
  • the fuel cycle, both at the front end (optimization and work on enrichment techniques) and back end (spent fuel processing and waste management);
  • support studies, including in particular research into protection and safety of plants, humans and the environment.

• the sector covering fast neutron reactors and the associated cycle, including:
  • Generation IV sodium-cooled fast neutron reactors and research into fast gas reactors;
  • the back end of the future cycle and refining of advanced plutonium and uranium recycling systems, including separation and transmutation of long-lived radionuclides.

However, there is no standard and sustained classification for nuclear power research expenditure recognized by all operators. It is therefore difficult to monitor sums spent on a specific sector like reprocessing or safety over a period or on a consolidated basis.

\textsuperscript{16} The scope of the analysis does not cover military research costs, nor those of fundamental research whose objective is the understanding of nuclear fission and not producing electricity.
A - 1945 – 1969: the first research programmes

The history of research expenditure on civil nuclear power in France broadly coincides with the history of the CEA, a scientific, technical and industrial establishment created by an Order dated 18 October 1945, which has conducted research since its creation into complete control of the nuclear cycle.

In the early years of the CEA, the distinctions between civil and military application and fundamental and applied research were somewhat arbitrary. The amount spent during those pioneering years has not therefore been included in the calculations below.

The third five-year plan from 1957-1961 launched the first French nuclear programme. A credit line of 5 billion Francs, or €7.5 billion\text{\$\text{1910}}, was provided to the CEA for, inter alia, military and fundamental research. The Cadarache centre was opened. The Pégase pool reactor, designed to test fuel behaviour, was built. The first experimental breeder reactor, Rapsodie, was launched and commissioned in 1967, as was the Pierrelatte enrichment plant. At the same time, EDF undertook construction of an initial programme of six graphite-gas power plants which gradually became operative from 1963; the CEA was responsible for studying the core, while EDF was responsible for studying the projects as a whole. The Brennalis heavy water reactor achieved criticality in 1966.

The graphite-gas sector represented the major research subject until 1963 (Pégase, Marius, César cells, irradiation studies, etc.) but the competing light and heavy water sectors were also being developed. The fast neutron sector had moved into first place by 1964, even before launch of the first Phénix development studies in 1968.

From 1957 to 1969, the total spent on civil nuclear power research was €14.4 billion\text{\$\text{2010}} (an annual average of €1.1 billion\text{\$\text{2010}}), including €10.7 billion\text{\$\text{2010}} for the CEA and €3.7 billion\text{\$\text{2010}} for industry. €11.2 billion\text{\$\text{2010}} of that total was spent on the two first generation reactors (graphite-gas, heavy water, light water) and the fuel cycle, €3.2 billion\text{\$\text{2010}} on the fast neutron sector.
Civil nuclear power research from 1957 to 1969

<table>
<thead>
<tr>
<th>€billion 2010</th>
<th>CEA</th>
<th>Industry</th>
<th>Total</th>
<th>current sector*</th>
<th>fast neutrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total for period</td>
<td>10.7</td>
<td>3.7</td>
<td>14.4</td>
<td>11.2</td>
<td>3.2</td>
</tr>
<tr>
<td>Average/year</td>
<td>0.85</td>
<td>0.28</td>
<td>1.1</td>
<td>0.85</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Source: Cour des Comptes * generation I to III sectors


The 1969-1970 decade marked a watershed with France’s commitment to the light water reactor under licence from the American WESTINGHOUSE\(^{17}\), abandonment of the graphite-gas reactor developed by the CEA and of heavy water reactors. The CEA Articles of Association and organization were thoroughly reformed via decentralization and division.

Promotion of fast neutron reactors then became the main focus of CEA research. Total expenditure on the Phénix prototype reactor, including construction and operation until 1976, was 943 million adjusted Francs, with a further 266 million Francs for the first three charges of plutonium, i.e., 1.2 billion adjusted Francs in total (€1 billion\(_{2010}\)), 120 million Francs of which was borne by EDF. To make the fuel and ensure reprocessing for fast neutron reactors, the CEA used the Cadarache manufacturing complex and the prototype fast oxide processing plant at Marcoule. These were later reconverted to produce MOX at a cost of €300 million\(_{2010}\)\(^{18}\).

\(^{17}\) FRAMATOME, a mostly privately-owned company formed in 1958 to promote PWR reactors, purchased the WESTINGHOUSE licence until 1973 for $1 million plus royalties of 1 percent of the full construction price, i.e., 7 to 8 million adjusted Francs per power plant built with this technology. The licence payment therefore replaced most development for perfecting PWR reactors in France.

\(^{18}\) Special report by the Cour des Comptes on the accounts and management of the CEA, financial years 1983 to 1986 – unpublished.
The second focus was on uranium enrichment to supply the second EDF investment programme for 58 light water power plants. The Tricastin EURODIF plant, using the gaseous diffusion process, already proven at Pierrelatte, became operational in 1979. At the same time, the CEA was working on alternative processes: the Chemex chemical processing programme from 1969 to 1988 at an aggregated cost of 2.75 billion Francs\textsubscript{1990} (or €590 million\textsubscript{2010}), and the Silva programme, using atomic vapour laser separation, from 1985 to 2004 at an aggregated cost of 1.1 billion adjusted Euros (or €1.5 billion\textsubscript{2010}), 25 percent from resources allocated to the CEA by COGEMA\textsuperscript{20}. Neither the Chemex nor Silva process was selected for industrial use.

The third focus was on adapting the WESTINGHOUSE technology to light water power plants and developing their output. In 1975, France negotiated a 1976-1980 joint development programme costing 500 million adjusted Francs (€250 million\textsubscript{2010}), equally financed by FRAMATOME, the CEA and WESTINGHOUSE for perfecting power plants of over 1000 MWe whose technology was not covered by the initial licence.

The fourth focus was on waste processing, especially research associated with construction of the La Hague plant, transferred to COGEMA after it became a subsidiary in 1976.

Finally, with the multiplication of nuclear power plants and the accidents at Three Mile Island in 1979 and Chernobyl in 1986, the CEA developed nuclear protection and safety programmes. Safety programmes accelerated, with Cabri (fast neutron reactors, reactivity accidents), Scarabée (fast neutron reactors, cooling accidents) and Phébus (water reactors).

***

\textsuperscript{19} 2004 public report by the Cour des Comptes, chapter on CEA management of major civil nuclear programmes.

\textsuperscript{20} Special report by the Cour des Comptes on the accounts and management of the CEA, financial years 1998 to 2001 – unpublished.
During the period 1970-1989, the amount spent by the CEA on applied research on civil nuclear power was €14.8 billion\textsubscript{2010} (€740 million\textsubscript{2010} per year), allocated as shown in the table below.

About €5 billion\textsubscript{2010} (€250 million\textsubscript{2010}/year) can be added to that amount for industry. Overall research investment therefore remained at about €1 billion per year, equivalent to that of the previous period, although it declines at the end of the period.

### Research expenditure 1970-1989

<table>
<thead>
<tr>
<th>(€million 2010)</th>
<th>Object</th>
<th>Total expenditure</th>
<th>Annual expenditure</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEA</td>
<td></td>
<td>14 800</td>
<td>740</td>
</tr>
<tr>
<td>generation 1 to 3 reactors</td>
<td>Reactors</td>
<td>2 600</td>
<td>130</td>
</tr>
<tr>
<td>Fuel cycle</td>
<td></td>
<td>5 300</td>
<td>270</td>
</tr>
<tr>
<td>Safety and other</td>
<td></td>
<td>2 400</td>
<td>120</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>10 400</td>
<td>520</td>
</tr>
<tr>
<td>Fast neutron reactors</td>
<td></td>
<td>4 400</td>
<td>220</td>
</tr>
<tr>
<td>Industry</td>
<td></td>
<td>~ 5 000</td>
<td>~ 250</td>
</tr>
<tr>
<td>Overall total</td>
<td></td>
<td>~20 000</td>
<td>~ 1 000</td>
</tr>
</tbody>
</table>

*Source: Cour des Comptes*

**C - 1990 - 2010: more structured research and partnerships**

The 1989 "Rouvillois report"\textsuperscript{21} painted a critical portrait of nuclear research and made recommendations for resizing resources, guidance of programmes by industry, development of partnerships and loosening ties with subsidiaries. This period is marked by a gradual shift away from publicly-funded research towards research undertaken by a growing number of industry players.

\textsuperscript{21} The May 1989 Report on the results and outlook for the civil nuclear sector in France by H.Guillaume, R.Pellat and Ph.Rouvillois, disclosed a crisis of identity and motivation, loss of image and a questioning of the role of the CEA as leader in its relationship with EDF then with COGEMA.
Steady reduction in CEA resources

Three major developments mark the changed role and resources of the CEA during this period:

− Fewer and more limited research programmes

  It was decided in 2004 to acquire, particularly for enrichment, the URENCO ultracentrifugation process, the rival of those developed by the CEA, and to use it in the new Tricastin plant (George Besse 2) which progressively commenced operation in 2011. The research associated with this process is done by ETC, equal subsidiary of AREVA and URENCO.

− Reduction in public financing

  Publicly-funded CEA research into the current nuclear sector reduced from €540 million\textsubscript{2010} per year during the 1970-1989 period to €390 million\textsubscript{2010} per year during the 1990-1999 decade, then €210 million\textsubscript{2010} per year in the 2000-2009 decade and €174 million\textsubscript{2010} in 2010. In addition to the major reduction in expenditure, its direction has changed: research into reactors and the fuel cycle has significantly reduced while research into support technologies, especially safety and protection studies, has taken their place.

  In the fast neutrons sector, costs rose from €30 million\textsubscript{2010} per year at the end of the 1980s to €80 million\textsubscript{2010} per year in the 1990s and 2000s, and €97 million in 2010. The cost of renovating and updating Phénix in the early 2000s must be added to these figures: the Phénix reactor, which maintained its operating equilibrium until 1989, stopped between 1990 and 1994. The authorities decided to keep the workforce, operating costs and investment, then to upgrade and renovate it to conduct research which could no longer be done at Superphénix. The Cour des Comptes estimated these costs at 6 billion Francs\textsubscript{1994}, or €1.2 billion\textsubscript{2010} between 1990 and 2002, 80 percent payable by the CEA and 20 percent by EDF\textsuperscript{22}.

− Major external resources

  Nuclear research by the CEA is also financed by dividends paid to it by COGEMA and FRAMATOME until 2000 and AREVA from 2001: in addition to a fixed sum of €104 million per year allocated to specifically civil funds (see Chapter III-C), the CEA has applied the surplus, and also the proceeds of the sale of its head office in 2004, to research, i.e., a total of €604 million\textsubscript{2010} from 2002 to 2010.

\textsuperscript{22} Special report by the Cour des Comptes on the accounts and management of the CEA, financial years 1987 to 1993 and 1998 to 2001 – unpublished.
Devolution of research on new organizations

- French Institute for Radiological Protection and Nuclear Safety (IRSN)

The IRSN, created by Act No. 2001-398 of 9 May 2001 (Article 5) whose assignments and organization were defined in Decree No. 2002-254 of 22 February 2002, took over the work on nuclear safety, including transport, and protection against ionizing radiation, of the Office for Protection against Ionizing Radiation (OPRI) and the Institute for Nuclear Safety and Protection (IPSN), created in 1976 within the CEA; its jurisdiction also covers protection and control of nuclear materials, and protection against malicious acts of nuclear plants and transport of radioactive and fissile substances.

It has had an average of €130 million in annual resources since 2005 for nuclear power research, financed 88 percent by State subsidies, the remainder by joint financing with industry (EDF, AREVA, etc.). Apart from research on plant safety, the IRSN includes research into human and environmental protection within its ambit, but excludes research into medical radiation.

Article 25 of the IRSN Decree provides that the CEA "as a priority, places basic nuclear installations (...) which, before publication of this Decree, were allocated to safety research, at the disposal of IRSN for the purposes of research programmes defined and conducted by the latter." This provision concerns two experimental reactors, part of the "civil" activity of the CEA for 30 years, of which the CEA remains owner and nuclear operator:

- Phébus, for the study of fuel cooling accidents and release of radioactive substances, was stopped in 2007;
- Cabri, for the study of fuel behaviour in accident situations, generates fixed costs of €14 million per year, including €11 million allocated to the CEA and €3 million in IRSN resources. Halted for safety upgrading, it will return to service in 2013.

23 Special report by the Cour des Comptes on the accounts and management of IRSN, financial years 2002 to 2006 – unpublished.
In all, 28 percent of the IRSN nuclear power research budget in 2007-2010 was allocated to the CEA.

- **French National Radioactive Waste Management Agency (ANDRA)**

Under the Act of 31 December 1991, ANDRA became independent from the CEA. The act provided that it would "explore the possibilities for reversible or irreversible disposal in deep geological formations, including through the construction of underground laboratories".

ANDRA has conducted its research into clay and granite geological environments suitable for deep disposal purposes. It constructed an almost 500-metre deep underground laboratory in Bure. The total cost of civil research, mainly into high-level and intermediate-level long-lived waste (HLW-ILW-LL), has been €1.5 billion since 1990, i.e., €73 million per year average increase over the period (€63 million per year until 2003 then €93 million per year). This research was financed by the producers of waste until 2006 and, since 2007, by a tax on basic nuclear installations (INBs) paid by the same producers, the division of civil financing having been stable since 2000 (84 percent from EDF, 11 percent from the CEA, 5 percent from AREVA).

- **French National Centre for Scientific Research (CNRS)**

The CNRS spent €28 million in 2010 on nuclear power research, including €8 million on existing reactors, €3 million on front end facilities, €10 million on waste disposal, €3 million on Generation IV, the balance not being capable of breakdown. It has difficulties in assessing costs in previous years due to changes in the structure of its units but considers that the amounts are stable in unadjusted Euro.

The growing influence of industry in research-development

Simultaneously with the reduction in public funds provided to the CEA, this period has been marked by a significant increase in financing from EDF and AREVA.

- **Electricité de France (EDF)**

EDF had an average annual research budget of €215 million from 2000 to 2009, slightly less at the end of the period (€200 million in 2010), including tax credits for research (an annual average of
€20 million during 2005-2009, €34 million in 2010) which EDF states is impossible to apportion between nuclear and non-nuclear research.

In 2010, per category and excluding generation IV (€9 million), fuel and component behaviour represented 38 percent of expenditure, reactors (instrumentation, working processes, etc.) 20 percent, back end of the cycle and decommissioning 12 percent, modelling 11 percent, safety 10 percent, contribution to the major resources of CEA, 9 percent.

- **AREVA**

AREVA was formed in September 2001 by the merger of COGEMA, FRAMATOME and other trading interests of the CEA in CEA-Industrie. It has had an average annual research budget of €210 million since 2000 for civil nuclear research, excluding TECHNICATOME. The research budget was stable during 2000-2005 and unlike that of EDF, has increased since 2006 (€295 million in 2010).

In 2010, per category and excluding Generation IV (11 million), front end research (extraction procedures, transformation of ore, enrichment, fuel properties) represented 33 percent of expenditure, reactor research 34 percent, back end research (reprocessing-recycling) 26 percent and 7 percent on cross-sector studies.

***

The aggregated expenditure on CEA public subsidies from 1990 to 2010 was therefore €8.8 billion including €6.2 billion on the existing nuclear industry, €1.6 billion on the fast neutron sector excluding Phénix and €1 billion for Phénix. Expenditure on the existing nuclear industry is split between €1.6 billion (€75 million per year) on reactors, €2.5 billion (€120 million per year) on the fuel cycle and €2.1 billion (€100 million per year) on support studies (safety and other expenditure). The CEA has also received a total of €800 million to €1 billion in external financing via dividends from its subsidiaries for nuclear power research.

Other public operators, which became independent from the CEA in 1990 (ANDRA), and 2002 (IRSN), spent €2.8 billion over the period, including €1.5 billion by ANDRA, €1 billion by IRSN and about €300 million by the CNRS.

Except for the 2000s, the Cour des Comptes is unable to discern the overall investment by industry, but by extrapolating figures for the 1990s, their research investment can be estimated at over €8 billion during the period, shared equally between EDF and AREVA.
Overall research investment (table below) therefore amounted to €21 billion between 1990 and 2010, i.e., **€1 billion per year**, including an annual average of €850 million on existing nuclear facilities and €150 million per year on the fast neutron sector, €470 million per year for the CEA, €130 million per year for the other public operators and €400 million per year for industry.

**Civil nuclear power research from 1990 to 2010**

<table>
<thead>
<tr>
<th>€billion 2010</th>
<th>CEA from public resources</th>
<th>CEA from dividends</th>
<th>Other operators</th>
<th>Industry</th>
<th>Total</th>
<th>On existing sector</th>
<th>On fast neutrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total for the period</td>
<td>8.8</td>
<td>1.0</td>
<td>2.8</td>
<td>8.4</td>
<td>21.0</td>
<td>17.9</td>
<td>3.1</td>
</tr>
<tr>
<td>Annual average</td>
<td>0.42</td>
<td>0.05</td>
<td>0.13</td>
<td>0.40</td>
<td>1.0</td>
<td>0.85</td>
<td>0.15</td>
</tr>
</tbody>
</table>

*Source: Cour des Comptes  *reactor generations I to III

**D - Total research expenditure on nuclear power from 1957 to 2010**

Total research expenditure on nuclear power from 1957 to 2010 is about **€55 billion2010, or €1 billion2010** per year. €43 billion2010 of this total was spent on existing nuclear facilities (including generations prior to the existing plants) and €12 billion2010 on fast neutron reactors.

**Summary: Civil nuclear power research from 1957 to 2010**

<table>
<thead>
<tr>
<th>€billion 2010</th>
<th>CEA</th>
<th>Other operators</th>
<th>Industry</th>
<th>Total</th>
<th>on generations I to 3</th>
<th>on fast neutrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total for the period</td>
<td>35.3</td>
<td>2.8</td>
<td>17.1</td>
<td>55.2</td>
<td>43.0</td>
<td>12.2</td>
</tr>
<tr>
<td>Annual average</td>
<td>0.65</td>
<td>0.05</td>
<td>0.32</td>
<td>1.02</td>
<td>0.8</td>
<td>0.22</td>
</tr>
<tr>
<td>on generations I to 3</td>
<td>26.1</td>
<td>2.8</td>
<td>14.1</td>
<td>43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>on generation 4</td>
<td>9.2</td>
<td></td>
<td>3</td>
<td>12.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Source: Cour des Comptes*
The CEA financed €26 billion \textsubscript{2010} for existing nuclear plants (generations 1 to 3) and per operator, including €9 billion \textsubscript{2010} for reactors, €12 billion \textsubscript{2010} for the fuel cycle and €5 billion \textsubscript{2010} for support studies. Other public operators provided €2.8 billion \textsubscript{2010} (€1.5 billion \textsubscript{2010} from ANDRA for waste management, €1 billion \textsubscript{2010} from IRSN for safety, the balance from the CNRS) and industry about €14 billion \textsubscript{2010} in comparable proportions from EDF and AREVA. The CEA spent €9 billion \textsubscript{2010} on the fast neutron sector and industry (principally EDF), spent €3 billion \textsubscript{2010}.

The annual expenditure has remained broadly stable but its apportionment between the nomenclature themes has changed: a reduction in resources for reactors and increased spending on support technologies (especially safety). The concentration of resources in the CEA, the original driving force of French nuclear power policy, has also given way to a diversification among operators (public or industrial establishments); research is coordinated through joint financing, enabling research to meet the requirements of industry, which is more involved in use of its results.

Expenditure on the fast neutron sector has fluctuated greatly throughout the period with an initial peak at the beginning of the 1970s (construction of Phénix), a second at the end of the 1990s (consequences of the Superphénix stoppage), a trough since 2003 and then a new lease of life in 2010 with the ASTRID programme.

As far as methods are concerned, both public and private operators would benefit from adopting a standard nomenclature for research expenditure per reactor generation and per research type (enrichment of ore, fuel properties, reactors, protection and safety, waste treatment and recycling, decommissioning of installations, various studies, etc.). Application of such nomenclature is vital for having an overview of the direction taken by operator research and any deviation.

The Cour des Comptes also notes that the historical public research data provided to the IEA is not exhaustive (the costs of Phénix, not taken into account, had to be reincorporated), is sometimes wrong (the figure for the IRSN in 2009 and CNRS had to be corrected) and uses a nomenclature which lacks precision\textsuperscript{24}. The current reform of the

\textsuperscript{24} As an example, research on the climate, radiobiology and radiotoxicology are in the same section, which led to their exclusion from 1994 while a more precise nomenclature would have enabled reincorporation of the cost of research into environmental contamination; moreover, the "support studies" item is insufficiently precise.
nomenclature should enable a much needed improvement in the analytical precision of data.

E - Superphénix

Superphénix cost €12 billion\textsubscript{2010} over the 1974-1997 period in construction and operation, but its change of "status" from an industrial to a research facility, has made it a special case.

Launched in 1974, this reactor with an industrial output of 1200 MWe was built at Creys-Malville by NERSA, a dedicated company majority-owned by EDF, with Italian and German partners and without direct involvement by the CEA beyond preliminary studies. Connected to the grid in January 1986, it was not intended to be used for research purposes but for producing electricity. However, it operated for only ten months until 1994, until being redirected as a sub-generation research tool at an annual cost of 100 million adjusted Francs, fully borne by EDF, before being closed in 1997.

Excluding CEA and EDF preliminary studies and also dismantling costs, the Cour des Comptes estimated in its 1996 public report the full cost of Superphénix at 60 billion Francs\textsubscript{1994}, or €12 billion\textsubscript{2010}, including €2.5 billion\textsubscript{2010} in financial charges.
Research and creating value

Apart from the fact that research has enabled the knowledge and techniques of nuclear power production to advance, it has also led to the creation or development of structures or activities which have a value of their own.

AREVA, several parts of which derive from CEA activities or holdings, could be considered as a "product" of enrichment and reprocessing research. However, besides the fact that the value of AREVA is not easy to define, it is more involved today with its mining, rather than industrial activities associated with CEA research activities.

Moreover, the CEA has a portfolio of 512 active nuclear energy patents. 57 new patents were filed in 2010, including 17 in partnership (5 with the CNRS, 2 with IRSN, 2 with AREVA, 1 with EDF, 7 with other partners). While the number of filed patents is significant, the royalties they generate are limited. The CEA received €14 million in royalties in 2010 for its 1,470 active patents covering all activities. Given the small amount involved, it did not seem important to determine the portion attributable to nuclear power. The situation is explained by the fact that in most cases, the CEA makes patented technologies available to industrial partners for new jointly-financed research and development projects or, more rarely, it alone uses them for its own requirements. In the first case, partners who have jointly financed the research are given user rights over patents without paying royalties. Less frequently, the CEA grants user rights over patents when there is no partnership link with the user.

The CEA also enhances the value of its research results by creating start-up companies. The CEA has developed 140 start-up businesses, covering all activities, with an overall turnover of €500 million. Expertise acquired through nuclear power research has resulted in the creation of companies in nuclear medicine (imaging, diagnostics, radiotherapy), performance of materials, robotics (originally for accessing contaminated areas) and software security (originally for power plant instrumentation and control). Created in the nuclear sector, these businesses have then gone on to expand by re-using their technology in industry. The CEA is unable however to enhance the value of the portfolio of activities it holds or generates.
CONCLUSION – PAST COSTS

Total past investment in developing nuclear power production and enabling construction of existing plants and associated basic nuclear installations is estimated at €188 billion\textsubscript{2010}. It is broken down as follows:

- physical investment of about €121 billion\textsubscript{2010} overall, invested mainly by EDF (about €102 billion\textsubscript{2010}) for building the 1\textsuperscript{st} generation plants (about €6 billion\textsubscript{2010}) and above all the existing plants (€96 billion\textsubscript{2010}, including €13 billion\textsubscript{2010} in precommissioning interest). Investment in existing plants after initial construction is not included in this total. Other investment relates to the fuel cycle (about €40 billion\textsubscript{2010} only €19 billion\textsubscript{2010} of which is included as being for the requirements of French plants);

- applied research and development investment amounting to €55 billion\textsubscript{2010} between 1957 and 2010, or about €1 billion\textsubscript{2010} per year, including €38 billion\textsubscript{2010} financed by public funds. These costs cover both research expenditure and investment in experimental laboratories and reactors;

- the cost of construction, operation and closure of Superphénix (excluding dismantling costs) which is estimated overall at €12 billion\textsubscript{2010}, including financial costs, mostly borne by EDF.
Chapter II

Current costs

Production of nuclear power involves annual expenditure, some of which is directly linked to production and therefore borne by EDF as producer; other expenses, principally for research and safety, are indirect and financed from a number of sources.

I - EDF operating costs

EDF cost accounting enables separation of the nuclear business, 84 percent of whose costs are direct charges and 16 percent indirect charges (Annex 8). These costs are attributable to the annual production of plants to assess the kWh cost.

A - The cost of nuclear fuel

There are two fuel cost components:

− annual costs paid by EDF to AREVA and its other suppliers for supply of fuel ready to be used in power plants;
− the cost of fuel stock management.

There is also the future cost of treating this fuel after use, which is examined later (Chapter III).
a) Nuclear fuel invoices

The cost of annual fuel consumption in reactors varies according to unit production: it includes the cost of natural uranium consumption and of services linked to manufacture of the various types of fuel used (conversion, fluoridation, enrichment and fuel handling). Consumption of front end fuel is valued at a weighted average cost. It represents most of the variable costs in any given year.

The annual fuel cost is attributable to invoices from AREVA and other EDF suppliers. It appears that, as a result of its price terms, AREVA passes on all costs incurred in supplying these services to its customer EDF; these price terms correspond to normal market conditions for the following reasons:

− the Areva 2010 reference document, which is submitted to the auditors and the French financial markets authority (AMF) for approval, specifically states that Areva effects "current account transactions" with EDF;

− EDF is a major customer (25 percent of Areva turnover) but it is far from being its only customer. In particular, EDF is the principal customer in two Areva nuclear business areas (front end for fuel supply and back end for spent fuel reprocessing); the combined operating profit for these two areas in 2010 was €241 million on a turnover of €5,673 million, from which it may be implied that the AREVA invoices incorporate all its costs.

Given that AREVA makes provision in its accounts for decommissioning its facilities and future management of its waste (see Chapter III), these invoices may be seen as incorporating future fuel-linked expenditure into the cost of the fuel.

b) Cost of stocks required for operating nuclear plants

The operation of existing reactors and the need to secure supplies have led EDF to keep a stock of raw materials and fuel amounting to €7,523 million on 31 December 2010 (as against €7,016 million on 31 December 2009 and €6,639 million on 31 December 2008), or about four years’ consumption. A large part of the value of fuel stocks is represented by fuel in reactors.
The cost of financing this stock is a charge as EDF must tie up capital to finance it. This amounted to €632 million in 2010.

### Cost of keeping fuel stocks

<table>
<thead>
<tr>
<th>Adjusted €millon</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of keeping stocks</td>
<td>558</td>
<td>589</td>
<td>632</td>
</tr>
</tbody>
</table>

*Source: EDF*

c) **Evolution of nuclear fuel cost**

The fuel cost per MWh increased by 6.9 percent between 2008 and 2010.

### Evolution of overall cost of nuclear fuel

<table>
<thead>
<tr>
<th>Adjusted €</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear fuel costs in € millions (a)</td>
<td>1 485</td>
<td>1 504</td>
<td>1 503</td>
</tr>
<tr>
<td>Annual production in TWh</td>
<td>417.6</td>
<td>389.8</td>
<td>407.9</td>
</tr>
<tr>
<td>Cost of fuel used over year in € per MWh</td>
<td>3.56</td>
<td>3.86</td>
<td>3.68</td>
</tr>
<tr>
<td>Cost of keeping stock in € millions (b)</td>
<td>558</td>
<td>589</td>
<td>632</td>
</tr>
<tr>
<td><strong>Total costs (a + b) in € millions</strong></td>
<td><strong>2 043</strong></td>
<td><strong>2 093</strong></td>
<td><strong>2 135</strong></td>
</tr>
<tr>
<td>Annual production in TWh</td>
<td>417.6</td>
<td>389.8</td>
<td>407.9</td>
</tr>
<tr>
<td>Total fuel cost in € per MWh</td>
<td>4.89</td>
<td>5.37</td>
<td>5.23</td>
</tr>
</tbody>
</table>

*Source: EDF*
B - EDF personnel costs

Personnel costs comprise salary costs of EDF employees working in nuclear power production as shown in EDF cost accounting, together with costs calculated on a more fixed basis for benefits received by all EDF employees.

The personnel charges taken into account are exclusively those for personnel involved in nuclear power production which in 2010 represented 37 percent of the EDF SA payroll. Personnel involved in marketing, distribution and in the "engineering production" division working in other energy sectors (including hydraulic and thermal power) are excluded.

<table>
<thead>
<tr>
<th>Personnel included in the cost of nuclear power</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total EDF SA workforce</td>
<td>59 131</td>
<td>59 837</td>
<td>60 380</td>
</tr>
<tr>
<td>Employees in engineering production division</td>
<td>34 344</td>
<td>32 646</td>
<td>33 696</td>
</tr>
<tr>
<td>EDF SA personnel charges (adjusted € millions)</td>
<td>5 095</td>
<td>5 290</td>
<td>5 502</td>
</tr>
<tr>
<td>Personnel charges for engineering production division</td>
<td>2 823</td>
<td>2 769</td>
<td>2 839</td>
</tr>
<tr>
<td>Personnel charges included in calculating nuclear power costs (adjusted € millions)</td>
<td>1 979</td>
<td>1 993</td>
<td>2 042</td>
</tr>
<tr>
<td>Percentage of total personnel charges</td>
<td>39 percent</td>
<td>38 percent</td>
<td>37 percent</td>
</tr>
</tbody>
</table>

*Source: EDF*

a) Salary costs

Personnel costs were €2,042 million in 2010 according to EDF cost accounting, corresponding to the salary costs of staff involved in nuclear power.

These personnel costs were relatively stable between 2008 and 2010. However, quite apart from changes in nuclear power generation, these costs will probably rise as a result of increasing the workforce to improve maintenance and safety.
**Salary costs**

<table>
<thead>
<tr>
<th>Adjusted € million</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel costs</td>
<td>1 979</td>
<td>1 993*</td>
<td>2 042</td>
</tr>
<tr>
<td>Annual change</td>
<td>+0.7%</td>
<td>+2.4%</td>
<td></td>
</tr>
<tr>
<td>Output in TWh</td>
<td>417.6</td>
<td>389.8</td>
<td>407.9</td>
</tr>
<tr>
<td>Personnel costs /MWh in €</td>
<td>€4.74</td>
<td>€5.11</td>
<td>€5.01</td>
</tr>
</tbody>
</table>

* The small increase in the "personnel" item between 2008 and 2009 is mostly explained by an organizational change which led to increasing staff in the "power plant and shared facilities" item, reducing those directly involved in nuclear power services.

**b) Other personnel costs**

Three other types of personnel costs must be included in nuclear energy costs, even if they are not costs specific to this method of production, as they are inherent in the status of gas and electricity industry workers. They are:

- the employee tariff, a benefit in kind enabling personnel in the electricity and gas industries – especially EDF employees – to be supplied with electricity on more favourable terms than the general public. The cost in the table below is the financial cost of the loss of income for EDF, calculated after comparing the price for the general public and that for employees;

- the impact of the Act of 9 August 2004 which reformed staff pensions in the electricity and gas industries by attaching them to the ordinary social security system;

- post-employment and other personnel benefits.

Unlike salary costs directly resulting from the cost accounting referred to above, assessment of the other personnel costs is based on less sound estimates, particularly as concerns the allocation basis used or the calculation methods. They are however consistent from one year to the next and, given the limited sum involved, inaccuracies will have no significant impact on the total cost.
### Other personnel costs

<table>
<thead>
<tr>
<th></th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employee tariff</td>
<td>101</td>
<td>116</td>
<td>116</td>
</tr>
<tr>
<td>Cost of 2004 reform</td>
<td>114</td>
<td>122</td>
<td>123</td>
</tr>
<tr>
<td>Cost of other personnel benefits</td>
<td>366</td>
<td>375</td>
<td>395</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>581</td>
<td>613</td>
<td>634</td>
</tr>
</tbody>
</table>

*Source: EDF*

### c) Total personnel costs

Relative to output, personnel costs increased, in adjusted Euros, by 7 percent between 2008 and 2010. In its opinion of 3 January 2012 on additional safety assessments (ECS) following the Fukushima accident, the ASN stated that it would be mindful of socio-organizational and human factors, "essential safety matters"; it especially observed that "renewal of the workforce and operator skills is fundamental whilst simultaneously undertaking a major upgrading of generations and works following the ECSs". In conjunction with the creation of a rapid action force, itself the result of ECSs, this concern should lead to an increase in staff to bolster maintenance and safety, already noticeable in 2011, a financial year in which salary costs rose by 13.5 percent.

### Total personnel costs

<table>
<thead>
<tr>
<th></th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salary costs</td>
<td>1 979</td>
<td>1 993</td>
<td>2 042</td>
</tr>
<tr>
<td>Other personnel costs</td>
<td>581</td>
<td>613</td>
<td>634</td>
</tr>
<tr>
<td><strong>Total personnel costs</strong></td>
<td>2 560</td>
<td>2 606</td>
<td>2 676</td>
</tr>
<tr>
<td>Output in TWh</td>
<td>417.6</td>
<td>389.8</td>
<td>407.9</td>
</tr>
<tr>
<td>Personnel costs /MWh in €</td>
<td>€6.13</td>
<td>€6.69</td>
<td>€6.56</td>
</tr>
</tbody>
</table>

*Source: EDF*
C - External costs

External costs other than fuel include all purchases made for nuclear power generation. These include maintenance costs not considered as investment and not therefore capitalized, unlike those examined above (in Chapter I), logistical costs and certain other sundry operating charges. Maintenance expenditure mainly comprises subcontracting costs.

Evolution of external costs

<table>
<thead>
<tr>
<th></th>
<th>Adjusted € million</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating maintenance</td>
<td>196</td>
<td>196</td>
<td>229</td>
<td></td>
</tr>
<tr>
<td>Asset maintenance</td>
<td>1 132</td>
<td>1 257</td>
<td>584</td>
<td></td>
</tr>
<tr>
<td>Shutdown maintenance</td>
<td>53</td>
<td>653</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance sub-total</td>
<td>1 328</td>
<td>1 506</td>
<td>1 466</td>
<td></td>
</tr>
<tr>
<td>Logistics</td>
<td>143</td>
<td>160</td>
<td>170</td>
<td></td>
</tr>
<tr>
<td>Other operating charges</td>
<td>297</td>
<td>434</td>
<td>459</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1 768</strong></td>
<td><strong>2 100</strong></td>
<td><strong>2 095</strong></td>
<td></td>
</tr>
</tbody>
</table>

Source: EDF

All subcontracting charges incurred by EDF, mainly for maintenance, are entered as external costs, with the notable exception of subcontracted capitalized maintenance. ASN also emphasized this in its opinion on the additional safety assessments after Fukushima. It states that "organization of outsourcing, which is a major and difficult subject" is one of the "priorities which it will follow closely". "In particular, supervision of subcontractors working in nuclear power plants must be reinforced and should not be delegated by the operator when it involves overseeing important safety work". The cost consequences of these provisions which reflect the concerns of OPECST in its March 2011 progress report after the Fukushima accident (see below, II-2-c), are not currently quantifiable by the Cour des Comptes. However, the increase in maintenance work to improve power plant availability, meet post-Fukushima safety requirements and prepare an extension of the operating period of reactors (see below, Chapter VI), whether as external costs (in operating charges) or tied-up assets, will lead to a significant increase in subcontracting charges.
Overall and relative to output, external costs increased, in adjusted Euros, by 21.5 percent between 2008 and 2010.

### External costs, excluding fuel

<table>
<thead>
<tr>
<th>Adjusted € million</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>External costs</td>
<td>1 768</td>
<td>2 100</td>
<td>2 095</td>
</tr>
<tr>
<td>Subcontracting</td>
<td>1 187</td>
<td>1 381</td>
<td>1 322</td>
</tr>
<tr>
<td>Output in TWh</td>
<td>417.6</td>
<td>389.8</td>
<td>407.9</td>
</tr>
<tr>
<td>External costs in € per MWh</td>
<td>€4.23</td>
<td>€5.39</td>
<td>€5.14</td>
</tr>
</tbody>
</table>

*Source: EDF*

### D - Rates and taxes

Neither Corporation Tax nor VAT has been included in operating charges.

#### Evolution of rates and taxes

<table>
<thead>
<tr>
<th>Adjusted € million</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rates and taxes</td>
<td>1 027</td>
<td>1 091</td>
<td>1 176</td>
</tr>
<tr>
<td>Output in TWh</td>
<td>417.6</td>
<td>389.8</td>
<td>407.9</td>
</tr>
<tr>
<td>Cost per MWh</td>
<td>€2.46</td>
<td>€2.80</td>
<td>€2.88</td>
</tr>
</tbody>
</table>

*Source: EDF*

Rates and taxes paid by EDF and included in the cost of producing nuclear power comprised in 2010:

- the tax on basic nuclear installations (INBs) of €516 million;
- business rates and the tax which succeeded them, i.e., the Cotisation Foncière des Entreprises (€104 million) and the Cotisation sur la Value Ajoutée (€99 million);
- fixed tax on energy network companies of €187 million;
- land tax of €165 million;
- the French "Voie Navigable de France" Waterways Tax of €72 million;
- fees paid to water management agencies of €32 million.
Total rates and taxes amounted to €1,176 million in 2010 and increased by 14.5 percent between 2008 and 2010 and by 17 percent in relation to output.

**E - The cost of central and support operations**

The calculation of the cost of central and support operations is intended to allocate to nuclear power generation a portion of the costs incurred by support operations (costs of research, training, IT, insurance, property excluding power plants, overheads), on behalf of "engineering production" management, a portion of the costs incurred by the service centres shared by the EDF Group (payroll, human resources, accounts and telecommunications departments), and a portion of the costs incurred by group management (general, financial and communication management).

**Detailed costs of central and support services**

<table>
<thead>
<tr>
<th>调整后百万欧元</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT</td>
<td>&quot;other&quot;线</td>
<td>&quot;other&quot;线</td>
<td>176</td>
</tr>
<tr>
<td>IT和电信维护</td>
<td>5</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>R&amp;D研究</td>
<td>175</td>
<td>183</td>
<td>187</td>
</tr>
<tr>
<td>保险</td>
<td>43</td>
<td>44</td>
<td>41</td>
</tr>
<tr>
<td>人力资源, 工资, 培训</td>
<td>4+&quot;其他&quot;线</td>
<td>&quot;其他&quot;线</td>
<td>71</td>
</tr>
<tr>
<td>购买和维护</td>
<td>47</td>
<td>35</td>
<td>40</td>
</tr>
<tr>
<td>财务</td>
<td>2</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>会计</td>
<td>3</td>
<td>&quot;其他&quot;线</td>
<td>3</td>
</tr>
<tr>
<td>非共享的管理支持服务</td>
<td>190</td>
<td>212</td>
<td>216</td>
</tr>
<tr>
<td>其他</td>
<td>200</td>
<td>428</td>
<td>127</td>
</tr>
<tr>
<td><strong>总和</strong></td>
<td><strong>669</strong></td>
<td><strong>910</strong></td>
<td><strong>872</strong></td>
</tr>
</tbody>
</table>

*Source: EDF*

These costs, amounting to €872 million in 2010, increased by over 30 percent between 2008 and 2009-2010, due mainly to the 2009 creation of the shared services directorate which took over some of the staff previously allocated to direct charges for personnel in the nuclear sector. This reorganization also explains the small increase in personnel charges between 2008 and 2009.

The three main expenditure items are the general management support services share, research and development expenditure and IT costs. Insurance costs are modest at €41 million in 2010, which includes €6 million for EDF public liability. The latter figure may significantly
increase in the future (by a factor of 7 or 8) with the application of new insurance regulations (see Chapter VII-II on insurance).

**The cost of central and support services**

<table>
<thead>
<tr>
<th>lsen</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central and support services</td>
<td>669</td>
<td>910</td>
<td>872</td>
</tr>
<tr>
<td>Output in TWh</td>
<td>417.6</td>
<td>389.8</td>
<td>407.9</td>
</tr>
<tr>
<td>Cost in € per MWh</td>
<td>1.60 €</td>
<td>2.33 €</td>
<td>2.14 €</td>
</tr>
</tbody>
</table>

**Source:** EDF

**F - Total operating costs**

Total operating costs for nuclear power generation in 2010 was **8.9 billion, or €22 per MWh.** The total amount increased by 11 percent between 2008 and 2010 and by **14 percent** relative to output.

**Summary: operating costs**

<table>
<thead>
<tr>
<th>Types of charge</th>
<th>2008</th>
<th>2009</th>
<th>2010 adjusted €</th>
<th>Change 2010/2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel</td>
<td>€2 043 million €4.89</td>
<td>€2 093 million €5.37</td>
<td>€2 135 million €5.23</td>
<td>+ 5 percent + 7%</td>
</tr>
<tr>
<td>Personnel costs</td>
<td>€2 560 million €6.13</td>
<td>€2 606 million €6.69</td>
<td>€2 676 million €6.56</td>
<td>+ 5 percent + 7 percent</td>
</tr>
<tr>
<td>External costs</td>
<td>€1 768 million €4.23</td>
<td>€2 100 million €5.39</td>
<td>€2 095 million €5.14</td>
<td>+ 19 percent + 22 percent</td>
</tr>
<tr>
<td>Rates and taxes</td>
<td>€1 027 million €2.46</td>
<td>€1 091 million €2.80</td>
<td>€1 176 million €2.88</td>
<td>+ 15 percent + 17 percent</td>
</tr>
<tr>
<td>Central services</td>
<td>€669 million €1.60</td>
<td>€910 million €2.33</td>
<td>€872 million €2.14</td>
<td>+ 30 percent + 34 percent</td>
</tr>
<tr>
<td>Total</td>
<td>€8 067 million €19.3</td>
<td>€8 800 million €22.6</td>
<td>€8 954 million €22.0</td>
<td>11 percent 14 percent</td>
</tr>
</tbody>
</table>

**Source:** Cour des Comptes
II - Other types of current costs

Nuclear power production not only incurs annual operating costs for EDF, but also costs which, while not being "directly" attributable to production itself, are its consequence and would not exist without nuclear power production. This is publicly funded expenditure which is not allocated to the production costs of operators. There are two categories of costs which meet this description:

- Publicly funded research
- Expenditure on security, safety and information transparency not borne by producers.

A - Publicly funded research

1 - Total current research investment

As explained in the Past Costs chapter, nuclear power research today is conducted by 2 types of organization:

- public bodies: the CEA, CNRS, IRSN and ANDRA;
- two companies: EDF and AREVA.

There are two kinds of resource for this research:

- public budgetary subsidies paid by the State to public bodies;
- financing provided mainly by the two companies, EDF and AREVA, either by direct financing given to their own laboratories or those of public bodies via jointly-financed partnerships, or by paying an additional INB tax to fund ANDRA research.
### Nuclear research funds received in 2010

<table>
<thead>
<tr>
<th>Origin of funds</th>
<th>CEA</th>
<th>CNRS</th>
<th>IRSN</th>
<th>ANDRA</th>
<th>EDF</th>
<th>AREVA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Subsidies</strong></td>
<td>271</td>
<td>28</td>
<td>115</td>
<td></td>
<td></td>
<td></td>
<td>414</td>
</tr>
<tr>
<td><strong>Other resources</strong></td>
<td>189</td>
<td>13</td>
<td>112</td>
<td>158</td>
<td>227</td>
<td></td>
<td>699</td>
</tr>
<tr>
<td><strong>EDF</strong></td>
<td>40</td>
<td>3</td>
<td>94</td>
<td>158</td>
<td></td>
<td></td>
<td>295</td>
</tr>
<tr>
<td><strong>AREVA inc. dividend</strong></td>
<td>104</td>
<td>2</td>
<td>6</td>
<td></td>
<td>227</td>
<td></td>
<td>339</td>
</tr>
<tr>
<td><strong>ANDRA</strong></td>
<td>1</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td><strong>IRSN</strong></td>
<td>42</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>42</td>
</tr>
<tr>
<td><strong>CEA</strong></td>
<td></td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td><strong>Total inc. double counting</strong></td>
<td>460</td>
<td>28</td>
<td>128</td>
<td>112</td>
<td>158</td>
<td>227</td>
<td>1,113</td>
</tr>
<tr>
<td><strong>Total excl. double counting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,056</td>
</tr>
</tbody>
</table>

*Source: Cour des Comptes*  
*Grey: double counting to be subtracted*

The table above and graph below show the interrelationship between these various players which received total public and private financing of €1,113 million in 2010. However, the total includes double counting, certain bodies having subcontracted part of their activity to another. Payments to the CEA by ANDRA (€3 million) and IRSN (€42 million), and the tax on civil INBs from the CEA to ANDRA (€12 million) must therefore be subtracted to arrive at the total financing of nuclear power research in 2010, i.e., **€1,056 million**.

The above table also shows total financing by EDF of nuclear power research (€295 million, including €158 million in internal expenditure, €43 million for financing partnerships with the CEA and IRSN, €94 million in INB tax for ANDRA research), and by AREVA (€339 million, including €227 million internal expenditure, €68 million for financing partnerships with the CEA and IRSN, €6 million in INB tax for ANDRA research, and a proportion of the €38 million dividend paid to the CEA which finances civil nuclear power research).

The CEA carries out 41 percent of this research and public subsidies represent 37 percent of funding.
2 - Public research investment

Financing paid by companies is entered in the EDF accounts, either directly for financing EDF itself\(^{25}\), in its central services charges or in rates and taxes, or indirectly via the price for services it pays to AREVA for fuel and its reprocessing.

Only public funds (€414 million) should therefore be included in addition to finance already incorporated in the production cost of a kWh via the EDF operating costs.

From 2003 to 2010, total public funds allocated to applied research into nuclear power was stable at about €400 million per year. The amount devoted to the Generation IV, an average of €75 million per year, rose in 2010 to €102 million.

\(^{25}\) In 2010, EDF entered €187 million in its current financial costs, equal to its total research funding (€201 million) less the amounts for the Generation IV (€9 million) and the EPR (€5 million).
Nuclear power research: distribution of public funds

<table>
<thead>
<tr>
<th></th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEA</td>
<td>275</td>
<td>259</td>
<td>266</td>
<td>253</td>
<td>260</td>
<td>251</td>
<td>258</td>
<td>271</td>
</tr>
<tr>
<td>IRSN</td>
<td>97</td>
<td>95</td>
<td>114</td>
<td>118</td>
<td>111</td>
<td>117</td>
<td>116</td>
<td>115</td>
</tr>
<tr>
<td>CNRS</td>
<td>28</td>
<td>28</td>
<td>28</td>
<td>28</td>
<td>28</td>
<td>28</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>303</td>
<td>291</td>
<td>343</td>
<td>337</td>
<td>340</td>
<td>327</td>
<td>326</td>
<td>312</td>
</tr>
</tbody>
</table>

for current plants

<table>
<thead>
<tr>
<th></th>
<th>2003</th>
<th>2004</th>
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<th>2006</th>
<th>2007</th>
<th>2008</th>
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<tbody>
<tr>
<td>Total for generation 4</td>
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<td>92</td>
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<td>61</td>
<td>60</td>
<td>69</td>
<td>76</td>
<td>102</td>
</tr>
</tbody>
</table>

Source: Cour des Comptes
CEA excluding climate, radiobiology, and radiotoxicology

B - Publicly funded costs of security, safety and transparency

For nuclear security and safety, Article 1 of Act No. 2006-686 of 13 June 2006 on nuclear transparency and security (known as the TSN act) provides:

"Nuclear security includes nuclear safety, radiation protection, crime prevention and anti-criminality and civil security in the event of accident.

Nuclear safety means all technical and organizational measures for the design, construction, operation, stoppage and decommissioning of basic nuclear installations, and transport of radioactive substances, taken to prevent accidents or limit their effect.

Radiation protection means protection against ionizing radiation, i.e., all rules, procedures and means of prevention and monitoring for preventing or reducing the harmful effects of ionizing radiation directly or indirectly on people, including through environmental damage.

Nuclear transparency means all measures taken to guarantee the right of the public to reliable and accessible information on nuclear security."

Security and safety in the nuclear power sector is primarily the responsibility of the four operators involved: EDF, AREVA, the CEA and ANDRA. However, the State, due to its responsibility for protecting populations, plays an important role in this domain through its
supervisory, planning, expertise and control functions and its operational resources in a crisis.

Several governmental entities are involved in the system for nuclear operator security and safety. They carry out complementary action in close cooperation with each other. However, while the security and safety activities are very closely linked, a distinction may be made between purely security activities and those of safety and transparency.

1 - Public spending on nuclear security

In the narrow sense of the International Atomic Energy Agency definition, nuclear security covers prevention and detection of and response to theft, sabotage, unauthorized access, illegal transfer or other malicious acts involving nuclear material, other radioactive substances or their associated facilities.

Most security costs are borne by the operators and entered in their accounts. There are however quantifiable complementary costs payable by the State

a) Ministerial and administrative responsibility

Governmental responsibility for nuclear security is shared by three ministries: the Energy Ministry, the Environmental Protection Ministry and the Interior Ministry. Although it has no budgetary impact, the jurisdiction of the Energy Minister does not comply with the Vienna Convention on the Physical Protection of Nuclear Material, signed by France and pending ratification, which recommends independence of authorities responsible for control from those responsible for nuclear energy policy (amendment adopted on 8 July 2005).

Nuclear security is also shared between several administrative entities:
• **the Secrétariat Général de la Défense et de la Sécurité Nationale (SGDSN)** (General Secretariat for Defence and National Security)

The SGDSN is part of the Prime Minister’s department; it is responsible for interministerial coordination and planning in this field.

• **Le Haut fonctionnaire de Défense et de sécurité et le service de défense de sécurité et d’intelligence économique**

The SDSIE (defence, security and economic intelligence service) is under the authority of the Senior Official for Defence and Security (HFDS) in the Ecology Ministry (MEDDTL) which acts as the nuclear security authority. The SDSIE defines national nuclear security policy. It adapts treaties, conventions and international recommendations to domestic law. It issues and manages permission to keep or transport nuclear material (MN), approves the means therefor and ensures control. It monitors protection of confidentiality.

Together with the SDSIE, the HFDS has within his office a nuclear security department (DSN), created in January 2010 and staffed by a total of 10 officers under the authority of a Gendarmerie general and the deputy HFDS. The duties of the nuclear security authority are exercised by the SDSIE with technical support from the IRSN which provides personnel to carry out security inspections in nuclear facilities, not to be confused with the safety inspections made by the ASN.

Whether programmed or unscheduled, the inspections cover physical protection and monitoring and account auditing. They may be accompanied by measurements and tests. Among the inspections conducted each year (100 on facilities and 50 on transport) the DSN carries out about 35 (30 on facilities and 5 on transport). Given the stated objectives, the number of inspections seems low as there are 259 authorized facilities, including 58 nuclear energy reactors spread over 19 sites, plus about 300 companies subject to declaration.

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26 MEDDTL: Ministry for Ecology, Sustainable Development, Transport and Housing
• **County prefects**

County prefects are responsible for local management of any crisis occurring in their county, especially those arising accidentally or through criminal acts which might affect a nuclear facility. The county prefect’s primary crisis role has given the prefect the power to approve the special protection plan (PPP) prepared by the operator, and realization of the external protection plan (PPE), specified by the regulations on vital importance activities.

To summarize, the administrative services involved in nuclear security are limited in size and do not represent a significant cost. They are gradually being structured in the form of specialist nuclear security and safety services within SDSIE and the DGPR, enabling better organization of an essential interface with the control authorities.

**b) The National Gendarmerie**

The role of the gendarmerie in nuclear security is both the protection of nuclear facilities and transport of civil nuclear material.

• **Protection of nuclear power plants**

To ensure protection of nuclear powers plants in 1980 and at the request of operators, the National Gendarmerie created nuclear surveillance and intervention squads which in 2009 became specialized Gendarmerie protection squads (PSPGs). These units are supported by local county gendarmerie units and by regional or national intervention units in the event of a wider response (inter-regional intervention squads of the gendarmerie, GIGN and the CBRN national cell).

A circular dated 29 April 2009 defined the organization and deployment of the specialized Gendarmerie protection squads (PSPGs) in facilities of vital importance. The purpose of these units is continuously to monitor the plants and their surroundings, including areas near pumping stations. PSPGs must be capable of intervening very quickly at any time on each site and reinforcements may be deployed in support.

Relations between EDF and the National Gendarmerie are governed by an agreement which specifies the terms for financing and reimbursement for the "nuclear squads". The objective is full reimbursement of the costs of the 742 military personnel provided, i.e., their pay (including pensions) and employer charges, operational expenses (rent, fuel, change of residence, travel and transport, energy and liquids), costs of individual equipment and depreciation of material, and
an annual provision covering the cost of ammunition for training personnel.

To assess the cost of the system in the absence of detailed accounting data, the Cour des Comptes applied modelling to 2010 using the actual costs of two PSPGs. After extrapolation, conducted with the DGGN, of all PSPGs, the Cour des Comptes found that invoicing to EDF by the DGGN is generally close to the actual costs both of personnel and operations. An endorsement in April 2011 settled the issue by expressly providing for reimbursement of actual personnel costs.

- **Escorts for transport of civil nuclear material**

TN International, the operator selected by AREVA, chose to assign escort duties to the National Gendarmerie for transports of non-irradiated nuclear material (about 170 escorts per year), which mostly concern exchanges between the waste reprocessing plant at La Hague and Marcoule-Melox and less frequently, between the Neuville, Cadarache, Aubange, St Aybert and Romans facilities.

The agreement signed on 18 March 2008 by the DGGN and TN International stipulates that full-time escorts are provided for protecting convoys from the loading to the delivery location. It also states that the escort composition will be determined according to the threat, type of material transported and the route taken. Rules for financing and reimbursement of escorts are contained in this agreement which specifies that the company will pay fixed compensation for personnel assignments, the fuel used and a portion of the cost of personnel sustenance and equipment maintenance.

The audit shows that the amounts paid by TNI are well below the actual costs of the DGGN which plans to update the 2008 agreement to ensure that the cost payable by the beneficiary is more consistent with full remuneration, actual operating expenses and equipment depreciation.

Overall, the €450,000 paid by TNI-AREVA to the DGGN in 2010 for escorting transport of nuclear material represents about 10 percent of the actual cost to the Gendarmerie, leaving **about €4 million** to be borne by the Gendarmerie.
c) Civil security

The State has established a full arsenal for nuclear security to protect the population. The ORSEC (civil protection response organization) system is the government national emergency action plan, whether for anti-terrorism (Circular 800 of 23 April 2003 of the SGDSN) or for organizing emergency operations in the event of an accident.

- **Planning**

  The operator’s internal emergency plan (PUI) is the first line of defence in an accident but if it is unable to contain the situation the prefect must activate, via the ORSEC system, the special nuclear intervention plan (ORSEC nuclear PPI), or provisions specific to accidents involving transport of radioactive material (ORSEC TMR). Mayors are also civil security officials, and are obliged to draw up municipal protection plans if their communes are wholly or partially within a PPI zone.

  The time and human resources mobilized for preparing all emergency and risk prevention plans is unknown and assessment of the cost of planning is therefore currently impossible.

- **Iodine tablets**

  From 1997, the Government decided that populations within a 10-kilometre area around basic nuclear installations (INBs) should have access to stable iodine tablets. The operator is responsible for preventive distribution of iodine in the PPI zone. The Health Ministry finances distribution outside PPI zones. 110 million iodine tablets have been manufactured the use period of which, authorized by the Agence française de sécurité sanitaire des produits santé (AFSSAPS, *French Agency for the Safety of Health Products*), is 4 years although the latter may extend the period. The Etablissement de Préparation et de Réponse aux Urgences Sanitaires (EPRUS, *Health Emergency Preparedness and Response Agency*) is responsible for purchasing these tablets - which are kept at wholesalers - on behalf of the State and collecting expired tablets.

  The programmed purchase cost over 2010, 2011 and 2012 is €4.95 million.
- **Crisis management**

If there is an accident, the prefect implements six population protection actions after an alert: sealing-off the area, providing shelter, information, evacuation, taking iodine tablets and dietary restrictions. Management of a nuclear crisis involves numerous operational bodies in addition to the county prefect (including the Gendarmerie, police, county council, ASN and IRSN, county fire and emergency services-SDIS, Agence Régionale de Santé (ARS, *Regional Health Agency*), SAMU/SMUR, and Météo-France).

The State gave a major role in the steering of crisis management to the Direction de la Sécurité Civile (DSC, *Directorate for Civil Protection*) which became the Direction Générale de la Sécurité Civile et de la Gestion des Crises (DGSCGC, *General Directorate for Civil Protection and Emergency Response*) from 7 September 2011.

This directorate is assisted in central government by the Centre Opérationnel de Gestion Interministérielle des Crises (COGIC, *Interministerial Crisis Management Operational Centre*) and by the "mission nationale d’appui à la gestion du risque nucléaire" (MARN, *National Nuclear Risk Management Support Unit*) which signed an agreement with EDF in 2003. It currently has only two staff members.

While dedicated resources have been identified, they are more often than not shared to address all the "CBRN" risks (nuclear, radiological, bacteriological and chemical). However, it is the nuclear risk itself which justifies the particularity of the acquired equipment and materials. The State finances mobile decontamination units (UMDs), which can be used in the event of nuclear accident by the SDIS and the Unités d’Instruction et d’Intervention de la Sécurité Civile (UIISC) (*civil security instruction and intervention units*) with a view to tripling decontamination capacity. The three-year equipment programme provides financing for 70 UMDs (i.e., a total of €13.4 million), but the budgetary funds provided (€11.2 million) enables only 80 percent to be financed.

For CBRN risks, the Formations Militaires de la Sécurité Civile (ForMiSC) (*military civil security units*) and the bomb disposal service are the sole DGSCGC field units. The bomb disposal service only acts in anti-terrorism situations and has specialized equipment valued at €10.3 million.

The DGSCGC does not have air resources adapted to nuclear risks. In the event of nuclear accident, air evacuation of contaminated people could only be done by military aircraft.
The investigation at the DGSCGC shows that it is difficult to assess the full cost of the nuclear civil security sector. The cost elements exist but are dispersed, unconsolidated, often not specific to nuclear risks and are sometimes attributable to several years, while other costs are isolated. However, the various cost items found enable at least a rough assessment of €50 million over the 2009-2012 period, i.e., an annual average of 12.5 to 13 million for expenditure on both equipment and operations. This amount includes the cost of training and iodine tablets.

This estimate will probably have to be revised upwards in the light of the results of investigations into civil security following the Fukushima crisis and especially the investigation requested by the Minister of the Interior from the Inspection Générale de l’Administration (home affairs inspectorate-general), whose report is expected before the end of 2011.

d) Operator security resources

To provide security on their sites, including fire prevention and rescue services, operators have four options: the first consists in using unarmed in-house staff for caretaking and filtering duties (EDF); the second is to develop a specialized service modelled on a private armed security service (local security units at AREVA and CEA); the third is to use specialist security subcontractors (ANDRA); the fourth is based on the participation of law enforcement officers, the National Gendarmerie and SDIS (EDF and AREVA). To fulfill security obligations at their facilities, operators have therefore based their systems either on private or public resources.

The Cour des Comptes sought to identify expenditure by operators specifically on this activity so as to have an idea of the size of the cost involved. This gave a total of about €240 million, about €50 million was reimbursement to the National Gendarmerie by EDF, compared with the €17 million (€4 million for the Gendarmerie and €13 million for civil security) financed from the public funds referred to above. These costs will probably increase as a result of the measures announced at the beginning on 2012 against intrusion into nuclear sites.
Estimated security costs financed by operators

<table>
<thead>
<tr>
<th></th>
<th>€million</th>
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</thead>
<tbody>
<tr>
<td>EDF</td>
<td>150</td>
</tr>
<tr>
<td>AREVA</td>
<td>50</td>
</tr>
<tr>
<td>CEA</td>
<td>35</td>
</tr>
<tr>
<td>ANDRA</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>240</td>
</tr>
</tbody>
</table>

Source: Cour des Comptes

2 - Public spending on safety and transparency

Publicly funded safety and transparency expenditure mainly involves specialist investigations and audits carried out by two organizations (ASN and IRSN), but various other bodies also participate in this work.

a) Direction Générale de la Prévention des Risques (DGPR)

The risk prevention general directorate (DGPR) of the Ministry of Ecology, Sustainable Development, Transport and Housing (MEDDTL) manages the "nuclear safety and radiation protection assignment" (MSNR), one of the State nuclear safety and radiation protection programmes.

It is the ministerial interface for ASN. Liaising with the authorities concerned, it prepares all laws and regulations within the remit of the ministers responsible for nuclear safety and radiation protection. It also participates in national nuclear crisis organization and information and communication action on subjects associated with nuclear safety and radiation protection.

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27 Article 1 of the Act of 13 June 2006 on nuclear transparency and security provides: "nuclear transparency covers all steps taken to guarantee the right of the public to reliable and accessible information concerning nuclear security".
It also has its own specific functions: coordination and implementation of the supervision policy for former uranium mines (ASN and IRSN carry out inspections on its behalf) and polluted orphan radioactive sites (decontaminated by ANDRA); the secretariat of the Haut Comité à la Transparence et à l’Information sur la Sécurité Nucléaire (HCTISN) (high-level committee for transparency and information on nuclear security).

The DGPR is also watchdog of the Institut de Radioprotection et Sûreté Nucléaire (IRSN).

The DGPR resources in this field are modest and represent a total of about 9 ETPs (equivalent of full-timers): 7.5 for the MSNR (6 ETPs filled on 1 December 2011, 7 on 1 January 2012), about 1.5 ETPs if the "supervision of public establishments" unit and the staff of the general management for nuclear issues are included.

b) ASN

- **Organization and assignments**

  The ASN is an independent administrative authority created by the 2006 nuclear transparency and security law. It "contributes to supervising nuclear safety and radiation protection and informing the public".

  It comprises five commissioners appointed for six years under a Decree, the chairman and two members appointed by the French President and the other two members by the presidents of the National Assembly and the Senate.

  ASN management comprises a general directorate with eight central directorates and eleven territorial divisions located near nuclear activities and facilities, organized into eleven DREALs (Directions Régionales de l'Environnement, l'Aménagement et du Logement (regional environment, development and housing directorates) whose directors are "part-time" regional delegates of the ASN.

  It takes decisions subject to government approval to clarify decrees and orders relating to nuclear safety and radiation protection, and individual decisions concerning nuclear activities (e.g., requirements for the design, construction, operation or decommissioning of nuclear facilities, authorizations for use of transport packaging for radioactive material and authorizations for use of radioactive sources).
It supervises compliance with general rules and special requirements for nuclear safety and organizes continuous supervision of radiation protection throughout national territory. For this purpose, it has nuclear safety and radiation protection inspectors and issues licences to organizations participating in audit and supervision of nuclear safety and radiation protection.

It assists the Government in emergency radiological situations, assists the appropriate authorities and informs the public of the safety status of the facility concerned in the emergency situation, and of substance release into the environment and its risk for health and the environment. During such period, it audits the measures taken by operators and at any time may order any necessary assessment or action.

It has the technical support of the Institut de Radioprotection et Sécurité Nucléaire (IRSN) and standing groups of experts.

In its supervisory role, ASN inspects basic nuclear installations (INBs). The total number of inspectors has been stable for three years (248 in 2010). In 2010, 737 inspections of basic nuclear installations took place, representing only a little over a third of all inspections carried out by ASN (1,964). INB inspections primarily related to "electricity generation" and the "nuclear safety" theme; 25 percent are spot checks.

While the ASN is responsible for safety, i.e., prevention of accidents, the Haut Fonctionnaire de Défense et de sécurité (HFDS) (senior officer for defence and security) of the Ministry of Ecology, Sustainable Development, Transport and Housing is responsible for nuclear anti-criminality and physical protection (against loss, theft and misappropriation of nuclear material), unlike the system abroad where most nuclear safety authorities also have jurisdiction over security.

• **Resources**

ASN personnel increased from 432 employees in 2008 to 451 on 31 December 2010; in 2010, there were 85 secondments (therefore repaid by ASN), mostly from the IRSN and CEA.
All ASN resources derive from the State. In 2010, they were divided between four programmes in three different ministerial missions:

- "Ecology, sustainable development and planning", for programme 181 (risk prevention), managed by the DGPR and 217 (management of policies for ecology, energy, sustainable development and the sea), managed by the SG-HFDS of the Ministry for Ecology (MEDDTL);
- "Management of public finance and human resources", for programme 218 (management of economic and financial policies), managed by the secretary-general of the finance ministries;
- "Research and higher education" for programme 190 (energy, sustainable development and planning research), managed by the director of research and innovation of the Ministry for Ecology (MEDDTL).

This complicated budgetary organization should be reviewed and simplified as several reports have already pointed out.

### ASN budget

<table>
<thead>
<tr>
<th>Adjusted €million</th>
<th>LFI 2010</th>
<th>LFI 2011</th>
<th>Completion 2011</th>
<th>PLF 2012</th>
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<td>6.36</td>
<td>6.36</td>
<td>6.36</td>
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<td>Programme 181</td>
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<td>51.90</td>
<td>49.5</td>
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<td>Programme 190</td>
<td>78.13</td>
<td>46.4 + 30*</td>
<td>46.4 + 30*</td>
<td>46.4 + 37.6*</td>
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<td><strong>Total</strong></td>
<td><strong>146.02</strong></td>
<td><strong>144.43</strong></td>
<td><strong>142.03</strong></td>
<td><strong>158.54</strong></td>
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*additional contribution to tax on INBs paid by operators

**LFI = Finance Act**  
**PLF = Draft Finance Act**

ASN also receives support services from the Economy and Finance ministries, the Prime Minister’s office and the DREAL network which hosts its eleven regional divisions. These services are entered in programmes 217 and 218.
Under the 2010 LFI, ASN had a total budget of €146 million, including the programme 190 budget for the IRSN support activities given to ASN, representing half of its budget (€78 million).

Following the Fukushima accident, ASN requested a review of its resources for 2011-2013, to enable it to conduct the audits it was then asked to make and which would require "additional safety assessments" (ECS) of the 150 French INBs (requested by the Prime Minister), coupled with "stress-tests" requested by the European Commission, an inspection campaign targeted on all of the 150 facilities and work on harmonizing international safety standards. ASN calculated that it would need 40 extra staff at an additional cost of €1.6 million in 2011 and €3.2 million in a full year.

During an interministerial meeting held on 23 June 2011, the creation of 44 posts was agreed, 22 experts for IRSN and employees 22 for ASN in the form of secondment from IRSN, explaining the €4 million increase in the ASN budget for programme 181 for 2012, as a result of the Fukushima accident and which will enable in particular ASN to repay IRSN for these secondments, which are defined in the agreements between the two organizations; according to the DGPR, in the medium term – and perhaps from 2013-2015 – a reduction in secondments is planned, to be replaced by direct hiring by ASN, by increasing its employment ceiling and correspondingly reducing that of IRSN.

c) The IRSN

- **Organization and assignments**

  The IRSN was created by Article 5 of Act No. 2001-398 of 9 May 1981 and its operation is specified in Decree No. 2002-254 of 22 February 2002. It is subject to joint supervision by the Ministers for Defence, the Environment, Industry, Research and Health.

  The Institute’s assignments, to the exclusion of any responsibility as a nuclear operator, are: nuclear safety; safe transport of radioactive and fissile material; protection of people and the environment against ionizing radiation; the protection and control of nuclear material and protection against criminal acts of nuclear facilities and transport of radioactive and fissile material.
Its first assignment is to make available its expertise both in nuclear safety and security and protection against ionizing radiation to the public authorities and any requesting public or private French or foreign entity. In particular, it gives technical support to ASN.

The IRSN public research assignment has two objectives: enable it to have an expert capacity and improve safety through problematics and research findings. The IRSN directs its problematics towards establishing methods which allow an understanding of the uncertainties associated with the risk studied, assessing the safety margins available via means independent of those proposed by operators, and assessing the situations created by accidents, going beyond the "design scenarios" retained by operators and accepted by the public authorities. A major part of this experimental research is done in cooperation with French and foreign partners.

- **Resources**

  In 2010, the IRSN had a total workforce of 1,768 (including 62 on secondment, 44 of them to ASN), spread over eleven sites.

  Expert support services for public authorities were financed by subsidies paid to IRSN under programme 190; in 2010, funds specific to ASN technical support amounted to €78 million. Pursuant to the TSN Act of 2006, ASN is consulted on the appropriate level of financing for its work. An agreement between the IRSN and ASN, also required under this act, specifies the terms under which ASN directs use of these resources according to its operational requirements. Every year, an ASN/IRSN "protocol" provides a detailed and hierarchical framework for the planned technical support action.

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28 From 2011, part of this subsidy is replaced by a contribution payable by INB operators, as from authorization for the installation until its removal from the list of INBs. This contribution was €30 million in 2011, the programme 190 subsidy increasing to €45.3 million, and €484 million in 2012.
The DGPR directs Action No. 11-02, "Risk research" of programme 190 "energy, sustainable development and planning research" under the "research and higher education" assignment. Its objective is to improve understanding of industrial risks such as ionizing radiation or toxic substances, including through IRSN research. The results obtained enable the risk prevention systems to be optimized, and to reinforce the quality of expert services provided to public authorities.

IRSN financing in 2010

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<tr>
<th></th>
<th>€million</th>
<th>2010*</th>
<th>%</th>
<th>2011*</th>
<th>%</th>
<th>2012**</th>
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<td>115</td>
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<td>Total support for ASN</td>
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<td>100</td>
<td>309.7</td>
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</table>

Source: IRSN and DGPR

* Completed
** IRSN 2012 budget forecast

The only public funds attributable to nuclear power relate to programme 190 (€243.8 million in 2010) as programme 212 is a defence programme. To avoid double counting, the €115 million of IRSN funds for research already included under part II-A above should be subtracted, leaving €129 million, including €78 million for its work with ASN.

d) OPECST and parliamentary review

As with all public activities, the nuclear sector is subject to review by parliament via standing committees which hear the directors of the companies or organizations concerned or examine budgetary opinions; laws governing the nuclear energy sector are also - like other laws - subject to preliminary scrutiny in committee.
A specific parliamentary body, l’Office Parlementaire d’Evaluation des Choix Scientifiques et Technologiques (OPECST) (Parliamentary Scientific and Technological Assessment Office), created by the Act of 8 July 1983, informs parliament of the consequences of scientific and technological choices so as to clarify its decisions. For this purpose, it collects information, implements studies and makes assessments. It comprises eighteen MPs and eighteen senators and is assisted by a scientific committee comprising twenty-four prominent specialists selected for their expertise.

Studies cover all scientific and technological fields but mainly concern energy, the environment, new technologies and life sciences. As a result of referral to parliament and in application of legislative provisions specifying the special procedures for parliamentary review of the nuclear sector²⁹, it frequently reviews the nuclear sector, producing a dozen reports annually at least one of which is specific to the nuclear sector. It has frequently studied the problems of waste management and supervision of safety and security. The act also requires it to review the national plan for management of radioactive material and waste (PNGMDR), updated every 3 years by the government.

Following the Fukushima nuclear plant accident on 11 March 2011, the June 2011 interim report of the parliamentary enquiry into nuclear security, the position of the sector and its future, made a series of recommendations including on the over-reliance on subcontractors. The final report, filed on 15 December 2011, analyses three scenarios for developing the energy mix.

It is impossible to separate nuclear-specific expenditure in the overall expenditure of the Office (about €500K annually).

²⁹ E.g., the procedure for presenting ASN annual reports to parliament.
d) HCTISN

The Haut Comité à la Transparence et à l’Information sur la Sécurité Nucléaire (HCTISN) (high-level committee for transparency and information on nuclear security) was created by the TSN Act of 13 June 2006. It was established on 18 June 2008. It is "an information, consultation and discussion platform for risks associated with nuclear activities and the impact of those activities on health, the environment and nuclear security".

In pursuance of its assignment, the Haut Comité issues and publishes opinions. It is free to consider any issue concerning the accessibility of information about nuclear security and to propose any measure to guarantee or improve nuclear transparency; it may commission expert enquiries to assist it and organize discussions with the parties concerned.

The Haut Comité had forty members on 31 December 2010 split into seven colleges: members of parliament, representatives of local information committees, environmental and public health protection associations, entities responsible for nuclear activities, trade unions, qualified specialists, State department representatives and the ASN and IRSN.

The Haut Comité is based in the premises of the DGPR and secretarial services are provided by a MSNR employee. Financing for its work is included in the State budget (programme 181 "Risk prevention") and amounted to €150,000 under the initial 2011 Finance Act. This budget principally covers travel costs for participants attending meetings.

e) The ANCCLI and CLIs

The Commissions Locales d’Information (CLI, Local Information Committees) operated for a long time with no legal status. In 1981 however, the Government issued a circular to facilitate establishment of information committees in each major energy site. On 5 September 2000, the Association Nationale des Commissions Locales d’Information (ANCLI, French National Association of Local Information Commissions) was formed to federate the then 30 CLIs.

Article 22 of the TSN Act of 13 June 2006 gave legal status to these committees "I.-A local information committee shall be established in any site containing one or more basic nuclear installation as defined by Article 28, responsible generally for monitoring, informing and consulting on nuclear safety, radiation protection and the impact of
nuclear activities on health and the environment caused by the site facilities. The local information committee shall provide wide distribution of its findings in a form accessible to the largest number of people”.

In 2009, the ANCLI became the Association Nationale des Commissions et des Comités Locaux d’Information (ANCCLI, French National Association of Local Information Commissions and Committees) combining the underground laboratory committees and local information committees. It has a General Meeting, Board of Directors, Scientific Committee, Consultative Committee and permanent groups. It works closely with the IRSN. It is financed by fees from member CLIs and subsidies from the European Union, the State (in the form of an ASN subsidy of €300k) and local authorities.

Along with resources from the ANCCLI, the CLIs have been financed to date by local authorities and the ASN (€377k in 2010). Their budget in 2009 was a modest €600k\(^{30}\) given their general interest assignment of informing the public. Moreover, Article 22 of the TSN Act provides that the CLIs may receive part of the income from the INB tax, introduced by Article 43 of the 2000 Finance Act (No. 99-1172 of 30 December 1999), but this possibility has not yet been implemented.

3 - Total public spending on security, safety and transparency

On the basis of the above analyses, total publicly funded expenditure on nuclear power security, safety and transparency is estimated at **€230 million in 2010**.

As previously stated, part of this total is based on rough estimates due to unavailable figures. Only major sums concerning the National Gendarmerie, civil security forces, the ASN and IRSN are recorded, while the ASN budget provides the subsidies for the ANCCLI and CLIs and the IRSN funding for the ASN expertise is entered in the IRSN budget. The latter does not include research subsidies which are entered in part II-A as R&D activities.

\(^{30}\) Not including costs for secondment of part-time project managers by local authorities (mostly county councils) for CLIs which have no legal personality.
These amounts are supplemented by France’s contribution to the IAEA budget for LOLF (constitutional bylaw) programme 105 "Action by France in Europe and the world", which was €16 million in 2010.

### 2010* publicly funded security, safety, transparency

<table>
<thead>
<tr>
<th></th>
<th>€million</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Gendarmerie:</td>
<td></td>
</tr>
<tr>
<td>excess costs not repaid by operators</td>
<td>4</td>
</tr>
<tr>
<td>Civil security:</td>
<td></td>
</tr>
<tr>
<td>estimated annual cost inc. iodine tablets</td>
<td>13</td>
</tr>
<tr>
<td>ASN (2010 Finance Act excl. IRSN)</td>
<td>68</td>
</tr>
<tr>
<td>IRSN (2010 Finance Act excl. research)</td>
<td>129</td>
</tr>
<tr>
<td>AIEA Contribution (2010 F. Act forecast)</td>
<td>16</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>230</strong></td>
</tr>
</tbody>
</table>

*only includes State funds; local authority expenditure, principally on CLIs, is not entered.

Source: Cour des Comptes
CURRENT COSTS

CONCLUSION – CURRENT COSTS

Current annual costs for nuclear power production may be divided into two major categories:

• Expenditure directly linked to production and entered in EDF’s accounts, of €8,954 million in 2010 for production of 407.9 TWh. It increased by 11 percent between 2008 and 2010. Compared with production, it represented €22 /MWh in 2010 (+ 14 percent between 2008 and 2010). The biggest cost item is personnel (30 percent), followed by fuel (23.8 percent) and external costs (including maintenance charges) and operating charges of 23.3 percent;

• Publicly funded expenditure which would not exist without nuclear power production; expenditure on research (€414 million) but also on security and safety (€230 million) was about €644 million in 2010: this approximates with the INB tax paid to the State by the operators totalling €580 million in 2010 31. This nuclear-specific tax can be considered as covering public expenditure for that purpose32. Their amount is about the same33.

31 Excluding additional tax paid to legally-designated beneficiaries including ANDRA, not entered in public research expenditure.
32 This tax was created in 2000 and replaced a fee which financed ASN and IRSN safety expenditure but not research costs. Annex 9 shows its significant increase since 2000 (multiplication by 4.5 in adjusted € between 2000 and 2010).
33 Nuclear operators are also subject to taxation under ordinary law which is considered to be for funding “ordinary law” public expenditure, as is the case with all other companies. Furthermore, the EDF dividend, the fruit of its entire business and most particularly of the State-fixed tariffs, has not been taken into account in the reasoning but should not be forgotten.
Chapter III

Future costs

A particular characteristic of nuclear power generation is that part of its costs are carried over until after the period of generation itself; furthermore, as yet there is often insufficient knowledge of both the schedule for payment and the extent of this expenditure, and costing is based on many assumptions. The aim of this chapter is therefore to identify and cost the future expenditure which will result from current nuclear power generation.

The order of 21 March 2007 relating to financial provision for nuclear costs identifies several different categories of future costs:

− the dismantling of power plants at the end of their operating life;
− the management of spent fuel;
− the recovery and treatment of old waste, the long-term management of packages of radioactive waste and monitoring after closure of repositories – these three categories may be grouped together as waste management.

The evaluation of gross costs for these three types of expenditure is a complicated exercise and is based on many assumptions: for a significant proportion of the action to be completed, little or no reference can be made to past experience, and foreign experience is not fully comparable.

Article 20 of Planning Act 2006-739 of 28 June 2006 relating to sustainable management of radioactive material and waste makes it compulsory for nuclear operators to make a “prudent evaluation of the costs of dismantling their plants and, for their radioactive waste disposal
facilities, the costs of final shutdown, maintenance and monitoring. They must evaluate the management costs for their spent fuel and radioactive waste in a similar manner, taking into account evaluation as set forth in the application of article L. 542-12 of the Environmental Code.’”

Article 2 of the decree of 23 February 2007, which applies this law, lays down the principles to be brought to bear on the evaluation of these costs: analysis of the different options which can reasonably be envisaged, the choice of a reference strategy, taking into account residual technical uncertainty, unforeseen circumstances, and feedback from experience.

As a result, operators are carrying out evaluations of their costs commensurate with the specific circumstances of their activities and resources and including in their accounts the costs they will have to bear, adjusted to take into account the deferral of these actions in time.

I - Dismantling nuclear power plants

A - Dismantling explained

The aim of dismantling nuclear power plants is to reduce the related pollution and radioactivity to levels deemed to be safe for humankind and the environment, bearing in mind the planned reuse of the sites and buildings, in line with regulations. In France, nuclear operators are responsibility for conducting all the operations necessary, the extent of which will depend on the future use of the site. These operations are long and complex, sometimes involving deadlines a long way into the future, thus requiring operators to implement full-orbed technical and financial strategic planning.

The 2006 Acts\(^{34}\) and the 2007 decree\(^{35}\) altered the previous legal provisions\(^{36}\), establishing better monitoring and supervision of dismantling operations, in particular in terms of nuclear safety. Like all

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\(^{35}\) Decree no. 2007-1557 of 2 November 2007 relating to basic nuclear installations and inspections in respect of nuclear safety for the transportation of radioactive substances (see Annex 7).

\(^{36}\) For a presentation of the previous system, see the Cour des Comptes report dated January 2005 on the dismantling of nuclear facilities and management of radioactive waste.
the stages in the life of a basic nuclear installation, shutdown and dismantling operations must be authorized by Government decree following an opinion issued by the ASN. The administrative operation by which plants are removed from the list of “basic nuclear installations” is known as delisting.

Since 2007, each operator has been obliged to draw up a dismantling plan for their facilities, an updated version of which must be sent to the administrative authority at least three years prior to the date envisaged for final shutdown. The plan must specify not only the arrangements for carrying out the related operations, in particular the time between shutdown of operations and the start of dismantling, but also for restoring and monitoring the site. In this plan, the operator provides grounds for the final condition\(^{37}\) in which they envisage leaving the site.

In France, basic nuclear installation operators have all accepted the principle of immediate dismantling\(^{38}\) of facilities, i.e. dismantling operations engaged on shutdown of the facility, with no waiting period. This strategy is recommended by the ASN, which says “[it] avoids leaving the burden of dismantling to be borne by future generations, in both technical and financial terms,” and makes it possible to benefit from the expertise and memory of the staff working on the site prior to shutdown of the facility. However, it does not follow that dismantling does not take a long time; on the contrary, the difficulties inherent in such works often mean they can last for well over a decade.

The table below presents the comparative burden of dismantling costs as calculated by the three main French nuclear operators for their civil activity in France, as of 31 December 2010.

\(^{37}\) Annex 10 specifies the choices made by each operator.

\(^{38}\) The two other possibilities identified by the IAEA are (i) deferred dismantling: The parts of the facility containing radioactive substances are maintained or placed in safe conditions for several decades prior to the commencement of dismantling and (ii) safe confinement: the parts of the facility containing radioactive substances are placed in a reinforced confinement structure for as long as it takes to reach a sufficiently low level of radioactivity for the site to be cleared – Source: ASN annual report 2010.
Gross dismantling costs

<table>
<thead>
<tr>
<th>€ million, 2010</th>
<th>Gross costs as of 31 December 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDF</td>
<td>20 902.9</td>
</tr>
<tr>
<td>AREVA</td>
<td>7 108.4</td>
</tr>
<tr>
<td>CEA (civil)</td>
<td>3 911.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>31 922.5</strong></td>
</tr>
</tbody>
</table>

Source: Cour des Comptes

**B - Evaluation of dismantling costs for EDF nuclear facilities**

EDF’s dismantling costs are essentially made up of costs relating to the fleet of reactors in operation.

**EDF nuclear facility dismantling costs**

<table>
<thead>
<tr>
<th>As of 31/12/2010</th>
<th>€ million 2010</th>
<th>Number of facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facilities in operation</td>
<td>18 398.5</td>
<td>62</td>
</tr>
<tr>
<td>Facilities shut down (1)</td>
<td>2 504.4</td>
<td>12</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>20 902.9</strong></td>
<td><strong>74</strong></td>
</tr>
</tbody>
</table>

Source: Cour des Comptes

(1): these are remaining costs to be paid and not the total cost of dismantling for these facilities

**1 - Programme for dismantling halted facilities**

**a) Total cost of the programme**

As of 31 December 2010, 12 basic nuclear installations were included in this “first generation” dismantling programme; these include the nine reactors forming the first generation fleet by the strictest definition39, which have undergone final shutdown and are currently being dismantled, as well as three additional facilities shut down, under construction or still being operated: the St-Laurent silos used for storing

39 See chapter I – I-A-1 for the composition of this fleet of reactors.
LLW-LL from the plant, the fuel storage workshop (APEC) essentially comprising a tank designed to hold fuel taken from Superphénix, and the activated waste conditioning and storage facility (ICEDA). The latter, currently under construction on the Bugey site, is designed to handle ILW-LL from dismantling work on the shut-down reactors and reactors in operation, as well as provide buffer storage for waste produced by dismantling Bugey 1\textsuperscript{40}, as of late 2013 - early 2014.

The nine reactors use four different technologies. Dismantling costs are therefore difficult to compare, as the technical characteristics of the buildings and components located close to the fuel are different. For instance, according to the most recent estimates available, the cost of dismantling the Chooz A PWR reactor (pressurized water reactor) is equivalent to 68 percent of the average cost for “graphite-moderated gas-cooled” reactors and 59% of that of the Brennilis (heavy water) reactor.

![Provisional cost plan](image)

*Source: EDF*

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\textsuperscript{40} The building work was interrupted by EDF in January 2012 following a ruling by the Lyon administrative tribunal, which overturned the building permit for the facility.
Of the total dismantling cost (reactors and ancillary facilities), estimated at €4 billion\textsubscript{2010}, the remainder to be paid as of the end of 2010 amounts to €2.5 billion\textsubscript{2010}, taking into account the adopted schedule of charges for dismantling the facilities presented in the graph above.

It can be noted that the total estimated amounts for dismantling the reactors alone, not including Superphénix (approximately €2.65 billion\textsubscript{2010}) represent some 43 percent of their construction costs as set out in chapter I (€6.1 billion\textsubscript{2010}, overnight cost + interim interest during construction).

\textit{b) Elements for the calculation of dismantling estimates}

Dismantling costs are calculated by EDF in the form of estimates which are drawn up and regularly revised, based on all the technical, financial and contractual data available at the time at which they are produced. From one revision to the next, information from sites where dismantling is in progress is appropriately extrapolated if possible, or limited to the site concerned if this information is specific.

The engineering, works, site and waste costs\textsuperscript{41} are evaluated using data gathered in the previous and current years. With respect to works, the experience feedback from partial dismantling operations already carried out on power plants is used by EDF, in particular that of Brennilis, except for the reactor block; estimates for “graphite-moderated gas-cooled” units are calculated by extrapolation from the recorded and estimated costs for Bugey I.

According to EDF, a large proportion of the items of works costs, waste packages and studies, in particular preliminary design studies, are now reliable and most time constants, administrative lead times and purchases are known. However, analysis of the changes in estimates suggests that the costs presented should be treated with caution.

\textsuperscript{41} \textit{Engineering costs:} EDF head office labour costs, subcontracted services, work carried out by EDF as project owner and project manager (design, site monitoring); \textit{works costs:} contractor invoicing (works studies and work itself, including engineering, design and performance costs); \textit{waste costs:} empty packages, transport; \textit{site costs:} operation and inspection of waste removal, overheads (incl. taxes other than Basic Nuclear Installation tax).
c) long-lived Changes in estimates

The first estimates were drawn up in 2001, revised in 2003, and then again in 2006 and 2008. The next revision is due to be carried out in 2012.

At first sight, on the basis of an overall view and constant 2010 euros, the total estimate appears to have increased by only 1.3 percent between 2001 and 2008. However, this is due essentially to a change in scope which caused the fall noted between 2003 and 2006, with the charges relating to the disposal of waste no longer being booked in provisions for dismantling.

On a like-for-like basis, without taking into account APEC and ICEDA, the increase reported between 2006 and 2008 was 17.3 percent.

### Dismantling estimate for first-generation facilities

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinon A1</td>
<td>GCR</td>
<td>70</td>
<td>1963</td>
<td>1973</td>
<td>2035</td>
<td>694.7</td>
<td>649.0</td>
<td>586.5</td>
<td>810.0</td>
<td>820.4</td>
<td></td>
</tr>
<tr>
<td>Chinon A2</td>
<td>GCR</td>
<td>200</td>
<td>1965</td>
<td>1985</td>
<td>2034</td>
<td>563.7</td>
<td>518.0</td>
<td>465.0</td>
<td>690.0</td>
<td>700.0</td>
<td></td>
</tr>
<tr>
<td>Chinon A3</td>
<td>GCR</td>
<td>480</td>
<td>1966</td>
<td>1990</td>
<td>2031</td>
<td>822.1</td>
<td>733.0</td>
<td>614.8</td>
<td>803.0</td>
<td>813.3</td>
<td></td>
</tr>
<tr>
<td>St Laurent A1</td>
<td>GCR</td>
<td>1969</td>
<td>1971</td>
<td>1992</td>
<td>2025</td>
<td>348.4</td>
<td>373.0</td>
<td>289.9</td>
<td>412.0</td>
<td>417.3</td>
<td></td>
</tr>
<tr>
<td>St Laurent A2</td>
<td>GCR</td>
<td>515</td>
<td>1990</td>
<td></td>
<td></td>
<td>254.0</td>
<td>260.0</td>
<td>265.6</td>
<td>373.0</td>
<td>377.8</td>
<td></td>
</tr>
<tr>
<td>St Laurent silos</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>254.0</td>
<td>260.0</td>
<td>265.6</td>
<td>373.0</td>
<td>377.8</td>
<td></td>
</tr>
<tr>
<td>Bugey 1</td>
<td>GCR</td>
<td>540</td>
<td>1972</td>
<td>1994</td>
<td>2026</td>
<td>348.4</td>
<td>373.0</td>
<td>289.9</td>
<td>412.0</td>
<td>417.3</td>
<td></td>
</tr>
<tr>
<td>Brennilis</td>
<td>Heavy water</td>
<td>70</td>
<td>1967</td>
<td>1985</td>
<td>2023</td>
<td>254.0</td>
<td>260.0</td>
<td>265.6</td>
<td>373.0</td>
<td>377.8</td>
<td></td>
</tr>
<tr>
<td>Chooz A</td>
<td>PWR</td>
<td>300</td>
<td>1967</td>
<td>1991</td>
<td>2019</td>
<td>254.1</td>
<td>224.0</td>
<td>216.5</td>
<td>220.0</td>
<td>222.9</td>
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<tr>
<td>Creys-Malville</td>
<td>Super-phenix</td>
<td>1,200</td>
<td>1986</td>
<td>1997</td>
<td>2026</td>
<td>941.6</td>
<td>952.0</td>
<td>912.4</td>
<td>943.0</td>
<td>955.1</td>
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<tr>
<td><strong>Total, current €</strong></td>
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<td></td>
<td></td>
<td></td>
<td>3 305.9</td>
<td>3 191.0</td>
<td>2 885.7</td>
<td>3 561.0</td>
<td>3 606.8</td>
<td></td>
</tr>
<tr>
<td><strong>Total, 2010 €</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>3 886.8</td>
<td>3 598.4</td>
<td>3 074.6</td>
<td>3 606.8</td>
<td></td>
<td></td>
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<tr>
<td>APEC</td>
<td>Creys storage facility</td>
<td>2000</td>
<td>2039</td>
<td>2046</td>
<td></td>
<td>36.0</td>
<td>36.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICEDA</td>
<td>Storage facility</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td>240.8</td>
<td>291.0</td>
<td>294.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total, current €</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3 305.9</td>
<td>3 191.0</td>
<td>3 126.5</td>
<td>3 888.0</td>
<td>3 938.0</td>
<td></td>
</tr>
<tr>
<td><strong>Total, 2010 €</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3 886.8</td>
<td>3 598.4</td>
<td>3 331.2</td>
<td>3 938.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Cour des Comptes based on EDF data

(1): schedule of the most recent estimate updated in 2008 and since partially revised
Specifically with respect to the reactors, the dismantling estimates changed in widely differing ways between 2001 and 2008, apart from inflation: estimates went down by 23 percent for the Chooz A reactor, a forerunner of the PWR 900 series but smaller in size (300 MW), by 14 percent for Superphénix and by 7 percent for the Chinon and Saint Laurent graphite-moderated gas-cooled reactor, whereas estimates for the Brennilis heavy water reactor rose by 26 percent.

The table below shows how changes differ considerably in different cost categories.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering</td>
<td>-34%</td>
<td>Engineering</td>
<td>-34%</td>
</tr>
<tr>
<td>Works</td>
<td>+53%</td>
<td>Works</td>
<td>+64%</td>
</tr>
<tr>
<td>Waste</td>
<td>+75%</td>
<td>Waste</td>
<td>-73%</td>
</tr>
<tr>
<td>Site</td>
<td>+123%</td>
<td>Site</td>
<td>+6%</td>
</tr>
<tr>
<td>Total</td>
<td>+26%</td>
<td>Total</td>
<td>-7%</td>
</tr>
</tbody>
</table>

Source: Cour des Comptes; EDF data

The variations in the estimates are due to administrative reasons, arising firstly from the postponement from 2013 to 2019 of the opening of the graphite waste and radiferous waste (LLW-LL) disposal facility which, due to the time taken to find sites and the withdrawal of some applications from municipalities approached to host it, has pushed back the schedules for dismantling Bugey 1 by five years and the other graphite-moderated gas-cooled units by ten years, automatically leading to an increase in engineering and site costs. In addition, the annulment by the Council of State of the decree authorizing the dismantling of Brennilis due to a legal technicality caused increases arising from the postponement of the works and additional study costs with a view to obtaining a new decree. Other reasons for the increases noted are industrial in nature and are linked in particular to the identification of significant additional costs for the works to be carried out. For example, in the 2008 estimate for the dismantling of Bugey 1, EDF included a probable additional cost of €103 million2008 subsequent to a new study. By extrapolation, this led to an increase in the estimated costs for Saint Laurent A (+€137 million2008) and Chinon A (+€185 million2008).

With respect to dismantling of the Chooz A and Superphénix reactors at Creys-Malville, the estimates have not significantly changed course since 2001 and the cost of work on the Chooz A reactor has gone down in the estimates; this could be considered to be an encouraging sign.
as regards the dismantling of the PWR fleet in operation. However, it should be borne in mind that these are only estimates and not actual costs and relate to operations which have not yet been carried out.

For instance, an EDF internal audit report dated 31 March 2011 notes the technical difficulties and cumbersome nature of the aforementioned administrative processes and also draws attention to the faster than expected use of budgets for Chooz A and Superphénix compared to the actual progress of operations, which means that the 2012 estimate for these two operations will probably be higher than the amounts on the current estimates, in proportions which cannot be calculated at present.

Lastly, the suspension of building work on ICEDA could have consequences which are not yet known or costed in detail, not only on the cost of the project but also on the estimates for dismantling first-generation reactors. Due to the postponement (or even the permanent impossibility of disposal in this facility) of ILW-LL waste from dismantling these reactors, as was planned from 2014 onwards, dismantling work could be delayed, thus causing additional site, engineering, or even works costs if other storage solutions need to be found.

d) Taking into account contingencies and uncertainties

The changes in estimates and in the actual cost of works show that there are many uncertainties in the estimates, which is normal given the lack of precedent for the operations to be costed.

It is therefore regrettable that these estimates do not include uncertainty margins. These would enable better measurement of the scope of uncertainty. In fact, for the proposed dismantling projects, the ASN recommends\(^\text{42}\) that for each facility, both the methods for evaluating uncertainties and the main contingencies and their financial effects should be specified.

Indeed, to do so would be relatively simple: EDF uses a method which consists of calculating cost brackets for all the parameters and assigning them a probability of occurrence. For instance in 2008, EDF assigned an uncertainty margin for the total amount on the estimate in 2006 of +/-€120 million\(_{2006}\) (+/-3 percent). However, as discussed above,

\(^{42}\) Letter from the ASN to the DGEC pursuant to each operator issuing the second three-yearly report in application of article 20 of the 2006 law - no. CODEP-DRC 2011-011599 of 3 March 2011
changes in costs for reactors show that each module for each reactor or type of reactor has changed in a very specific way, making any overall approach to contingencies and uncertainties in the fleet highly hypothetical.

Even so, EDF does not include this bracket or rate in its estimates; it prefers to confine itself to what are known as “bare” costs: in its opinion, these reflect best current knowledge and the regular revisions significantly limit any adverse effects of this choice.

2 - Programme for dismantling facilities currently in operation

a) Overall cost of the programme

EDF’s fleet of power plants in operation in France has several particular characteristics that directly influence the estimated costs for dismantling them. The 58 reactors concerned are pressurized water reactors (PWR), the duration of operations used for the calculation is 40 years and the final dates for dismantling them range from 2035 to 2057.

Four facilities which are not reactors are included in the dismantling programme: two interregional stores for new fuel (Chinon and Bugey Magasins InterRégionaux (MIR, Inter-Regional Stores), a nuclear maintenance base (Tricastin hot operational unit) and the atelier de traitement des matériaux irradiés (AMI, Irradiated Material Workshop) in Chinon.

As previously stated, the chosen principle is that of immediate dismantling of halted units from which the fuel has been unloaded. However, due to the technical nature of the operations, in the 2009 Dampierre study, dismantling operations for a unit are said to take a total of 15 years\(^{43}\) (i.e. 19 years for dismantling a 4-unit site) from shutdown of the first unit. The weighted mean point (barycentre) of expenditure is 8

\(^{43}\) Preceded by a 4-5 year preparatory phase during the final years of generation, 5 years for the final halting of operations; final shutdown and preparatory work phases; 7 years for dismantling work on the reactor building; 3 years for final dismantling work other than the reactor building and cleanup; 2 years for demolition; some of these phases overlap.
As of 31 December 2010, future expenditure amounted to €18.4 billion\textsubscript{2010} and is set to be distributed according to the schedule shown in the following graph.

\begin{center}
\includegraphics[width=0.5\textwidth]{schedule.png}
\end{center}

\textit{Source: EDF – Expenditure valuations as of end 2009}

It can be noted that the total amount of dismantling estimates is equivalent to 19 percent of construction costs for the power plants concerned (€96 billion\textsubscript{2010}, overnight cost + interim interest).

\textit{b) Estimated costs: the “reference cost” method}

Historically, dismantling costs for the fleet in operation were based on a study conducted in 1979 by the PEON commission (commission on nuclear power generation). The commission had recommended that the full investment cost of the nuclear components of the 900 MW PWR power plants should be used as a reference for estimating dismantling costs. Practically speaking, the calculation of costs was based on the application of a “reference cost” expressed in Francs/kW for the installed power of each unit.

A study by the Ministry of Trade and Industry confirmed this mode of calculation in 1991 and today, the dismantling costs for the fleet are still evaluated by EDF by applying a reference cost, discounted by the rate of inflation noted up to 2001 inclusive and then by two percent per

\footnote{EDF uses 9 years for the calculation of its provisions based on the Péon reference cost. This option reduces the difference between the result produced by the traditional method and the Dampierre estimate.}
year. In 2010 this amounted to €291.28 /installed kW, not including waste.  

Until 1991, the costs calculated in this way were equivalent to 16 percent of the full investment costs for PWR nuclear power plants. In 1991, the rate was re-evaluated at 15 percent, without the investment base being clearly identified.  

Today the dismantling cost calculated using the “reference cost” method is equivalent to around 22 percent of the “overnight” construction costs of the 58 PWR reactors. If interim interest is included, as calculated in chapter I-I-B, this figure rises to 19 percent.  

To the dismantling charges calculated in this way (€18,118 million in 2005) are then added the provisional estimate for the costs of dismantling and reprocessing the steam generators which have already been replaced, plus the four other facilities included in the programme, in the sum of €197.3 million and €83.2 million respectively. The total is therefore €18,398.5 million.  

This calculation, which can be described as the “historic” method, has some weaknesses, as it is not based on an actual calculation or precise analysis of the dismantling of an EDF power plant. In 2005, the Cour des Comptes had already noted that “in fact, the figure of 15 percent given from the outset as a reference was not itself the result of very thorough studies.” There can be no doubt that applying this reference cost calculation to the power capacity of reactors is highly simplistic.  

c) The “Dampierre method”  

In addition, from 1996 to 1999, EDF conducted a study known as Dampierre 98 (or DA98), the aim of which was to validate the evaluations used for accounting provisions using actual costed parameters. To do this, it evaluated the cost of dismantling a power plant with three 900 MW PWR reactors, in this case Dampierre, which was  

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45 Management of waste from dismantling is now included in provisions for long-term waste management. In 2008, the reference cost was €306/kW including waste. Analysis in the rest of this report does not include waste except where otherwise specified.  
46 According to EDF, dismantling is equivalent to some 17 percent of the economic rent base (€110.9 billion) but this calculation has the drawback of including dismantling costs themselves, as well as interim interest, in the assessment base.  
taken as being representative. In 2005, the Cour des Comptes noted\textsuperscript{48} that “the exhaustive studies conducted show that the amounts used to calculate provisions are “reliable”. ”

This evaluation was updated in 2009 and renamed Dampierre 09 (or DA09), firstly to incorporate regulatory, technical\textsuperscript{49} and economic changes which had emerged since 1998, as well as experience feedback from dismantling programmes in progress (both on the EDF first-generation fleet and the PWR fleets of other operators in the United States) and secondly to examine the relevance of the “historic” calculation method, based on reference costs, using the evaluation process presented below.

The exercise carried out in 2009 by EDF was based on an update of the 1998 cost parameters (average hourly rates for EDF personnel, costs for using dismantling technology, etc.) using 2009 values and experience feedback from current and past operations.

In particular, EDF made use of information drawn from waste management (packing, density, etc.) and the dismantling in progress of Chooz A, the only pressurized water reactor currently being dismantled in France. Indeed, despite the fact that this reactor’s output is less than that of the reactors in the current fleet and that it has a certain number of specific operations, EDF has considered this reactor\textsuperscript{50} as featuring all the characteristic technical considerations which will be encountered by industry when dismantling other PWR reactors. Experience feedback should be particularly useful when dismantling the main primary system\textsuperscript{51}.

EDF has also made use of the experience gained from construction operations for power plants, replacing steam generators and dismantling the first-generation fleet.

\textsuperscript{48} January 2005 Cour des Comptes report on dismantling nuclear facilities and radioactive waste management – p.175.
\textsuperscript{49} Notably the establishment of a single decree for the final shutdown and dismantling of units in pairs. The effect is a gain of 2 years for the schedule for a 4 x 900 MW site.
\textsuperscript{50} Processing operating waste disposed of in tanks, reconstruction of certain shutdown systems and facilities which would have been of interest for deconstruction, unit decontamination of facilities (and not decontamination of the complete circuit on final shutdown of the unit, using the existing facilities as for the existing fleet), dimensional differences between tanks, complex waste kinematics (presence of galleries to leave the caves), complex handling of steam generators, etc..
\textsuperscript{51} Tank lid, tank, pipework, pumps and valves, steam generator, pressurizer, etc.
With the updated data, and based on precise, detailed identification of the operations to be carried out, the costs of each operation are evaluated using parameters relating to the quantities to be processed, unit costs and completion times. These parameters are subjected to sensitivity analysis to take into account identified uncertainties and determine cost brackets based on probabilities of occurrence.

The study did not consist of evaluating the cost of dismantling the four units of a power plant individually, which would have masked the fleet effect. On the contrary, it involved working out an estimate for a site with four 800 MW reactors, incorporated into a series of 58 reactors to be dismantled in order to take into account the size of the fleet, the uniform nature of its design, and, given the probable unit shutdown dates, the tight deadline for carrying out dismantling operations. The objective was to calculate a cost which, it is said, can be “directly extrapolated” for a power plant, including part of the costs borne by the fleet as a whole, as well as a “prototype” surcharge, which is also spread across all the units.

On the basis of these elements, EDF worked out a dismantling estimate for a standard site with four 900 MW units that could be directly extrapolated: this came to €962 million\textsubscript{2008} not including contingencies, i.e. €240.5 million\textsubscript{2008} per reactor (€1,058 million\textsubscript{2008} including contingencies, i.e. €264.5 million\textsubscript{2008} per reactor).

### Dampierre 2009 estimate (DA09) – standard 4 x 900 MW site

<table>
<thead>
<tr>
<th>Categories</th>
<th>DA09 € million\textsubscript{2008}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering</td>
<td>87</td>
</tr>
<tr>
<td>Site</td>
<td>62</td>
</tr>
<tr>
<td>Works</td>
<td>613</td>
</tr>
<tr>
<td>Waste</td>
<td>200</td>
</tr>
<tr>
<td><strong>Total for dismantling a 4 x 900 MW site</strong></td>
<td><strong>962</strong></td>
</tr>
<tr>
<td>Contingencies</td>
<td>96</td>
</tr>
<tr>
<td><strong>Total including contingencies</strong></td>
<td><strong>1 058</strong></td>
</tr>
</tbody>
</table>

*Source: EDF*
This basis was then extrapolated to the other power plants equipped with 900 MW reactors and to the 1,300 MW and 1,450 MW series to take a “size effect” into account. The DA09 calculation ultimately resulted in an amount for gross costs that is lower than that of the “reference cost” currently applied by EDF.

**Comparison of calculation method results for dismantling costs**

<table>
<thead>
<tr>
<th>Calculation method used</th>
<th>€ million (2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference cost</td>
<td>18 118.0</td>
</tr>
<tr>
<td>Dampierre 2009 inc. contingencies</td>
<td>17 474.6</td>
</tr>
</tbody>
</table>

*Source: Cour des Comptes*

These results depend on technical choices, in particular with respect to cost sensitivity ratios and reductions due to the series effect. Only technical audits specific to the nuclear industry would enable the inventories, costs and their uncertainty margins, contingency rates and the choices of EDF experts in the Dampierre 2009 financial year to be confirmed or disputed. Consequently, while the entire procedure and the way the calculations are structured appear to be consistent and grounded, the amount of costs as calculated in the DA09 financial year cannot be validated by the Cour des Comptes, since it does not have the competencies to do so.

In addition, the audits to be carried out by the Direction générale de l’énergie et du climat (DGEC, *General Directorate for Energy and Climate*)\(^{52}\) before the end of 2013 are vital for the supply of validation elements, provided that their analysis is sufficiently detailed and that they provide thorough technical cross-checking of the parameters and data used by EDF in its different tools and exercises for evaluation costs. The audit of data and parameters taken from experience feedback from dismantling Chooz A would be of particular interest in this respect.

\(^{52}\) These audits are for EDF, AREVA and the CEA: an audit of the methods used to manage residual technical uncertainties and contingencies when carrying out projects, an audit of the validity of the extrapolation method used in the Dampierre study, international comparison, an audit of the databases of unit costs and the incorporation of experience feedback, an audit of cost forecasting software and the duration of dismantling work, an audit of dismantling costs for the Georges Besse and La Hague plants, and an audit of the dismantling of UP1 in Marcoule.
d) Contingencies and uncertainties

In the Dampierre 2009 method, EDF evaluates dismantling costs for its fleet without seeking to differentiate contingency rates\(^{53}\) by cost category, applying a flat rate of 10 percent to the total estimate. According to the operator, this rate, which may appear to be reliable, reflects the fact that there are a large number of units, of very similar design, to be dismantled. The additional costs for the first units are said to be spread over the costs for the other units with the benefit of experience feedback, while any one-off additional costs encountered later on for any reactor are said to be absorbed by the series as a whole. Furthermore, EDF is of the opinion that its technical and economic model\(^{54}\) enables contingencies to be significantly limited and states that it has not taken into account “any opportunity for risk reduction”\(^{55}\) when drawing up the estimate.

Although it is not possible to take a view on the level of the average contingency rate per unit taken by EDF, it is probable that due to the existence of a series of reactors of virtually identical design, this rate is lower than that encountered on smaller series, such as the first-generation fleet. This is not however grounds for using an overall rate rather than variable contingency rates according to the type of operation and costs.

In addition, the summary document for the Dampierre 09 evaluation drawn up by EDF specifies cautiously that “at this stage of the study, the level of 10 percent of the total estimate earmarked for contingencies corresponds to the minimum required to consolidate the result of DA09 cost estimates.” What is more, the DGEC and ASN have also requested that EDF\(^{56}\) provide clarification on the methods used to calculate the levels of uncertainties and contingencies.

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\(^{53}\) Definition of contingencies: possible events which are not certain and which cannot be planned. If these occur, additional costs to the project expenditure plan would be entailed. Source: EDF.

\(^{54}\) “Centralized organization, with integrated engineering, for a standard fleet which it designs and operates; existence of a unit dedicated to deconstruction within this integrated engineering, capitalizing on experience feedback from successive operations”: quoted from *Mémorandum aléas et incertitudes dans les devis de déconstruction* by EDF.

\(^{55}\) Source: EDF: *Mémorandum aléas et incertitudes dans les devis de déconstruction*

\(^{56}\) In correspondence following the release of the second three-yearly report in application of article 20 of the 2006 law.
Lastly, EDF’s estimates do not include the risks relating to decontamination of sites after dismantling, either for fleets no longer in use or in those in operation. At present, a project has been implemented by EDF aimed at improving the precise knowledge of subsoils and their level of radioactive and chemical pollution. A cleanup methodology has been developed in liaison with other nuclear operators, but this needs to be approved by the ASN. Cleanup costs may therefore change to an as yet unevaluated degree.

The rate of 10 percent is consequently only a baseline. The new and probably higher estimates for dismantling Chooz A in 2012 will no doubt provide a clearer picture in this respect.

It must however be emphasized that over and above the “contingency” parameter itself, which is applied as a whole to the Dampierre method evaluation result, the very calculation of the latter includes an uncertainty margin which is inherent in the calculation method used. For each piece of data, this consists of evaluating a cost bracket along with the probability of occurrence rather than a cost itself. This additional uncertainty margin, incorporated into the calculation of the cost itself, is evaluated at 4 percent by EDF.

The overall level of uncertainties and contingencies in the Dampierre 09 estimate is therefore evaluated at 14 percent by EDF, without applying the conservatism principle which itself entails an uncertainty margin evaluated by the operator at between 0 and 12 percent, i.e. between €0 million and €105 million of the €962 million on the estimate, not including contingencies. With an average of 6 percent for this margin, the overall rate is in fact 20 percent.

e) The relevance of the calculation methods used

As stated above, at present it is not possible for the Cour des Comptes to validate the results of the Dampierre method, since these are based on choices of technical parameters for which it has no particular competence or legitimacy.

This method does however appear to be preferable to the one currently used by EDF, which continues to calculate the future gross costs

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57 The reference scenario for estimates used by EDF is reuse of sites for industrial purposes.
58 10 percent contingencies + 4 percent sensitivity margins.
59 The term “uncertainties” is used to refer to the inaccuracies inherent in any forecast cost estimate based on a certain number of assumptions. Source: EDF.
for dismantling its fleet using the historic “reference cost” method. In support of its argument that the amount of provisions in its accounts is appropriate and its continued use of the historic calculation method, EDF argues that the result of the two methods is similar and that the reference cost method gives a slightly higher result than the Dampierre 2009 method.

However, the use of the historic calculation method has the major drawback of not allowing the provisional amount of gross dismantling costs to be adjusted in line with improved knowledge in this area, in particular thanks to experience feedback from dismantling the fleet no longer in use and foreign experience. The EDF statutory auditors, who audited the update of the Dampierre study in 2009, seem to be of the same opinion: they noted that calculation using the DA09 method enabled “a more rational estimate of standard dismantling costs. [...] As it is based on more tangible elements than ‘the formula derived from the Péon cost’, it would be likely to facilitate traceability and monitoring of this new evaluation over time by EDF and the auditors”

3 - Non-French evaluations

The utmost discernment must be exercised when carrying out any international comparison of dismantling costs. In 2010, the most recent summary report of the OECD’s Nuclear Energy Agency (NEA) entitled “Towards Greater Harmonization of Decommissioning Cost Estimates”, was published. Its specific purpose was to make international comparisons of dismantling costs. It summarizes these reservations as follows:

“At present, considerable variability in format, content and practices for cost estimates can be observed, both within countries and between different countries. Comparisons are therefore extremely difficult, even between facilities of the same type. The requirements of national regulations are largely responsible for these differences, with historic customs and practices. These have repercussions on the basic

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61 There is a detailed presentation of these international comparisons in Annex 18.
62 OECD/NEA no. 6868-2010: Summary of the report Cost estimation for decommissioning: an international overview of cost elements, estimation practices and reporting requirements: Study conducted in twelve countries: France, Germany, Belgium, Canada, Spain, USA, Italy, Japan, Sweden, Netherlands, United Kingdom, and Slovakia.
hypotheses, such as the planned dismantling strategy and the final condition of the site, as well as on the methods for dealing with uncertainties.”

In spite of these difficulties, the Cour des Comptes has attempted to carry out this exercise based on data from several countries in order to evaluate, with large uncertainty margins, a bracket for dismantling costs as assessed outside metropolitan France.

Whenever possible, the calculations carried out by the Cour des Comptes consisted in relating the foreign gross dismantling costs to a cost in €\textsubscript{2010} per installed MW, then taking this as the reference cost to be used in accordance with the method used by EDF. As stated previously, EDF’s reference value is €291\textsubscript{2010}/MW for the 58 PWR reactors in operation, i.e. €18.1 billion\textsubscript{2010} in total.

The major discrepancies in scope have been corrected wherever possible on the basis of available information; where information was not available, the Cour des Comptes arbitrarily chose to base itself on the data available, i.e. that of EDF, to adjust perimeters.

Costs for dismantling reactors in six countries were analysed (Germany, Belgium, Japan, United Kingdom, Sweden and USA, sometimes with several evaluations available per country) and applied to the EDF PWR fleet in operation.

**Extrapolation of the cost of dismantling the current fleet:**

<table>
<thead>
<tr>
<th>Methods used by</th>
<th>EDF</th>
<th>Sweden</th>
<th>Belgium</th>
<th>Japan</th>
<th>USA 3 methods</th>
<th>UK</th>
<th>Germany 4 methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extrapolation for 58 reactors</td>
<td>18.1</td>
<td>20</td>
<td>24.4</td>
<td>38.9</td>
<td>27.3</td>
<td>46</td>
<td>25.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>33.4</td>
<td></td>
<td>34.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>34.2</td>
<td></td>
<td>44</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>62</td>
</tr>
</tbody>
</table>

Source: Cour des Comptes

(1) See the presentation of comparisons in Annex 18

In general, and once again, with the necessary measure of caution called for due to the differences between regulations, strategies, schedules and organizations of operators and reactor technologies, it appears from the comparisons that the 11 evaluations reconstituted on the basis of foreign data and extrapolated to the EDF fleet of 58 PWR reactors are all higher than those of EDF. The table above gives a summary of the extrapolation to EDF’s 58 pressurized water reactors of the dismantling
costs calculated using the international data available, not including EDF sources. It also shows the major differences in the results obtained, demonstrating the high degree of uncertainty in this field worldwide.

The Cour des Comptes also analysed two international comparisons used by EDF in its communications.

The first one is based on an OECD survey which enabled an international comparison to be made for dismantling costs for PWR sectors, as estimated by the main nuclear operators. The reference cost for EDF was $314\,2005/kW and, for the category strictly above 900 MW corresponding to the EDF fleet, the international average was $304\,2005/kW, which is slightly lower than the estimate of the French electricity company. However, the 58 French reactors account for 80 percent of the basis taken to perform the calculation for reactors over 900 MW; EDF’s costs are therefore to a large extent those of the panel studied, thus significantly limiting the evidentiary value of this comparison.

As part of the Dampierre 09 exercise, EDF also commissioned an audit from La Guardia in the United States, which specializes in the evaluation of dismantling, requesting a theoretical estimate for dismantling a site with two 1,150 MW PWR units and a comparison with that of DA09. The result of the exercise was consistent with EDF’s evaluations.

The details of the calculations relating to all the comparisons can be found in Annex 18.

**C - Evaluation of AREVA dismantling costs**

AREVA’s dismantling costs are composed essentially of costs relating to the seven facilities at La Hague, which account for 81.5 percent of the group’s costs, and dismantling the George Besse 1 plant belonging to Eurodif, a subsidiary of AREVA, which accounts for 9.2 percent of its costs.

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63 OECD - NEA-- *Decommissioning Nuclear Power Plants. Policies, Strategies and Costs* (2003). The figures were then reprocessed by AON Accuracy based on the exchange rate on 31 December 2005.

64 A uranium enrichment plant which is to cease activity at the end of 2012 and be decommissioned in 2024 at the latest, i.e. 3 years end of service life after shutdown,
Gross dismantling costs for AREVA civil nuclear facilities

<table>
<thead>
<tr>
<th>As of 31 December 2010</th>
<th>Number of facilities</th>
<th>Remaining costs € million 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facilities in operation breakdown</td>
<td></td>
<td></td>
</tr>
<tr>
<td>La Hague: UP2 800 and UP3</td>
<td>10</td>
<td>5 247.8</td>
</tr>
<tr>
<td>Eurodif</td>
<td></td>
<td>4 256.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>660.2</td>
</tr>
<tr>
<td>Halted facilities breakdown</td>
<td>7</td>
<td>1 860.6</td>
</tr>
<tr>
<td>La Hague: UP2 400</td>
<td></td>
<td>1 542.3</td>
</tr>
<tr>
<td>Total breakdown</td>
<td>17</td>
<td>7 108.4</td>
</tr>
<tr>
<td>La Hague</td>
<td></td>
<td>5 799.2</td>
</tr>
<tr>
<td>Eurodif</td>
<td></td>
<td>660.2</td>
</tr>
<tr>
<td>Others</td>
<td></td>
<td>649.0</td>
</tr>
</tbody>
</table>

Source: Cour des Comptes  *total amount, without taking into account the fact that part of these investments were funded by foreign investors.

To date, the dismantling programme for the La Hague facilities covers the UP2 400, an irradiated fuel processing plant \(^{65}\) which is currently being dismantled, and the UP2 800 and UP3 plants which are in operation \(^{66}\).

These gross dismantling costs can, very approximately, be compared with the construction costs for the facilities concerned, which amount to €7 billion 2010 for Eurodif (9 percent) and €19.5 billion for the facilities in operation at La Hague (22 percent).

and approximately 9 years for dismantling (7 years for dismantling processing facilities + 2 cleanup of civil engineering).

\(^{65}\) The dismantling operations for UP2 400 will end in around 2034. The operator notified the ASN of the end of spent fuel processing at UP2 400 in December 2003. Source: AREVA.

\(^{66}\) The end of industrial operations in the UP2 800 and UP3 plants is envisaged for around 2040. The dismantling operations will take place over an estimated period of twenty years. Source: AREVA.
1 - Changes in dismantling estimates for AREVA facilities

a) Estimates for halted facilities

The total estimate for dismantling UP2 400, corrected for inflation, has increased since 2006 by 36.8 percent in constant euros (up 29 percent between 2006 and 2007; up 6 percent between 2007 and 2010).

**Estimate for dismantling UP2 400**

<table>
<thead>
<tr>
<th>Commissioned shutdown date</th>
<th>Year dismantling completed</th>
<th>Total dismantling costs as of 31/12 current €, million</th>
</tr>
</thead>
<tbody>
<tr>
<td>1966</td>
<td>2003</td>
<td>2030</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1192 1578 1768 1779 1738</td>
</tr>
</tbody>
</table>

Source: Cour des Comptes - AREVA data

Most of the increase in the estimate is due to an extension in the calculation perimeter to take into account the monitoring costs for the facilities which have not yet been dismantled at La Hague (+ €326 million\(^67\)). These were covered, prior to the 2006 Act, by commercial contracts and therefore included in operating costs and costs for dismantling facilities and waste recovering and processing (€65 million). Given the progress of operations, the current estimate for UP2 400, in the absence of any major contingency before the end of 2011, is probably stable now.

b) Estimates for facilities in operation

Between 2006 and 2010, the estimate for dismantling UP2 800 and UP3 remained stable, whereas the estimate for Eurodif increased by some €200 million in constant euros, i.e. by 42 percent.

This increase is the result of changes in scope between 2006 and 2009, increasing the estimate by €86 billion\(^{2010}\) and a new evaluation, in 2010, of the operations to be completed, entailing additional costs of €110 million\(^{2010}\), due to volumes of waste and contamination which were larger than planned.

\(^{67}\) This was for the UP2 400, 800 and UP 3 facilities as a whole, but the costs relate mostly to UP2 400.
Estimates for dismantling facilities in use

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>UP2 800 - UP3</td>
<td>4,295</td>
<td>4,257</td>
<td>-0.9%</td>
</tr>
<tr>
<td>Eurodif</td>
<td>462</td>
<td>660</td>
<td>+43%</td>
</tr>
</tbody>
</table>

Source: Cour des Comptes

From 2002 onwards, many uncertainties became apparent, due, according to the operator, to the summary preliminary project status of this initial evaluation. AREVA also noted that it was very difficult to draw up an estimate for such a specific dismantling operation, since it could not base itself on any prior experience, either within or outside the group. The changes noted confirm the uncertainties expressed at that time.

2 - Cost evaluation methods

The La Hague facilities have the particular characteristic of not being able to benefit from a series effect. The evaluations of dismantling operations are therefore individual. AREVA nonetheless uses experience feedback for certain operations, in particular that of UP1, the first Marcoule processing plant and of course that of UP2 400 for the other two plants in operation.

Two methods are used, depending on whether the facility is in operation or being dismantled. They are both based on the physical and radiological inventories of the facilities to be dismantled, technical and economic ratios and the establishment of scenarios.

When facilities are in operation, the estimates are calculated using this data and identified standard costs, and then revised every 3 years. The estimate can be revised if significant events occur, as was the case for Eurodif in 2010. To do so, AREVA uses a cost evaluation method which it shares with the CEA, based on a tool called ETE-EVAL. The procedure is based on typical scenarios associated with each facility to be dismantled. Each scenario includes a number of cleanup or dismantling tasks. These tasks in turn are associated with ratios which are applied

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68 This has been the responsibility of the CEA since 2005. AREVA nonetheless considers that due to major design differences, the direct transposition of UP1 dismantling scenarios is difficult.

69 Examples of scenarios: high dose rate cells, medium dose rate, low dose rate, tanks, glove boxes, shielded enclosures; examples of tasks (70 in total): work on tanks, pools
to the result of the inventories in order to calculate primary costs. A large part of the ratio database is shared with the CEA and constantly updated as and when experience feedback is received. The ETE-EVAL tool has been certified by Bureau Veritas Consulting, whose 2006 report concluded that the tool was sufficiently reliable, with no points for improvement identified.

In the dismantling, preparation and works phases, the estimate is drawn up using a more detailed “project approach” called the “méthode des devis opérationnels” (OEM, operational estimating method), based on precise dismantling processes and detailing the works to be completed by type of task.

3 - Contingencies and uncertainties

The evaluations performed by ETE-EVAL during the operating phase do not include a “specific” margin for uncertainties and contingencies, either globally or for each site. AREVA is nonetheless of the opinion that it takes these into account as it has a prudent approach to the evaluation of the parameters used as a basis for calculations.

However, during dismantling, risk analysis is performed for the operational estimates to determine this aspect and include it. According to the operator, the margins involved are 11 percent for technical uncertainties and 5 percent for contingencies.

In 2010, AREVA compared the two evaluation methods on five OEMs for different operations on UP2 400 and noted that the results were similar; it therefore considers that “implicitly, the rate of technical uncertainties and contingencies in the ETE-EVAL evaluation tool is the same as that for the operational estimating method, i.e. 16 percent in total.” In addition, although it cannot cost it, AREVA considers that taking into account the dismantling of the UP2 800 and UP3 facilities from the design phase with the objective of reducing this cost reduces the overall uncertainties in their dismantling estimate.

and ponds, radiological controls (initial, intermediary, final), teleoperation (cutting and extraction in direct view or by camera) etc.

70 Primary ratios: enable the waste generated by different tasks to be quantified; scenario ratios: relating essentially to resistance, hourly yields; ratios according to the facility under consideration: relating to operational costs, hourly rates, costs of materials and consumables, waste and effluent treatment costs, etc. The ratios for the first two categories are common to the CEA and AREVA.
As to Eurodif, the company has incorporated contingency and risk rates relating to different lines\(^71\) in its 2010 estimate, amounting to €49 million\(^{2010}\). In addition, “positive” contingencies (sale of metals, industrial optimization, etc.) are evaluated at €80 million but are not included in the estimates. The main increases, corrected for perimeter effects, can be as high as 25 percent.

Dismantling costs for the George Besse 2 ultracentrifugation enrichment plant\(^{72}\) are evaluated by AREVA at €200 million for the two units which will ultimately be in operation, i.e. 6.6 percent of the total investment of some €3 billion. The dismantling estimate for GB1, which amounted to €660 million at the end of 2010, is equivalent to 10.2 percent of the original investment in this plant according to AREVA. According to the operator, it is not possible to compare these two estimates due to a number of factors: particular technical characteristics which make the dismantling of the GB1 facilities more costly than that of the GB2 facilities, the series effect for GB2 and the quantity of very low-level waste produced by the dismantling of GB2. The latter is equivalent to only 10 percent of that produced by dismantling GB1. Although these differences can indeed explain some of the difference in expected costs, the difference noted between the burden of costs compared to the initial investments for GB1 and GB2 nonetheless remains considerable.

The main increases in the estimates presented above, corrected for perimeter effects, are 10 percent for UP2 400 and 17 percent for Eurodif, as compared with the mean uncertainty rates of 16 percent referred to by AREVA.

Generally speaking, AREVA considers that it has implemented an adequate structure to ensure coherence between estimates, expected scenarios and provisions by setting up (in early 2008) its “Value Development Business Unit”, in charge of dismantling operations within the group, and, in 2010, establishing the Nuclear Assets Department, in charge of validating dismantling liabilities and overseeing the coordination of programmes.

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\(^{71}\) The risks relate essentially to the two-year increase in the duration of dismantling operations (€20 million), the slower-than-planned processing rate entailing production overtime (€6 million), additional investments and related costs for flow management (€21 million) and additional consumables (€2 million).

\(^{72}\) The first centrifuge cascade began rotating in 2009 and the first uranium container entered the facility for enrichment in 2010. Source: AREVA 2010 reference document.
In accounting terms, the three-yearly revision of estimates in ETE-EVAL and the implementation of the aforementioned organization limit the consequences of under-evaluation of costs to a limited period.

**D - CEA assessment of civil nuclear dismantling costs**

The CEA stands out from the other two major nuclear operators in France due to the diversity of its activities. These require the operation of a large number of different types of nuclear facility, including reactors, research laboratories and pilot fuel cycle facilities, which are characterized overall by the lack of any series effect in terms of dismantling.

**Breakdown of dismantling costs for CEA civil nuclear facilities by activity status**

<table>
<thead>
<tr>
<th>€ million2010</th>
<th>Number of facilities</th>
<th>Remaining gross costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facilities in operation</td>
<td>22</td>
<td>1 261.1</td>
</tr>
<tr>
<td>Halted facilities</td>
<td>21</td>
<td>2 588.6</td>
</tr>
<tr>
<td>Cross-functional costs</td>
<td></td>
<td>61.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>43</strong></td>
<td><strong>3 911.2</strong></td>
</tr>
</tbody>
</table>

*Source: Cour des Comptes*

As of the end of 2010, total dismantling costs amount to €3.9 billion spread over five major sites. It should however be noted that the CEA includes some costs for long-term waste management in dismantling costs which should be included in the cost perimeter later in the cycle. This aspect amounts to €372.1 million. The CEA’s presentation will be adjusted in line with legal specifications when the accounts are next closed.

Five civil facilities alone account for 58 percent of the CEA’s dismantling costs. With the exception of the Cadarache effluent processing plant73, they have all been shut down or have limited activity and are in the process of or awaiting dismantling.

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73 The purpose of the effluent and solid waste processing station (STEDS) is radioactive processing and conditioning of waste produced by the Cadarache centre as well as by other CEA and non-CEA centres.
Breakdown of dismantling costs for CEA civil nuclear facilities by site as of 31 December 2010

<table>
<thead>
<tr>
<th>€ million</th>
<th>Marcoule</th>
<th>Cadarache</th>
<th>Saclay</th>
<th>Fontenay-aux-Roses</th>
<th>Grenoble</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 015.4</td>
<td>972</td>
<td>480.2</td>
<td>306.3</td>
<td>53.1</td>
<td></td>
<td>3 911.2</td>
</tr>
</tbody>
</table>

**breakdown**

- Marcoule Pilot Facility 74
  - Effluent processing plant 199.4
- Phénix reactor 880.5
  - Rapsodie reactor 177.8
- Plutonium chemistry laboratory (building 18) 230.9

Source: Cour des Comptes

1 - Changes in dismantling costs

There has been a general upward trend in dismantling costs for CEA facilities over the last ten years.

The following table shows the changes in the estimates for six halted facilities, some of which have now been decommissioned or are in the process of being decommissioned, and one of which is in operation.

With the exception of the Siloette and the LAMA in Grenoble, for which estimates have gone down, the others have increased, by 13 percent in the case of the estimate for the Cadarache effluent processing plant and much more significantly in the case of the other estimates examined (by between 54 percent and 108 percent).

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74 Between 1962 and 1997, the Marcoule pilot facility (APM) enabled the design and development on a pilot scale of the reprocessing and nitrification processes used at UP1 and La Hague; it is currently used for storing the “hot” spent fuel elements from Phénix and the storage of blocks of vitrified waste, radioactive waste and radioactive sources. Dismantling work is planned after 2013 and decommissioning after 2026.
The evaluations as of 31 December 2001 (the year in which the dedicated fund for dismantling the CEA’s civil facilities was set up) were both “diverse and non-exhaustive”, according to the CEA itself, notably due to a lack of experience in dismantling on research sites. Between 2001 and 2005, the CEA commissioned technical and financial audits for the projects in progress and systematic evaluation campaigns for the medium and long-term projects being launched. These estimate revisions form the bulk of the changes between 2001 and 2007.

### Changes in dismantling estimates for six facilities

<table>
<thead>
<tr>
<th>Facilities</th>
<th>IC date</th>
<th>Shutdown date</th>
<th>Year dismantling completed</th>
<th>Evaluations 31/12/2001</th>
<th>Evaluations 31/12/2007</th>
<th>Evaluations 31/12/2010</th>
<th>Change 2010/2001 € million 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cadarache effluent processing plant</td>
<td>1965</td>
<td>2013</td>
<td>2026</td>
<td>181.4</td>
<td>204.5</td>
<td>204.7</td>
<td>12.8%</td>
</tr>
<tr>
<td>Rapsodie Cadarache</td>
<td>1967</td>
<td>1983</td>
<td>2050</td>
<td>131.9</td>
<td>130.5</td>
<td>219.9</td>
<td>66.7%</td>
</tr>
<tr>
<td>APM Marcoule</td>
<td>1962 Building 211 1988 building 214</td>
<td>1997</td>
<td>2028</td>
<td>487.1</td>
<td>894.5</td>
<td>1014.9</td>
<td>108.4%</td>
</tr>
<tr>
<td>Siloe Grenoble</td>
<td>1963</td>
<td>1997</td>
<td>2010</td>
<td>56.8</td>
<td>65.3</td>
<td>87.8</td>
<td>54.7%</td>
</tr>
<tr>
<td>Siloette Grenoble</td>
<td>1963</td>
<td>2002</td>
<td>2006</td>
<td>11.3</td>
<td>7.1</td>
<td>7.1</td>
<td>-37.5%</td>
</tr>
<tr>
<td>Mélusine Grenoble</td>
<td>1958</td>
<td>1988</td>
<td>2009</td>
<td>16.2</td>
<td>22.7</td>
<td>25.4</td>
<td>56.5%</td>
</tr>
<tr>
<td>LAMA Grenoble</td>
<td>1961</td>
<td>2002</td>
<td>2012</td>
<td>67.5</td>
<td>57.8</td>
<td>62.2</td>
<td>-7.8%</td>
</tr>
</tbody>
</table>

Source: Cour des Comptes

In 2010, due to the difficulties reported, in particular on the Fontenay projects and UP1 (a former defence facility), the CEA took the initiative of conducting a general review. This led to major revisions of the estimates drawn up in 2010. Following increases for certain facilities and decreases for others, the result showed a definitive increase in gross dismantling costs, adjusted for inflation, of €164 million\textsubscript{2010} between 2009 and 2010, i.e. 4.4 percent compared to 2009, whereas they had been constantly falling since 2006.

There are many different reasons for the increases: revisions of strategies and scenarios for final shutdown and dismantling of facilities relating to balancing priorities, changes in regulations, under-evaluation...
of the complexity of work to be carried out, insufficient knowledge of the contamination to be dealt with, and changes in choices concerning the allocation of human and financial resources.

For instance, with respect to the Marcoule pilot facility (APM), the dismantling scenario was extended by six years and the worksite difficulties re-evaluated. Furthermore, additional costs were identified, ascribed to “workforce considerations and the defined priorities, automatically entailing additional costs relating to the increased duration of operation.”

The Phénix reactor\textsuperscript{75} dismantling estimate increased by €70 million between 2009 and 2010 due to “unforeseen” technical problems, arising from unloading the core and the priority given by the CEA to dismantling UP1, the plutonium fuel processing plant for the defence sector: this caused a one and a half year delay in the project.

The schedule for dismantling the plutonium chemistry laboratory (building 18)\textsuperscript{76} at Fontenay-aux-Roses (initially resulting in the end of dismantling work in 2017) has been delayed by three years, causing an increase in the estimate. The CEA has had to manage more complex operations than foreseen, difficulties with the removal of waste and above all the unforeseen discovery of contaminated subsoils, which constitutes a major difficulty. This dismantling project is a priority for the CEA which hopes to make progress in this area soon as possible.

Lastly, with respect to the Rapsodie\textsuperscript{77} reactor, the CEA has been faced with a number of difficulties. Dismantling costs for the reactor block put forward by the industrial companies are much higher than initial estimates. In addition, in 2009 the ASN refused the final shutdown and dismantling application made by the CEA and requested that it be based, at least for the first few years, on more thorough studies. The CEA

\textsuperscript{75} Phénix: a sodium-cooled fast neutron reactor for electricity and the study of the transmutation of long lived radioactive waste. It ceased to be operated in 2009 and was shut down in 2010. The safety file for dismantling should be registered in 2011 for a decree in 2013, following the example of the APM. Decommissioning is planned for 2030.

\textsuperscript{76} Plutonium chemistry laboratory: facility dedicated to conducting radiochemical studies, in particular on significant quantities of plutonium from spent fuel and transuranic elements. Decommissioning is planned for 2020.

\textsuperscript{77} Rapsodie: an experimental fast neutron reactor which was finally shut down in 1985. A fatal accident in 1994 on the dismantling site delayed the resumption of work by three years. The ASN has informed the CEA that its file registered in 2008 is incomplete. Cleanup and dismantling work limited to certain facilities was carried out between 1997 and 2008. Decommissioning is planned for 2050.
would therefore like to postpone dismantling, but this option must fall within the new dismantling strategy currently being examined by the ASN. Furthermore, this dismantling does not rank among the priority projects for the CEA and is suffering the consequences of the financial and human resources considerations already referred to with respect to the Marcoule APM.

2 - Cost evaluation methods

Like AREVA, the CEA must calculate dismantling costs for a range of facilities without being able to base itself on any series effect. It uses the same principles as AREVA, notably also using ETE-EVAL for medium and long-term dismantling projects.

However the CEA states more clearly than AREVA in “article 20” of its report the principles it uses to calculate contingencies and uncertainties. This calculation is specific to each facility and is regularly updated as and when experience feedback is received or when events or new information occur; it thus depends on the state of progress of the dismantling project.

• For projects in the operational dismantling phase, the reference method is based on a risk analysis, amended by a calculation of probabilities, which relies on operational costing of works.

• For facilities for which cleanup and dismantling is planned only in the medium to long term, the CEA uses a statistical ratio method applied to four major lines of expenditure (project, ‘Senex’ work, waste) taking into account the specific characteristics of each facility.

For the facilities concerned as a whole, the CEA considers that the average rate of contingencies and uncertainties is around 30 percent. This is lower than the increases in the estimates noted between 2001 and 2010 for halted facilities, which were between 54 and 108 percent, with an average of 83 percent. Although some of these changes in estimates are due to causes which are sometimes due to factors external to the projects, changes in scope (including the original and final conditions), in scenarios and in the environment (in particular regulations and the waste industry) which are not included in the contingency rates calculated by the CEA, it is nonetheless the case that the estimates have increased for reasons which were not originally foreseen. In the light of the operations

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78 Senex: Expenditure for monitoring, upkeep and operation of halted facilities, corresponding to all the operations required to maintain them in a safe and secure condition, including during dismantling operations.
still to be carried out, and the particular characteristics of each facility and the distant deadlines for certain dismantling operations, there are still non-negligible risks in terms of increases in estimates.

While in general terms, the work conducted since 2001 (in particular the review of estimates in 2009-2010) certainly enables the risk of estimate revisions relating to scope and industrial scenarios to be limited in the future, the dismantling costs as of the end of 2010 should be assessed in the light of the increases noted on the estimates for these facilities. The increases noted confirm that the CEA ought to maintain a high contingency rate.

___________________
CONCLUSION – DISMANTLING

Dismantling charges (€31.9 billion\textsubscript{2010} in total) are difficult to estimate due to a lack of precedents and experience, in particular for the AREVA and CEA facilities. The three operators have therefore drawn up methods and tools, many of which are sophisticated, to fine-tune their evaluations. These are regularly reviewed, enabling the impact of underestimations in the accounts to be kept to a minimum. However, their circumstances differ, and the results of past changes are cause for concern in terms of the likelihood of future increases in certain estimates in the future.

- **EDF**

  * As of the end of 2010, out of a total dismantling estimate of €4 billion\textsubscript{2010}, the outstanding amount of gross charges for halted EDF facilities was €2.5 billion. This amount will probably increase following the revision of the estimate to be carried out in 2012. Analysis of these estimates since 2001 shows major differences between facilities and illustrates the significant consequences which industrial and administrative contingencies and uncertainties can have on the final cost. That said, while the evaluation policy chosen by EDF (which does not include contingencies and uncertainties) must face the reality of the major differences (noted in particular since 2006) for a number of facilities, regular reviews of the estimates limit the effects of this.

  * With respect to dismantling the fleet in operation, the Cour des Comptes is not in a position to validate the amount of dismantling costs for this fleet, calculated using the historic “reference cost” method
(€18.4 billion\textsubscript{2010}), due firstly to the fact that this is a lump sum and secondly to the lack of thorough studies prior to adoption of this method. This was already noted by the Cour des Comptes in its 2005 public report.

It is however possible to confirm that the “Dampierre 09” exercise, based on a sound, properly argued calculation method, leads to an evaluation of the future dismantling cost for EDF’s 58 PWR units and ancillary facilities of €17.7 billion\textsubscript{2010}, which is similar to the amount given by the historic evaluation (€18.4 billion\textsubscript{2010}). Despite this, it is not possible to assert that these amounts accurately reflect the correct level of costs due to the many choices and parameters used by the EDF experts. The Cour des Comptes is not in a position to advance a counter-argument to these.

Given the interest of this method, which enables changes in estimates to be monitored accurately, the Cour des Comptes is favourable to its use by EDF in calculating its future dismantling costs, rather than the historic reference cost method, the one still being used by the operator.

Furthermore, dismantling costs could increase due to more stringent requirements for site decontamination standards in the future. It is not possible to evaluate this potential increase.

* In general, and with the due caution called for given the discrepancies in regulations, strategies, operators’ schedules and organization, and reactor technologies, the international comparisons which it has been possible to establish all demonstrate that the amount earmarked by EDF for dismantling its reactors is lower than the cost calculated abroad, after extrapolation to make these comparisons possible. The spread of results obtained in this way (ranging from €20 billion\textsubscript{2010} to €62 billion\textsubscript{2010}) does however confirm the high degree of uncertainty surrounding these issues.

In the current state of analysis, within the limits stated above as to the value of these comparisons, the dismantling costs taken by EDF are at the bottom end of the range for international comparisons. The audits commissioned by the DGEC from 2012 onwards are therefore entirely necessary and should enable this uncertainty to be dispelled or reduced.
- **AREVA**

  The dismantling costs borne by AREVA are essentially current and future costs for the La Hague facilities, amounting to €7.1 billion.

  Due to its state of progress, the estimate for the dismantling project for the La Hague UP2 400 facility now appears to be stable and should not undergo any major change in the absence of any major contingency.

  With respect to the dismantling of the facilities still in operation, it is difficult to draw up an estimate for operations which are very specific in nature, in particular due to limited experience feedback. AREVA has implemented an ad hoc organization to have the best possible control over the evaluation of these costs and has taken into account dismantling issues right from the design stage of UP2 800 and UP3.

  There have however been significant increases in estimates, from 2006 to 2010, for UP2 400 (up 37 percent) and Eurodif (up 43 percent). These should cause the company to take a fresh look at evaluation and the level of contingencies and uncertainties it should apply to its future works: these account for €5.3 billion of the €7.1 billion worth of costs evaluated at the end of 2010.

- **The CEA**

  Future dismantling costs for the CEA amount to €3.9 billion. As the CEA is highly dependent on its particularly diverse fleet, it cannot benefit from series effects and remains subject to contingency risks which may, within an individual approach for each facility, entail major discrepancies from the mean contingency and uncertainty rate used for the facilities to be dismantled in the future.

  However, the CEA carried out systematic reviews of its estimates in 2009 and 2010, minimizing future risks of re-evaluation relating to the scopes of projects and industrial scenarios. However, while the CEA now has more accurate knowledge of the parameters of its estimates, the amount of dismantling costs for the CEA at the end of 2010 should be seen in the light of the considerable increases noted on the estimates for halted facilities.
II - Spent fuel management

Spent fuel management costs cover different operations depending on the type of fuel concerned. The following can be distinguished:

- recyclable fuel management costs in industrial facilities for which construction is completed or underway: in this case these costs cover the following stages:
  - storing fuel in one of the operator’s facilities;
  - transportation to the processing facility;
  - storage on site prior to processing;
  - processing;
  - disposal of ultimate waste packages on site after processing.

- non-recyclable fuel management costs in industrial facilities for which construction is completed or underway: these costs cover all reconditioning operations and any transport, as well as storage pending ultimate disposal.

Most spent fuel from the French nuclear power industry comes from plants in the current fleet. EDF must therefore bear all the costs relating to the management of this spent fuel. However, the CEA also manages spent fuel from its research reactors, in more limited quantities but which may nonetheless pose specific problems.

Gross costs of spent fuel management

<table>
<thead>
<tr>
<th>€ million, 2010</th>
<th>Gross costs as of 31 December 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDF</td>
<td>14 385.8</td>
</tr>
<tr>
<td>CEA civil</td>
<td>419.9</td>
</tr>
<tr>
<td>Total</td>
<td>14 805.7</td>
</tr>
</tbody>
</table>

Source: Cour des Comptes

79 In the case of EDF, the costs for temporary storage in pools are not included in these provisions. This is because these pools are necessary for the storage of new fuel and fuel loading and unloading operations, and pool operation costs are low and depend only slightly on their content.
A - EDF spent fuel management

There are three stages in the French nuclear power fuel cycle:

− The front-end stage: extraction, conversion, enrichment and fabrication of the fuel. After extraction, natural uranium must be enriched because the proportion of the fissile uranium-235 isotope is only 0.7 percent as opposed to 99.3 percent for the uranium-238 isotope. Enrichment consists of increasing the uranium-235 content to between 3 and 5 percent, the level required for use with PWR reactors. This enrichment is carried out after converting uranium oxide into gaseous uranium hexafluoride. In France this takes place at Eurodif’s Georges Besse plant, by gaseous diffusion, and, from 2011 onwards, at the Georges Besse 2 plant, by ultracentrifugation, a technique which uses far less energy than the previous one. Enriched uranium is then converted, first into powder and then pellets: these are inserted into the rods which make up the assemblies

− use of fuel. Fuel assemblies are placed in the reactor cores, where they produce energy from the fission of the uranium-235 and plutonium-239 nuclei, present in the fuel due to transmutation of uranium-238. On average, the fuel remains in the reactor for three to four years, managed on a staggered basis: once every 12 to 18 months, the fuel is unloaded. The oldest elements are replaced by new ones, and the other elements are repositioned in a different location in the reactor core. Spent fuel assemblies are unloaded to be cooled in the power plant pool for approximately four years before being transported to the La Hague pool, where they continue cooling;

− the back end part of the cycle in France: recycling and management of material and waste from recycling. After approximately eight years in La Hague, spent enriched natural uranium fuel (ENU) is sheared and subjected to chemical treatment, enabling part of the uranium and plutonium suitable for recycling to be separated from the fission products and minor actinides, which are processed as waste and vitrified. Recycled uranium is then suitable for enrichment, to be used once again as fuel (in the form of enriched recycled uranium or ERU), whilst the plutonium is used in the fabrication of fuel in the form of MOX assemblies (mixed depleted uranium and plutonium oxides).
To recycle or not to recycle?

In nuclear power generation, there are two solutions for what should be done with spent and used nuclear fuel.

The first solution is to consider it as waste. This choice has been made, for instance, by the United States\textsuperscript{80}, Sweden and Finland, which have currently opted for direct disposal or long-term storage of spent fuel.

The second solution consists of recycling all or part of the used fuel with a view to separating and conserving everything that is potentially recyclable, namely the uranium and plutonium\textsuperscript{81}. This route has been taken, for instance, by China, Russia, Japan and Switzerland.

France’s decision in favour of recycling is in line with this second option and has led in practical terms to the construction of the La Hague recycling plant and capabilities for the production of MOX fuel, the constitution of buffer stocks of spent fuel in pools, and recycled materials, awaiting reprocessing or recycling. During this time, these materials are not considered as waste. This choice was originally justified in several ways:

80 The United States has studied repository projects (in particular Yucca Mountain, which is currently suspended) as well as projects for creating a recycling industry. The Blue Ribbon Commission mandated to work on this issue in 2011 recommended storage of spent fuels for 100 years, without ruling out other solutions in the long term. In addition, a plant is being built at Savannah River to recycle military plutonium for civil nuclear reactors.

81 In the physical reprocessing process, a theoretical level of 96 percent of processed spent fuel can be made recyclable. In the French nuclear power industry, the annual share of recycled fuel (ERU and MOX) of all fuel (essentially enriched natural uranium - ENU) loaded into the reactors in 2010 is only 16 percent (by weight).
- the supply of plutonium from the fast neutron reactor sector, such as Phénix and Superphénix; the shutdown of Superphénix and slackening-off of demand for uranium have now focused the use of plutonium on the production and consumption of MOX fuel and, in the more distant future, on the supply of a “Generation IV” fast neutron sector if the research underway proves successful.

- a concern for saving natural uranium resources and energy independence; 96 percent of spent fuel is still usable, whereas a future shortage of uranium was envisaged in the long term. It should nonetheless be noted that in the absence of fast neutron reactors, only approximately 25 percent of ENU fuel is likely to be returned to the reactor core, and that current permits allow EDF power plant to actually use 20 percent of it.

- the reduction in ultimate waste, and thus the costs which may partially be brought to bear on future generations.

Conversely, partisans of direct disposal are of the opinion that the economic and ecological advantage has not been demonstrated, considering that recycling leads to high radionuclide emissions into the environment, and that isolating, handling and storing plutonium should be prohibited to avoid any risk of dissemination and proliferation of nuclear weapons.

The criteria for choosing between the two solutions are therefore political, economic and ecological.

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82 1,000 tonnes of spent ENU allows fabrication of 120 tonnes of MOX and approximately 130 tonnes of ERU. Current permits allow EDF to use 1,000 tonnes of ENU, 120 tonnes of MOX and 80 tonnes of ERU each year.

83 For example, the emissions authorized for La Hague are 300 times higher than those of both the Flamanville reactors for tritium released into the sea and almost 1,000 times higher for rare gases released into the air.

84 Inhalation of a few milligrams of plutonium causes death within a few days, and a dose of 0.1mg inhaled (200,000 Bq) is sufficient to cause long-term tumours in the lungs – source: IRSN.
Simplified diagram of the nuclear fuel cycle in France

Fuel fabrication

- Mox fuel
  - \( UO^2 \) + PuO2

- \( UO^2 \) fuel

Storage

- Fast neutron reactors

Enrichment

- \( U_2O_3 \)

Conversion

- Pure natural uranium

Concentration

- Recycled uranium

Mineral ore extraction

- Natural uranium

Reprocessing plants

- Spent \( UO^2 \) fuel
- Spent Mox fuel

Storage

- Fast neutron
- Thermal neutron
- PWR reactors

1 - The different fuel cycles and recycling

For its operations, the existing EDF fleet uses several types of fuel:

- enriched natural uranium (ENU)
- enriched recycled uranium (ERU);
- MOX, a mixture of depleted uranium produced by the enrichment of natural uranium and plutonium from reprocessed of spent fuel.
- The choice between these different types of fuel depends on the prevailing economic climate and the permits issued by the ASN for each nuclear unit, specifying the core management method and certain specific technical procedures (control, protection). At the present time, 22 units out of the 58 reactors are authorized for operation using MOX and 4 units may be operated with enriched recycled uranium.
- The table below shows consumption of new fuel and production of spent fuel from the current fleet of reactors:

<table>
<thead>
<tr>
<th>Year</th>
<th>Enriched Natural Uranium</th>
<th>Enriched Recycled Uranium</th>
<th>MOX</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>N/d</td>
<td>1049</td>
<td>18.5</td>
</tr>
<tr>
<td>2009</td>
<td>1004.7</td>
<td>995</td>
<td>51.6</td>
</tr>
<tr>
<td>2010</td>
<td>981.2</td>
<td>1030</td>
<td>71.9</td>
</tr>
</tbody>
</table>

Source: EDF

After combustion, spent fuel assemblies all contain a mixture of uranium, plutonium, fission products and minor actinides\(^85\). They are first cooled in the power plant pools before being reprocessed or stored depending on the types of fuel concerned (see diagram in Annex 11).

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\(^{85}\) Minor actinides and plutonium are produced by the successive transmutations of uranium, which reacts with the neutrons without fission.
Processing of spent enriched natural uranium (ENU)

At the present time this processing relates to approximately 1,000 tonnes of spent ENU fuel per year. It separates the following:

- recycled uranium (RU), which constitutes most of the material;
- plutonium, which accounts for approximately 1 percent of the material;
- hulls and end caps, which are compacted into packages of ILW-LL waste;
- the rest (approximately 4 percent), comprising fission products and minor actinides; these are mixed with a glass matrix to form packages of high-level radioactive waste (HLW).

This process is scaled to produce the quantity of uranium required each year to produce the MOX used by EDF power plants. Until 2009, only 850 tonnes per year were recycled, enabling 8.5 t of plutonium to be obtained, corresponding to the 100 tonnes of MOX consumed by EDF each year\textsuperscript{86}. Today, the 22 authorized units allow an annual consumption of 120 tonnes of MOX to be envisaged, in line with the contract signed with AREVA in 2010. This plans for recycling of up to 1050 tonnes of ENU fuel per year from 2010 onwards.

Storage of spent MOX

Spent MOX fuel is currently stored, as the flow of plutonium produced by recycling ENU fuel is sufficient to supply EDF power plants, and the residual plutonium in spent MOX fuel cannot be recycled a second time in second and Generation III reactors. This spent fuel could nonetheless constitute a source of raw materials (plutonium) for EDF in the case of the development of a fleet of Generation IV reactors.

Storage of enriched recycled uranium (ERU)

EDF has chosen not to recycle spent ERU fuel as this fuel contains a higher level of uranium-232, an isotope with a half-life of 68.8 years and highly radiotoxic decay products. This makes the recycled uranium unusable in existing power plants. As for MOX fuel, EDF plans to recycle this fuel at a later date to supply a Generation IV fleet.

\textsuperscript{86} With the average plutonium content gradually increased from seven to 8.5 percent from 2007 onwards (known as “MOX parity” management).
Processing and storing recycled uranium (RU)

RU, stored in Pierrelatte, constitutes a reserve of materials for EDF which may be used as a substitute for natural uranium. Recycling this effectively depends on market conditions for natural uranium and the medium and long-term outlook in the market. At the present time, of the 1000 tonnes of RU produced annually by recycling enriched natural uranium (ENU), 400 tonnes are stored and 600 tonnes of RU are re-enriched to produce the 80 tonnes of enriched recycled uranium (ERU) required to supply the four Cruas reactors.

Nevertheless RU contains impurities and uranium-232, making it complicated to use. It is currently converted and enriched in Russia; ERU fuel is fabricated by AREVA at the Romans plant. The contracts in force cover supplies through to 2012. As part of the “recycling processing” agreement signed in 2010, Areva has made a bid to develop a French subsidiary from 2017 onwards. As this subsidiary is not deemed to be competitive by EDF, and as Areva does not wish to make a bid for the 2013-2017 period only, the production of ERU is due to be discontinued in 2012 pending the establishment of a new route.

2 - EDF spent nuclear fuel repositories

Given these levels of processing, the storage of spent fuels, and the fact that these recycling techniques have been implemented only gradually, stocks of spent nuclear fuel have gradually built up.

The status of repositories, presented in the table below, shows in particular that spent enriched natural uranium (ENU) fuels are recycled approximately sixteen years after they are first loaded into the reactor: there are 16,540 tonnes of ENU awaiting recycling, while current level of recycling is 1,050 tonnes per year maximum.87

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87 This figure corresponds to current permits and the EDF contract, which may change in the future, given AREVA’s capacities, totalling 1,700 tonnes per year for recycling and 195 tonnes for the production of MOX.
Breakdown of the stock of nuclear fuel spent or in use\textsuperscript{88} as of 31/12/2010

<table>
<thead>
<tr>
<th>Tonnes</th>
<th>In power plants (pools or reactors)</th>
<th>Waiting at La Hague</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>9010 t</td>
<td>9530 t</td>
<td>18 540 t</td>
</tr>
<tr>
<td>ENU</td>
<td>8100 t</td>
<td>8380 t</td>
<td>16 480 t</td>
</tr>
<tr>
<td>MOX</td>
<td>690 t</td>
<td>900 t</td>
<td>1 590 t</td>
</tr>
<tr>
<td>URE</td>
<td>220 t</td>
<td>250 t</td>
<td>470 t</td>
</tr>
</tbody>
</table>

Source: Cour des Comptes based on the EDF three-yearly report and the flows featuring in EDF internal documents

3 - Management costs

a) Different approaches and applicable regulations:

EDF makes provisions for future expenditure for fuel at the same pace as effective use of this fuel, in other words as it is used in the reactors. This means that transport, recycling, storage and management costs for waste produced by the cycle are already included in the group’s income statement at the time when the spent fuel is removed from the core, according to the principle of tying costs to production.

Applicable regulations\textsuperscript{89} also require the expenditure for all fuel in the back end of the cycle be included in the provisions, from the time when it is placed in the core. This means that future costs for fuel in use but not yet spent must be taken into account in provisions; this part of the provision is not accounted in the income statement but booked to offset a capital asset. Provisions must reflect the costs which should theoretically be taken into account in the event of immediate shutdown of power plants, i.e. with half-spent fuel on average, but having to undergo all the back-end operations in the cycle.

\textsuperscript{88} Fuel is said to be “in use” when it has been placed in the power plant core and “spent” when it is removed from the core. By accounting convention, EDF considers that the power plant core comprises a decreasing share of new fuel and an increasing share of spent fuel, these shares being readjusted each time the core is reloaded.

\textsuperscript{89} The law of 28 June 2006 and more specifically article 1 of the order of 21 March 2007 relating to securing funding for nuclear costs.
Lastly, EDF calculates and includes a “final core provision” (see below), which is amortized for the provisional operational duration of power plants. This represents the back-end expenditure for that part of the fuel which will be in the core but not spent at the time of final shutdown of the power plant, thus constituting an inevitable cost to be included in the plant’s production.

b) Estimation of future costs relating to spent fuel management, not including waste management

On 19 December 2008, EDF and AREVA signed a general agreement, further detailed in a multiyear contract on 12 July 2010. This contract lays down the technical and financial procedures for processing and recycling operations for the period from 2008 to 2012 and specifies the principles which will govern industrial cooperation between EDF and AREVA for the back end of the cycle through to 2040.

EDF gives total gross management costs of €14,386 billion for its spent fuel as of 31 December 2010. These costs include transport, storage and shearing of spent fuel, component separation, hull compacting, vitrification of fission products, RU oxidation and storage of various materials and waste produced during recycling. They also include a R&D flat fee, costs for storing Superphénix fuel, and non-recycled fuels (MOX and ERU) pending an ultimate disposal route. Prudent accounting rules mean that due to the lack of certainty as to the construction of a Generation IV fleet justifying the recycling of spent MOX and ERU fuels, the reference solution for these fuels is disposal without recycling. This entails accounting major costs for “long-term management of radioactive waste”, but lower costs for “spent fuel management” as this covers only investments in storage facilities (pools) and operating costs for these facilities for several decades, pending ultimate disposal.

These costs are calculated on the basis of existing stocks of spent fuel and fuel in use and the long-term cooperation principles to which EDF and AREVA are committed until 2040. The contract with AREVA closely governs unit costs subsequent to 2012 for transport and recycling (shearing, separation and creation of waste packages). After 2012 costs relating to oxidation and storage of recycled uranium (RU) are based on the prudent hypothesis that all recycled uranium is stored and that there is no recycling, even partial recycling into enriched recycled uranium (ERU). The costs are calculated using the hypothesis of a maximum recycling rate based on the existing contract (i.e. 1,050 tonnes of ENU recycled per year).
Lastly, these costs include a contribution to the creation of a new storage pool in La Hague in 2015 to meet the need for a gradual increase in storage capacity there. The EDF-AREVA contract remains vague as to the likelihood of the creation of this new pool. This additional storage capacity is the result of the accumulation of non-recycled fuels (MOX, ERU) and partially recycled fuels (ENU) due to a difference between the “incoming” fuel flow and the recycled fuel flow. 2015 had been set by EDF as the date in its calculations by which the new recycling contract, increasing the flow of recycled ENU from 850 to 1050 tonnes per year, should be signed. In addition, operations have since been carried out to remove certain technical waste from the La Hague pools, and in its future investment plans (cf. chapter V–I: “the extension of the operating life of power plants”) EDF is envisaging “re-racking”\(^\text{90}\) of its power plant pools. This would allow an increase in their capacity so as to be better placed to respond to the changes in spent fuels, and, consequently, delay by several years the problem of saturation of La Hague pools, provided that this operation, which is also costly, is authorized by the ASN.

\(c\) Changes in costs

A review of the changes between 2007 and 2010 of the future costs estimated for fuel management does not identify any drift in costs.

\(^{90}\) i.e. reorganizing the layout of spent fuels by placing them in crates which absorb part of the neutrons, so as to be able to place them closer together and save space.
Changes in gross management costs for spent EDF fuel

<table>
<thead>
<tr>
<th>Gross costs</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>current €, million</td>
<td>16 208.6</td>
<td>13 375.3</td>
<td>13 969.5</td>
<td>14 385.8</td>
</tr>
<tr>
<td>€ million, 2010</td>
<td>16 834.5</td>
<td>13 547.4</td>
<td>14 083.2</td>
<td>14 385.8</td>
</tr>
</tbody>
</table>

Source: EDF

The 2008 agreement specifying a balancing payment of €2,300 million to fund its share of the dismantling of the La Hague facilities released EDF from its commitments in this regard and removed these costs from the amounts it had previously made provision for.

Aside from this, the estimation of costs is rising with inflation and increasing stocks. Recycling costs remain unchanged as they relate to a stock which remains fairly constant.

d) International comparisons

It is difficult to make direct comparisons between countries recycling spent fuel with regard to the prices practiced by AREVA. The method used is not always the same: vitrification in particular seems to be a particular process used by few industrial companies apart from AREVA.

The quantities concerned are not always comparable either. What is more, the La Hague facilities have already been amortized and EDF has already made the balancing payment for the funding of its share of dismantling costs in advance. Consequently, it is difficult to compare the price that has now been negotiated by EDF, based on audited recycling costs, with the price that would be applied by a private company that has to amortize its facilities and fund their dismantling, with a great degree of uncertainty as to the quantities to be processed in the future.

B - CEA fuel management costs

1 - Research reactors concerned by spent fuel management costs

Ever since it was set up, the CEA has constructed and operated over thirty reactors and models using nuclear fuel, for civil and military applications.

Five reactors are still in operation for the requirements of civil research:
OSIRIS: this experimental reactor with thermal power of 70 MW, located at Saclay, has been in operation since 1966. Its operation is due to be halted in 2015. It is used to support the nuclear fleet and to produce radioelements. It used “oxide” fuels until 1997 and has used “silicide” since then.

ISIS: the 700 kW OSIRIS model is also used for training.

ORPHEE: this 14 MW reactor located in Saclay is intended for the production of neutron beams for the requirements of pure research.

CABRI: this 25 MW reactor located in Cadarache enables the effects of an accidental power excursion situation to be reproduced in a fuel rod.

the high flux reactor (HFR): this heavy water-cooled highly enriched uranium reactor with thermal power of 57 MW is operated by the Institut Laue Langevin91 in Grenoble.

In addition, the fuel used by certain halted reactors is still awaiting a definitive solution (recycling or disposal):

Phénix: the fast neutron reactor power plant with thermal power of 563 MW, located on the Marcoule site, which was commissioned in 1973 and has been shut down since 2009, used FNR fuel, which is actually a MOX with high plutonium content.


The CEA also stores spent fuel elements from former civil and military facilities currently being dismantled, in dedicated repositories.

91 The ILL was created in 1967 with the status of a private company under French law. It is managed by three partner countries: France (the CEA and CNRS), Germany and the United Kingdom.
2 - Flows and stocks of the materials in question

The flows of nuclear fuel used today by research reactors (a few hundred kilograms) are nothing compared with the flow generated by the electricity generation fleet (1,200 tonnes), and much smaller than the flows generated at the time when fast neutron reactors were used (several tonnes). OSIRIS and ISIS use an average of 119 kgHM/year \(^92\), while ORPHEE requires 13kgHM per year of aluminide fuel. CABRI will be operated using the same stock of fuel until final shutdown of the facility. The core of the HFR comprises a single fuel element made from a uranium-aluminium alloy in which the mass of the 93 percent enriched uranium is 9 kg. The stocks of spent experimental fuels to be managed also remain limited (except for UOX, MOX and ERU).

<table>
<thead>
<tr>
<th>Inventory of spent experimental fuels</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tonnes of heavy metal (tHM)</strong></td>
</tr>
<tr>
<td>--------------------------------------</td>
</tr>
<tr>
<td>Fuels currently in use in research reactors</td>
</tr>
<tr>
<td>Spent fuels awaiting processing</td>
</tr>
</tbody>
</table>

*Source: ANDRA, national inventory, 2009*

Most of these stocks come from Phénix, i.e. 43 tHM as of the end of 2010, the long-term equivalent of 1350 “cartridges”, 642 of which are to be produced using assemblies that are still in the power plant and 708 of which are spread around several CEA facilities.

3 - Management costs

The most recent CEA three-yearly report summarizes the estimated costs for the management of its spent fuels as shown below.

\(^92\) HM = Heavy Metal.
### Costs for the management of spent CEA fuels

<table>
<thead>
<tr>
<th>Types of fuel</th>
<th>Cost by gross value in current €, million</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Spent fuels which can be recycled in existing industrial facilities and facilities under construction</td>
<td>2009</td>
</tr>
<tr>
<td>Phenix reactor fuels</td>
<td>228.4</td>
</tr>
<tr>
<td>Aluminide fuels from the ORPHEE reactor</td>
<td>201.1</td>
</tr>
<tr>
<td>Silicide fuels from the OSIRIS and ISIS reactors</td>
<td>1.2</td>
</tr>
<tr>
<td>Fuels from the PHEBUS reactor</td>
<td>21.0</td>
</tr>
<tr>
<td>Fuels from the CABRI reactor</td>
<td>2.5</td>
</tr>
<tr>
<td>2. Costs relating to other fuels</td>
<td>35.6</td>
</tr>
<tr>
<td>Oxide fuels s</td>
<td>2.3</td>
</tr>
<tr>
<td>Fuels from general-purpose experimental reactors</td>
<td>33.3</td>
</tr>
<tr>
<td>Removal of Saclay INB 72 fuel</td>
<td>-</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>264</td>
</tr>
</tbody>
</table>

*Source: update of the CEA three-yearly report*

Although these amounts of gross costs are limited compared to other future expenditure for the CEA or EDF, they increased considerably between 2009 and 2010 (up 58 percent in constant euros). This follows on from an internal audit in 2009, the conclusion of which was that the evaluation of the provisions was too optimistic; this was confirmed by an external audit in 2010. The main changes can be explained as follows:

- most of the future costs for reprocessing spent fuel for the CEA relate to fuel from the Phenix reactor, the removal of which to La Hague is due to be discontinued in 2018. Total costs for managing this are estimated at €253 million (€219 million for processing and €34 million for conditioning and storage). Most of the expenditure should be between 2011 and 2021, with operations completed by 2027, 18 years before shutdown of the reactor. This is a much higher unit cost than for reprocessing EDF fuel, due to the low quantities and particular characteristics of the fuel concerned (MOX). Negotiations with AREVA for phasing reprocessing operations were commenced in 2010. The bid put forward 2010 was considerably higher than the elements that emerged from earlier discussions with AREVA. As of the end of 2010, this situation and the appraisal of potential negotiating margins have led to including a revision of + €56.5 million gross, confirmed by the CEA’s statutory auditors.

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93 The contract was signed in November 2011 and is to apply until 31 December 2030.
− for experimental fuels, the amounts have more than doubled, due to the many technical difficulties encountered in the operations underway
− with respect to the removal of waste canisters from Saclay, the original scenario of direct removal of waste has not been confirmed. The reference option is now to carry out sorting on site to reduce the constraints on the processing and storage facilities: this has led to additional costs being included.

——— CONCLUSION – SPENT FUEL MANAGEMENT ———

Future management of spent fuels came to €14.8 billion in gross costs in 2010.

Most of this future expenditure is to be borne by EDF (€14.4 billion) and relates to the management of 18,546 tonnes of ENU, MOX and ERU fuels, located at EDF power plants, or in La Hague, awaiting recycling.

Most of these provisions, comprising the transport and reprocessing costs for ENU fuels, is calculated for precise quantities with unit costs based on current contracts with AREVA: these do not feature any major uncertainties.

The CEA’s costs (€420 million as of the end of 2010) are considerably lower, but often relate to complex work due to the major differences in the materials to be processed. The CEA plans to reprocess a total of 47 tonnes of spent fuel, most of this being Phénix fuel (€253 million). The average cost price is therefore high (€3,800/kgHM, not including long-term waste management costs) and the stability of the estimated costs is quite uncertain (+60 percent between 2009 and 2010).
III - Radioactive waste management

A - Types of waste and management methods

1 - The framework for radioactive waste management

Planning Act no. 2006-739 of 28 June 2006 relating to the sustainable management of radioactive materials and waste defined radioactive waste as “radioactive substances for which no further use is planned or envisaged” and ultimate radioactive waste as “radioactive waste which cannot be treated any further given current technical and economic conditions, including by extraction of the recyclable components or by reducing their pollutant or hazardous nature”. Article 2 of the 2006 law also confirmed the “polluter pays” principle, which stipulates that “producers of spent fuel and radioactive waste shall be responsible for these substances”. The ultimate management of radioactive waste is entrusted to a public industrial and commercial company, Agence nationale pour la gestion des déchets radioactifs (ANDRA, French national radioactive waste management agency), but the producers of waste still retain responsibility.

Law no. 91-1381 of 30 December 1991 relating to research on radioactive waste management entrusted ANDRA with the mission of “listing the condition and location of all radioactive waste on French national territory.” Since 2004, this mission has taken the form of a national inventory of radioactive materials and waste, updated every three years, and is used as the basis of the national radioactive materials and waste management plan drawn up by the French government, also on a three-yearly basis. This document constitutes the benchmark for radioactive waste and materials management strategy.

2 - Classification of radioactive waste

Most radioactive waste results from electricity generation (62 percent of waste by volume), but some also comes from research (17 percent by volume, part of which is linked to research on nuclear power generation), defence activities (17 percent by volume), non-nuclear industry (3 percent by volume), and the medical sector (1 percent by volume).
Radioactive waste management sectors

<table>
<thead>
<tr>
<th>Period / activity</th>
<th>Very short lived period &lt; 100 days</th>
<th>Short lived (SL) hal-life ≤ 31 years</th>
<th>Long lived (LL) hal-life &gt; 31 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>VLLW Very low-level waste</td>
<td>Management by radioactive decay.</td>
<td>Dedicated surface disposal</td>
<td>Recyling</td>
</tr>
<tr>
<td>LLW Low-level waste</td>
<td></td>
<td>Surface disposal (Aube repository)</td>
<td>Except for certain tritiated waste and certain sealed sources.</td>
</tr>
<tr>
<td>ILW Intermediate-level waste</td>
<td></td>
<td></td>
<td>LLW Low-level waste</td>
</tr>
<tr>
<td>HLW High-level waste</td>
<td></td>
<td></td>
<td>ILW Intermediate-level waste</td>
</tr>
</tbody>
</table>

Sectors currently being studied under article 3 of the Planning Act of 28 June 2006.

Source: French national radioactive materials and waste management plan 2010-2012

In general, radioactive waste is classified according to two criteria:

- its level of radioactivity, measured in becquerels. A distinction is made between high-level (HLW), intermediate-level (ILW), low-level (LLW) and very low-level waste (VLLW)

- its lifespan, which corresponds to the rate of radioactive decay over time. The French classification refers to the half-life of elements, i.e. the period of time necessary for their radioactivity to be halved. A distinction is made between very short-lived waste (less than 100 days), short-lived waste (half-life of less than 31 years) and long-lived waste (over 31 years).

The existing sectors enable 89 percent of the volume of waste produced to be disposed of. However, the most radioactive waste does not have a repository in use for the time being, although this accounts for over 99 percent of the total radioactivity of waste.

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94 This total does not take into account certain low-level radioactive waste from the front end of the cycle, notably mining waste and residue (cf. E below)
3 - Ultimate radioactive waste from the nuclear power sector

The ultimate radioactive waste produced by the generation of nuclear power has several sources: the operation of nuclear facilities, their dismantling, the recovery and conditioning of old waste (RCD) and recycled and non-recycled spent fuel.

The precision of future cost estimates varies depending on whether there is currently an ultimate destination (VLLW and LLW-SL/ILW-SL waste) or whether this is still being examined (LLW-LL, ILW-LL and HLW-LL), and is the subject of discussion. The recovery and conditioning of old waste, a concern only for the CEA and AREVA, is a particular case as the related expenditure should gradually decrease and become non-existent in the relatively near future. Lastly, for certain types of particular waste, the processing conditions have yet to be established.

Gross costs relating to the future management of this waste totalled €28.3 billion as of 31 December 2010; 81% of these costs related to EDF.

**Gross costs for the future management of radioactive waste**

<table>
<thead>
<tr>
<th>€ million, 2010</th>
<th>Gross costs as of 31 December 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDF</td>
<td>23 017</td>
</tr>
<tr>
<td>AREVA</td>
<td>2 859</td>
</tr>
<tr>
<td>CEA (civil)</td>
<td>2 403</td>
</tr>
<tr>
<td>ANDRA</td>
<td>83</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>28 362</strong></td>
</tr>
</tbody>
</table>

Source: Cour des Comptes and operators

B - Waste which currently has an ultimate destination

1 - Very low-level waste

VLLW waste comes mainly from the deconstruction of nuclear facilities, and is composed of debris, earth and scrap metal with a low level of contamination, often at levels close to those of natural radioactivity.
In most countries (notably Belgium and the United Kingdom), a large part of this waste would be considered to be non-radioactive, with the existence of a release threshold\textsuperscript{95}. On the contrary, France has chosen to have a specific disposal route for this type of waste since 2003: the very low-level waste repository in Morvilliers (Aube), with total disposal capacity of 650,000 m\textsuperscript{3}. The initial investment for its construction was €40 million. At the end of 2010, after seven years of operation, the centre was 26.8 percent full.

Given the volumes of waste from dismantling, the current capacity of the VLLW repository will not be sufficient: the national inventory forecasts 870,000 m\textsuperscript{3} of VLLW by the end of 2030, which is more than the disposal capacity of the Morvilliers repository. Four options may be envisaged: the extension of the current repository; the construction of a new centre; the establishment of a “release threshold” enabling the use of conventional solutions for this very low-level radioactive waste, or recycling within the nuclear industry: this avenue of thought remains to be examined in depth, and funding for it was allocated by ANDRA as part of the future investment programme\textsuperscript{96}.

The amounts concerned should in any case remain moderate: investment costs (€40 million) and operating costs (€14 million) for the current repository are low compared to the sums planned for the disposal of intermediate- and high-level waste. The only real contingency will be the location of a possible new repository, which would require new candidate municipalities to be found: a delay in this respect could slow down dismantling work on power plants and increase the related costs. This has been the case with the LLW-LL centre, for which delays have caused additional costs for the dismantling of first-generation power plants.

2 - Low- and intermediate-level short-lived waste

Low- and intermediate-level short-lived waste is produced mainly by maintenance operations on EDF, AREVA and CEA nuclear facilities (clothing, tools, filters, etc.) and the operation of these facilities.

There are two repositories for this waste:

\textsuperscript{95} Radioactivity threshold above which waste is considered to be radioactive and subject to specific treatment. This threshold does not exist in France: all waste from INBs must receive specific treatment.

\textsuperscript{96} See chapter VI-I-B-4.
the Manche repository, the first centre in operation (since 1969) has taken in 527,225 m$^3$ of waste. It has been closed since 2003 and has moved into a monitoring phase for a period of 300 years, established by decree.

- the Soulaines-Dhuys repository in Aube, built in 1992 for an initial investment of €221 million. It was designed to hold 1 million cubic metres of waste, and was full to 24.3 percent of its disposal capacity at the end of 2010, after 18 years of activity.

According to ANDRA, the forecasting carried out as part of the national inventory in 2009, based on data supplied by the producers, shows that the disposal capacity available at the end of 2007 at the Soulaines repository is sufficient to accommodate the waste which will be produced by the operation and dismantling of the facilities authorized as of the end of 2007, including the Flamanville EPR. This scenario is based on the hypothesis of continuing to process spent fuel and an operating period of 40 years for nuclear power plants.

However, should the operating period of power plants be extended to 50 years, the capacity of the Soulaines LLW-SL/ILW-SL repository would apparently not be fully sufficient given the waste produced by ten additional years of operation. The creation of a new repository or an extension of the capacity of the current repository could then prove necessary.

3 - VLLW and LLW-SL waste processing costs

The operation of these centres has already been taken into account in main operators’ costs, in the total annual amount of €58.2 million, split between the operators according to the quantities of waste deposited.

Disposal costs amount to approximately €450/m$^3$ for VLLW, including the contribution to costs for monitoring the centre after its closure, and approximately €3,000 for LLW. For the Manche repository, which has been closed since 2003, the amounts cover monitoring costs, work to preserve the overburden and site-related taxes. A similar system will be adopted on closure of the Soulaines repository.

97 Unless optimizations are carried out in the meantime with respect to the sorting, processing and conditioning of waste.

98 Not including initial investment costs and costs for closure and monitoring, as opposed to the costs for disposal of VLLW dealt with above.
2010 revenues for ANDRA repositories

<table>
<thead>
<tr>
<th></th>
<th>Revenues</th>
<th>EDF</th>
<th>AREVA</th>
<th>CEA</th>
<th>Other</th>
<th>ANDRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morvilliers VLLW centre</td>
<td>14 087</td>
<td>2 731</td>
<td>4 748</td>
<td>5 408</td>
<td>1 200</td>
<td>0</td>
</tr>
<tr>
<td>Manche centre</td>
<td>6 836</td>
<td>3 415</td>
<td>1 308</td>
<td>1 953</td>
<td>0</td>
<td>160</td>
</tr>
<tr>
<td>Soulaines centre</td>
<td>37 319</td>
<td>20 306</td>
<td>4 033</td>
<td>12 879</td>
<td>48</td>
<td>53</td>
</tr>
<tr>
<td>Total</td>
<td>58 242</td>
<td>26 452</td>
<td>10 089</td>
<td>20 240</td>
<td>1 248</td>
<td>213</td>
</tr>
</tbody>
</table>

Source: ANDRA

C - Waste without an ultimate destination

1 - Low-level long-lived waste (LLW-LL)

According to the national inventory of radioactive materials and waste, in 2030, low-level long-lived waste (LLW-LL) will account for 6.75 percent of the volume but only 0.007 percent of total radioactivity of waste. This waste comprises mainly radiferous waste (containing radium) and graphites, most of the latter being produced by EDF’s operation of old graphite-moderated gas-cooled nuclear power plants. The CEA also has a few reactors that contain graphite.\(^99\)

ANDRA had estimated costs for the construction and operation of this repository at €690 million\(_{2005}\) for 190,000 m\(^3\) of waste packages. The project for the repository consisted of disposal beneath a shallow, remodelled overburden in a layer of clay. The cost of the project for the repository is based on a study by ANDRA conducted in March 2005 which can be broken down into €423 million\(_{2005}\) for graphite waste and €267 million\(_{2005}\) for radiferous waste. These costs include investment in and operation of the repository for 20 years and monitoring it for 30 years. In the summer of 2009, the project was postponed, due to difficulties encountered in the site selection procedure for the future repository.

\(^{99}\) A significant proportion of this LLW-SL does not come from the nuclear power industry, but from other industrial activities: for instance, Rhodia produces 33% of radiferous waste.
This waste must nonetheless be the subject of a specific project, due to its long radioactive life. ANDRA’s budget for waste and research on waste amounts to €5 million per year, this amount being covered by producers of waste.

At the end of the 2010 financial year, the future gross costs of LLW-LL totalled €806 million (€690 million). All of these costs feature in the EDF accounts, with the amount of €727 million earmarked for the long-term management of its LLW-LL, mainly from the graphite-moderated gas-cooled sector.

However, the calculation of future costs is based on repository design. This could change, given the research programmes being conducted on the management of this waste. ANDRA is due to supply a report on the subject in 2012, having studied various scenarios. In any event, the amount provisioned will require adjustment in the light of ANDRA’s new project, taking into account new optimizations and considerations, without it being possible to say for the time being whether or not the cost will rise or fall.

2 - Long-lived intermediate and high-level waste (ILW-LL and HL)

a) The waste under consideration

*HL waste*: irradiation of nuclear fuel assemblies in reactors causes radioactive elements to be formed (fission products and minor actinides). This so-called “high-level” (HL) waste can be separated from the rest of the spent fuel (uranium and plutonium, which are recyclable materials) and from the metallic structure of the assemblies: this reprocessing is carried out at La Hague.

At present\(^{100}\), spent MOX fuel (112 tonnes used in 2010) and ERU (72 tonnes used in 2010) are not reprocessed. However, spent ENU fuels (981 tonnes loaded in 2010) are reprocessed, enabling the extraction of 96 percent of recyclable materials (uranium and plutonium) and 4 percent HL waste (40 tonnes). This waste is packaged in a glass matrix and

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\(^{100}\) Source: EDF and the report dated July 2010 by the French high committee for transparency and information on nuclear safety, *Opinion on transparency in the management of radioactive materials and waste produced at the different stages of the fuel cycle*, p. 14.
poured into standard packages. The reprocessing of one tonne of spent ENU fuel produces a total of 0.13 m³ HL waste.

**ILW-LL waste**: long-lived intermediate-level waste (ILW-LL) comes from three sources. These are: the metal structures of fuel assemblies when they are reprocessed, the dismantling of certain components of nuclear facilities exposed to radioactive rays and some operating waste, in particular from nuclear power plants and the La Hague reprocessing plant.

Annually, at the end of the financial year, the producers of HLW and ILW-LL (EDF, the CEA and AREVA) evaluate the quantity of “committed” waste, i.e. waste that has already been produced and waste that will be produced by dismantling operations on existing nuclear facilities and the reprocessing of the fuel loaded into reactors\(^1\). As of 31 December 2010:

- the inventory of waste, not including non-reprocessed spent fuel, destined for direct disposal, showed a total of 62,145 m³ of ILW-LL and 4,730 m³ of HLW
- with respect to non-recyclable spent fuel in existing facilities and those under construction, EDF reports 2,241 tonnes of assemblies, mainly MOX, enriched recycled uranium (ERU), fuels from Superphénix and Brennolis, plus 38 m³ of spent fuel from the CEA.

### Inventory of ‘committed’ HLW and ILW-LL as of end 2010, including spent fuel

<table>
<thead>
<tr>
<th></th>
<th>EDF</th>
<th>CEA-civil</th>
<th>AREVA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>ILW-LL</td>
<td>36 141</td>
<td>16 080</td>
<td>9 924</td>
<td>62 145</td>
</tr>
<tr>
<td>HLW</td>
<td>4 368</td>
<td>175</td>
<td>187</td>
<td>4 730</td>
</tr>
<tr>
<td>Spent fuel</td>
<td>2 241 t</td>
<td>38</td>
<td>0</td>
<td>&gt;2 200 t</td>
</tr>
</tbody>
</table>

*Source: Cour des Comptes, operators*

\(^1\) Approximately 90 percent of HLW and ILW-LL comes from the nuclear power industry and research, the rest from defence activities.
Future changes to this inventory depend on the commissioning of new nuclear facilities which will need dismantling (future EPRs for EDF, new research reactors for the CEA), the operation of current and future facilities\textsuperscript{102}, loading of new fuel into the reactors\textsuperscript{103} and changes in the conditioning of waste already produced or to be produced in the future.

For an operating period of 40 years for the existing nuclear fleet, EDF forecasts total production of approximately 6,000 m\textsuperscript{3} of HLW, 38,000 m\textsuperscript{3} of ILW-LL and 5000 tonnes of spent fuel (MOX, ERU, Brennitis and Superphénix). All things being equal, an extension of this operating period to 60 years would increase these volumes by 3,000 m\textsuperscript{3}, 4,000 m\textsuperscript{3} and 4000 tonnes respectively\textsuperscript{104}.

\textit{b) The solution envisaged: deep geological disposal}

The solution for disposal of HLW and ILW-LL envisaged in most cases internationally and in Europe is disposal in a deep geological layer\textsuperscript{105}. This is also the chosen solution in France, following period of research and national consultation leading to the adoption of the Planning Act of 28 June 2006, relating to the management of radioactive materials and waste: this confirms the choice of this solution for the most radioactive waste.

\textsuperscript{102} For instance, AREVA’s UP2 800 and UP3 (La Hague) plants and the Melox plant produce approximately 130 m\textsuperscript{3} of ILW-LL per year, provision for the long-term management costs of which is made as and when this waste is produced.

\textsuperscript{103} Currently, the CEA uses approximately 150kg of fuel each year. EDF produces 136 m\textsuperscript{3} HLW and 164 m\textsuperscript{3} ILW-LL per year.

\textsuperscript{104} The quantities produced over 20 years are not always equal to half of what is produced over 40 years, because these quantities also include waste produced by dismantling, RCD and the reprocessing of spent fuel from reactors other than the 58 pressurized water reactors in the current fleet.

\textsuperscript{105} This solution is not however free from scientific uncertainties or difficulties in implementation (cf. below d). This state of affairs, which also involves the requirement of reversibility, has led some parties to suggest temporary safe subsurface disposal, which they deem to be less expensive in the short term and better placed to enable the recovery of the waste when a definitive solution is found.
The legal framework for deep geological disposal in France

The law of 30 December 1991 relating to research on the management of radioactive waste made provision for research into three means of managing long-lived radioactive elements: deep disposal, separation/transmutation\(^{106}\) and long-term surface disposal.

To this end, the decree dated 3 August 1999 authorized ANDRA to operate an underground laboratory in Bure (on the border between Meuse and Haute-Marne) in order to study the deep geological formations where radioactive waste could be disposed of.

Article 6 of the law of 28 June 2006 now specifies that “ultimate radioactive waste for which, for reasons of nuclear safety, surface or near surface disposal is not appropriate” is destined for deep disposal.

Article 12 of this law requires that deep disposal should be reversible for at least 100 years: this corresponds to the operating period of the repository.

The 2006 law specifies the role and broad responsibility of ANDRA as designer and operator of the future repository. Article 14 of the 2006 law requires that the Agency “design, produce and manage radioactive waste storage and disposal repositories” and “carry out all necessary studies to this end”. With respect to finance, this article also specifies that ANDRA “should propose to the Minister of Energy an evaluation of the costs relating to the implementation of long-term management solutions for long-lived high and intermediate-level waste according to its nature”: the minister has the competency to finalize the evaluation of these costs on the basis of the operators’ comments and the opinion of the ASN.

This repository should be used for around one hundred years. The operating chronology of the repository chosen by the operators plans first to dispose of “cold” HLW (between 2026 and 2035) and ILW-LL (between 2026 and 2077) from the three operators. “Hot” HLW (between 2078 and 2112) and spent fuel assemblies (between 2113 and 2124) produced more recently will be disposed of in the second half of the centre’s operations. The repository will be in operation for a total of approximately 120 years, including the initial construction and closure phases.

\(^{106}\) Transformation of certain radioactive elements in the reactor to reduce their harmfulness and lifespan.
c) The uncertain cost of deep geological disposal

- **Costing history: broadly agreed on but dated**

The evaluation of the cost of deep disposal carried out by ANDRA in 2003 (based on the technical concepts of 2002) took into account several scenarios, for costs ranging between €15.9 and €55 billion\(^{2002}\). Scenario S1a took the hypothesis of reprocessing all spent fuel (ENU, ERU and MOX) as well as the disposal of ultimate waste resulting from reprocessing (minor actinides and fission products). It therefore excluded any direct disposal of fuel assemblies. Scenario S1b planned to reprocess only ENU fuels and dispose directly of other spent fuels. Scenario S2 planned to end all reprocessing in 2010: this therefore involved direct disposal of all spent fuel assemblies, even those using natural uranium.

**ANDRA costing scenarios in 2003**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Hypotheses</th>
<th>estimate € billion(^{2002})</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1a</td>
<td>“100% reprocessing”</td>
<td>15.9 – 24.3</td>
</tr>
<tr>
<td>S1b</td>
<td>Reprocessing spent ENU fuels and direct disposal of other fuels (in particular MOX)</td>
<td>20.9 – 32.3</td>
</tr>
<tr>
<td>S2</td>
<td>Reprocessing halted in 2010, direct disposal of spent fuels</td>
<td>33.2 – 55</td>
</tr>
</tbody>
</table>

*Source: ANDRA*

These evaluations were used as the basis for the costing process carried out in 2005 by a working group gathered under the aegis of the Direction générale de l’énergie et des matières premières (DGEMP, General directorate for energy and raw materials, now DGEC) composed notably of ANDRA and the main producers of waste (EDF, AREVA and the CEA).

Based on the low-end estimate in scenario S1a (€15.9 billion), requirements (disposal log, inventory) expressed by the producers in the industrial scenario (IS) and a risk analysis (costs and opportunities), the working group determined a “reasonable estimate range for the evaluation of storage costs” of between €13.5 and €16.5 billion\(^{2002}\)\(^{107}\).

\(^{107}\) The lower limit of the range, calculated using the producers’ costing, corresponds to taking 5 percent of production contingencies into account, plus a margin for risks and opportunities. The upper limit is calculated using ANDRA’s costing, taking 20
Within this range, the producers took into account a reference cost of €14.1 billion\textsubscript{01/2003} (i.e. €16.5 billion\textsubscript{12/2010}), €2.3 billion of which corresponded to construction contingencies as well as risks and opportunities. This costing, based on the “ultimate” inventory\textsuperscript{108}, is presently used by operators to calculate future costs and provisions for the disposal of HLW and ILW-LL, taking into account only the waste produced and “committed” on the date of calculation.

It should be noted that this figure (€14.1 billion\textsubscript{01/2003}) is lower than the bottom end of the least expensive ANDRA scenario in 2003 (€15.9 billion\textsubscript{2002}).

- **Calculation of long-term management costs for ILW-LL and HLW for each operator**

The order of 21 March 2007 established a reference list according to which the long-term management costs for packages of radioactive waste should include the cost of transportation of waste packages to the repository, in addition to disposal costs (studies and research, construction, operation and closure of the repository).

When estimating the relevant costs, EDF, the CEA and AREVA make a distinction between fixed costs, which do not depend on the quantity of committed waste, and variable costs. Fixed costs are shared between the producers of waste using an apportionment factor\textsuperscript{109} determined in 1999 to allocate ANDRA’s research costs. Variable costs are specific to each category of waste (ILW-LL, “hot” HLW and “cold” ILW) and depend on the inventory committed as of the end of 2010.

AREVA and the CEA apportion fixed disposal costs (initial investment, taxes and duties, etc.) between the different types of waste according to the proportional share of each type of waste in the total of variable costs. At the end of the day, they retain only that part of these total costs (shared variable and fixed costs) that corresponds to the quantity of waste committed at the end of the financial year with respect to the total inventory. By doing so, they potentially book only part of the fixed costs incumbent on them. Inasmuch as the CEA and AREVA’s percent of production contingencies into account as well as all risks identified by the 2005 working group, without a parallel estimate for opportunities.

\textsuperscript{108} i.e. all the waste which will be produced by the fleet over a period of 40 years.

\textsuperscript{109} In turn, this ratio is the result of considerations relating in particular to the waste inventory of each producer. It is 78 percent for EDF, 17 percent for the CEA and five percent for AREVA.
waste is almost all committed, however (see above), this calculation method does not present any major drawback in terms of cost estimates.

Long-term management costs for HLW and ILW-LL and spent fuel as of 31 December 2010

<table>
<thead>
<tr>
<th>€ million\textsubscript{2010}</th>
<th>EDF</th>
<th>AREVA</th>
<th>CEA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total costs as of 31 December 2010</td>
<td>19 791</td>
<td>1 069</td>
<td>1 555\textsuperscript{110}</td>
<td>22 415</td>
</tr>
<tr>
<td>- including disposal of HLW and ILW-LL</td>
<td>12 507</td>
<td>942</td>
<td>1 355</td>
<td>14 804</td>
</tr>
<tr>
<td>- including direct disposal of spent fuel</td>
<td>5 257</td>
<td>0</td>
<td>0</td>
<td>5 257</td>
</tr>
<tr>
<td>- including transport</td>
<td>879</td>
<td>108</td>
<td>58\textsuperscript{111}</td>
<td>1 075</td>
</tr>
</tbody>
</table>

Source: Cour des Comptes, operators

EDF, the main producer of HLW and ILW-LL, is also the leading funder of the deep repository: EDF’s share (€19,791 billion\textsubscript{2010}) covers almost 90 percent of total costs. The cost borne by EDF in 2010\textsuperscript{112} was higher than the estimated €14.1 billion\textsubscript{2003} earmarked in 2005 for the ultimate disposal project (€16.5 billion\textsubscript{2010} with 2 percent inflation per year). EDF now books €6.3 billion\textsubscript{2010} for the long-term storage and direct disposal of certain spent fuel assemblies (MOX, ERU, Superphénix and Brennilis): this corresponds to ANDRA scenario S1b in 2003 and is considerably more expensive than scenario S1a, which was used as the basis for the calculation of the €14.1 billion\textsubscript{2003} estimate.

As of 31 December 2010, approximately 75 percent of the HLW\textsuperscript{113} (except for direct disposal of spent fuel) planned for the repository had been produced. However, the producers of waste have already booked €14.9 billion in gross costs for the disposal of this waste, i.e. 90 percent of the total 2005 estimate (€16.5 billion\textsubscript{2010}). This higher proportion can be explained by the fact that provision is made for fixed disposal costs as soon as the first waste is produced: subsequent waste does not therefore affect fixed disposal costs.

\textsuperscript{110} €76 million (including €2 million for transport) corresponding to the long-term management of the 1,000 m\textsuperscript{3} of ILW-LL resulting from dismantling must be added to this figure. Contrary to regulations (order of 21 March 2003), the CEA books these costs in its provisions for dismantling.

\textsuperscript{111} It would appear that this sum of €58 million covers all transport costs (civil waste including ILW-LL from dismantling and military waste).

\textsuperscript{112} This is the case even though not all of the waste has been committed.

\textsuperscript{113} Since HLW is over ten times more expensive to dispose of than ILW-LL, the impact of the latter may be disregarded.
• **Changes in costing**

**Minimal update to the 2005 IS by ANDRA**

Without changing the technical concepts, ANDRA has updated the lower limit (€13.5 billion\textsubscript{2002}) of the 2005 costing, using an updated inventory of HLW and ILW-LL\textsuperscript{114}, taking into account an extension of the operating life of the repository (from 105 to 123 years) and taking a rate of inflation for the cost of works of some 4 percent, corresponding to the changes in INSEE construction and public works indexes\textsuperscript{115}. This results in a total gross cost of €20.8 billion\textsubscript{2010}.

To transpose the estimate of €14.1 billion\textsubscript{2003} to the economic conditions of the year under consideration, the producers use inflation rates which are well below those used by ANDRA. EDF takes a regular, conventional inflation rate of 2 percent\textsuperscript{116}, whilst AREVA and the CEA use the actual inflation rates.

**The ANDRA 2009 dossier**

In 2009, the DGEC convened a new working group to re-evaluate deep disposal costs. In this setting and in keeping with legislation, ANDRA, which is in charge of future operation of the repository, sent the producers a new design dossier and a new estimate (known as “IS 2009”) for the cost of deep disposal in the amount of €33.8 billion\textsubscript{01/2008} (i.e. €35.9 billion\textsubscript{2010}).

According to ANDRA, one development since the 2002 concept (which led to the IS 2005 costing) is that the 2009 dossier includes technical changes aimed at taking better account of safety and reversibility imperatives. The costing is also specified and more realistic as it takes into account experience feedback (excavation rate, maintenance and regeneration rates) and more cautious, as the

\textsuperscript{114} The inventory of HLW has increased by 21 percent and that of ILW-LL by 15 percent, notably due to the management methods for non-fully-spent fuels being taken into account (the last cores and management reserves) and for the operation and dismantling of the Flamanville EPR.

\textsuperscript{115} Between January 2001 and January 2011, the INSEE index of construction costs (ICC) increased by an average of 3.3 percent per year, the building index (BT01) by 3.7 percent and the TP01 index by 4 percent per year. Between 2004 and January 2011, the TP05a (conventional underground works) and TP05b (TBM underground work) indexes increased by four and 3.7 percent per year respectively.

\textsuperscript{116} For EDF, costs other than for disposal are in the majority (60 to 70 percent of the total) and are increasing no faster than the conventional inflation rate of two percent, which makes it possible for the rate of two percent to be taken as representative of the average change in disposal costs.
The contingency rate has been increased (often doubled, from 5 to 10 percent). Lastly, approximately 60 percent of the difference from the 2005 costing is explained in terms of methods and scope (which are otherwise identical to those used to update the 2009 costing): increases in the inventory, extension of the operating period, taking into account changes in unit costs, ancillary activities of ANDRA and the resulting effects on taxes and insurance.

Concepts from the ANDRA 2009 dossier including design, reliability and reversibility options for disposal have been submitted to the ASN. In June 2011, the ASN estimated on this basis that the disposal was feasible in terms of the conditions of reliability, reversibility and fire risk control.

**Nuclear operators’ alternative project: STI**

The producers disputed this evaluation carried out by ANDRA in 2009 and presented their own concept (known as “STI”), estimated at €14.4 billion. This is based on an inventory similar to that of the ANDRA 2009 dossier but which uses specific cost bases. This project has not been submitted to the ASN or validated by it. Consequently it does not have the same weight as the dossier and costing established by ANDRA, notably in terms of safety, reliability and reversibility.

For instance, in its IS 2009 dossier, ANDRA prudently includes in its new concept only those optimization avenues examined by the DGEMP 2005 working group which have been validated by experiments in the Bure underground laboratory. The studies and research conducted by this laboratory provide ANDRA with particular expertise in determining the realistic nature of certain technical options. Beyond these proven optimizations, ANDRA has not costed the other risks and opportunities.

Conversely, the producers’ STI costing includes all the technical optimizations identified by the 2005 working group, as well as the experience feedback from the three nuclear operators in their respective lines of business. However, it does not allow for a margin to cover production contingencies and project risks.

It can be therefore be seen that IS 2009 and STI are based on partly different concepts:

- the length of high-level cells: 40 metres for ANDRA and three times as long for the producers
− gallery architecture: dual-tube for ANDRA, single-tube for the producers, with an impact on fire risk management and the volumes excavated

− gallery digging method: progressive with a roadheader for ANDRA, TBM excavation for the producers, with uncertainties as to the behaviour of the clay

− the general architecture of the site: compact with right-angle intersections for ANDRA, more extensive for the producers with wide, curved galleries and spaced shafts

− the direction of the disposal cells: depending on geomechanical considerations for ANDRA, indifferent for the producers.

The difference between the two costings concerns investment costs (€14.6 billion compared to €5.6 billion), operating costs (€8.3 billion compared to €3.5 billion), administrative and design costs (€2.8 billion compared to €0.8 billion), taxes, duties and insurance (€8.1 billion compared to €3.7 billion). For certain lines of expenditure, the difference is mainly due to what is included in the assessment: project owner and project management costs, regeneration and maintenance costs, taxes, duties and insurance are calculated wholly or partially depending on the investment base.

According to the producers, if ANDRA’s costing (€35.9 billion, not including removal costs) were to be taken as definitive by the authorities, EDF’s provisions (discounted value) for deep disposal would increase by €4 billion, those of the CEA by €0.7 billion and AREVA’s by €0.5 billion.

An industrial scenario for total reprocessing of spent MOX and ERU that differs from the accounting process specified in legislation

In its 2003 dossier, ANDRA costed scenario S1b, the scenario that involves direct disposal of spent MOX fuel assemblies. Its “2005 dossier” also showed the feasibility of direct disposal of spent fuels in Bure argillite. Subsequently, the 2006 law opted for “reduction of the quantity [...] of radioactive waste [...] notably by processing spent fuel.” This industrial approach of “processing everything” in keeping with the choice of scenario S1a in 2003 has since been reflected in work done by ANDRA. As the ASN notes in its review of ANDRA’s “2009 dossier”, the inventory does not take into consideration direct disposal of spent

117 Source: EDF, AREVA, Synthèse de présentation du stockage industriel (STI) des exploitations nucléaires, October 2010.
fuels, mainly MOX. More generally, the technical disposal concepts studied and costed by ANDRA concern the disposal of ultimate waste (minor actinides and fission products) after reprocessing spent fuel, and not the disposal of fuel assemblies themselves\textsuperscript{118}.

For EDF, the reference industrial solution for the management of spent MOX and ERU fuels\textsuperscript{119} is deferred reprocessing, with the use of plutonium and depleted uranium as fuel in Generation IV reactors. However, the existing facilities do not allow the recycling of MOX on an industrial scale, in the absence of Generation IV reactors. In its accounts therefore, pursuant to legislation, EDF uses\textsuperscript{120} the hypothesis of direct disposal (without reprocessing) of spent MOX fuel to calculate its future costs and provisions, whereas the deep repository is not currently technically designed to accommodate such waste.

The most recent costing for the cost of this direct disposal of MOX is that carried out by ANDRA in its 2003 dossier (scenario S1b). From this, as of 31 December 2010, EDF deduces costs amounting to €5.2 billion\textsubscript{2010} for the disposal of 2,241 tonnes of spent fuel. It is not however certain that this amount covers the major works (such as the dimensions of the adit) required for the direct disposal of spent fuel. To these disposal costs EDF adds the cost of long-term storage\textsuperscript{121} of these fuels in the amount of approximately €1.1 billion\textsubscript{2010}, i.e. a total of €6.3 billion\textsubscript{2010} in gross costs.

Given the changes in design and costing that have affected scenario S1a since 2005, the use of costings for scenario S1b to calculate future costs for direct disposal of MOX will probably not reflect the state of the art in terms of deep disposal. In addition, this costing is all the more subject to discussion in that it is based on a hypothesis which is not envisaged in current projects.

\textsuperscript{118} The two objects have quite different characteristics: a package of fuel assemblies weighs several tonnes; a universal canister for vitrified waste (CSD-V) weighs 400 kg.
\textsuperscript{119} In smaller quantities, this management strategy also concerns spent fuels from the Superphénix and EL4 (Brennilis) reactors.
\textsuperscript{120} Article 5 of the 2006 law: “Ultimate radioactive waste is radioactive waste which cannot be processed in existing technical and economic conditions, notably by means of extraction of its usable component or by reducing its pollutant or hazardous nature.”
\textsuperscript{121} EDF plans to dispose of spent MOX fuel assemblies (and similar) between 2113 and 2118.
d) International comparisons

Apart from a repository for military waste in the United States, no deep-disposal repositories are currently in service. The planned American repository at Yucca Mountain which was to be the first to be commissioned (in 2017) was suspended in 2009. Except for the American project, the Finnish and Swedish repositories are in principle the furthest forward, since they are due to be commissioned between 2020 and 2025. The lack of progress on certain projects (Switzerland, Japan) and others that have been halted pending fresh scientific expert appraisals (Germany, United States) sometimes means that it is not possible to know which disposal hypotheses will finally be adopted; the projects examined are very diverse in nature.

There are two major types of disposal techniques for HLW and ILW-LL: direct disposal of spent fuel assemblies and disposal of waste from spent fuel reprocessing. It is generally accepted that the second type of disposal is the least expensive122 due to the smaller quantities of waste to be disposed of. However, this incurs spent fuel reprocessing costs which are not borne by countries that have chosen direct disposal. The Swedish, Finnish and American projects are “direct disposal” whereas the French, Belgian123, British and Japanese projects have opted for “disposal after reprocessing”. In Germany, due to reprocessing being discontinued in 2005, the project must be designed for the disposal of both fuel assemblies and waste from the reprocessing of these spent fuels. More specifically, in the case of disposal after reprocessing, it is sometimes uncertain whether the repository will accommodate ILW-LL in addition to HLW (Japan, Belgium).

Furthermore, the geological environments selected are not all the same: disposal in clay is favoured in France, Switzerland124 and Belgium, whereas Germany has opted for salt, the United States for tuff and Sweden and Finland for granite.

122 In clay, direct disposal (without reprocessing) is twice as expensive as disposal following reprocessing, for equivalent amounts of electricity generated.
123 Despite this, Belgium has suspended reprocessing of its spent fuel.
124 Switzerland is also conducting research on granite.
Moreover, some projects incorporate the requirement of reversibility\textsuperscript{125} on shorter and longer timescales: 50 years in the United States after 30 years of filling; at least 100 years in France after commencement of disposal; during the period of operation (approximately 100 years) in Belgium; 500 years proposed by the German Ministry of the Environment.

Lastly, although fixed costs (studies, research, excavating access shafts and main tunnels, closing and monitoring) are high, the volume of waste to be disposed of has a major impact on the total cost. This volume depends on the size of the each country’s nuclear fleet.

\textbf{International comparisons of deep disposal projects}

<table>
<thead>
<tr>
<th>Type of disposal</th>
<th>Reversibility</th>
<th>In reactor-years (1)</th>
<th>Cost (2) € billion\textsubscript{2010}</th>
</tr>
</thead>
<tbody>
<tr>
<td>France (ANDRA costing)</td>
<td>Required by law: at least 100 years</td>
<td>1758 (70 reactors 58 of which are in operation)</td>
<td>16.5 (IS 2005) 36 (IS 2009)</td>
</tr>
<tr>
<td>Japan</td>
<td>Taken into account in safety standards</td>
<td>1494 (60 reactors 54 of which are in operation)</td>
<td>30 (3) (1000 ¥ = €9.77)</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>Under discussion</td>
<td>1476 (45 reactors 19 of which are in operation)</td>
<td>16.3 – 37.2 (4) (£1 = €1.16)</td>
</tr>
</tbody>
</table>

\textit{Source: Cour des Comptes, IAEA, NDA, NUMO}

(1) the number of reactor-years enables the volume to be disposed of to be estimated
(2) tax and duty related costs are not reprocessed
(3) Source: Nuclear Waste Management Organization (NUMO). It should be noted that the Japanese project allows for disposal of waste produced only until 2020 (whereas the French project includes the ultimate waste inventory).
(4) depending on the type of rock in which disposal is carried out, according to the NDA (nuclear decommissioning authority). It should be noted that the British project also allows for the disposal of some types of LLW-LL.

\textsuperscript{125} The distinction between reversibility and recoverability is not clear or commonly agreed on. According to the NEA (Nuclear Energy Agency), reversibility refers to the decision-making process during the course of the project. It involves the disposal process allowing sufficient flexibility to be able, if necessary, to reverse or alter one or more decisions taken, at a later date. Recoverability refers to the technical capacity to recover waste which has been disposed of.
As with any international comparison, the financial data relates to a specific social, economic, geological and technical situation in each country, with differing requirements in terms of reversibility, exchange rate variations, tax and duty burden, and types of rock available for storage. Furthermore, some of the estimates are dated and do not include the same types of expenditure (transport, R&D costs); they are based on concepts which are subject to change, making comparisons difficult. The scopes of the projects examined are therefore not identical.

In terms of the volume of waste and type of disposal (reversible or non-reversible, direct disposal or disposal after reprocessing) – the criteria that structure the issue the most – the French project is relatively close to those of the United Kingdom and Japan. These two projects are however at a much less advanced stage than the French project.126

The operators have had a comparative study carried out by a private consultancy. This study, submitted in 2010, does not examine the Japanese and British projects and shows costs that are considerably lower than those put forward by ANDRA. It focuses on direct disposal projects for spent fuel; this involves complex reprocessing in order to reach figures that are comparable to those of the French estimate. It emphasizes the stability of the estimates of countries considered to be the most advanced (Sweden, Finland and the United States) as opposed to the increase in ANDRA’s IS 2009 estimate. However, the validity of this observation has since been called into question by the halting of the American Yucca Mountain project127 and by the request made by the Swedish radiation protection authority to revise the disposal estimate upwards by some 20 percent in October 2011 (€8.6 billion in October 2011 for 382 reactor-years).

e) The project and costing are both set to change

Under the 2006 law, the Minister of Energy is to finalize the evaluation of project costs prior to the public debate, before planning

126 For the other project, the estimates are very varied. In the United States (3,603 reactor-years), the cost of the project is estimated to be $96.2 billion, $64.7 billion of which is for disposal itself. The Belgian project (240 reactor-years) is estimated at some €3 billion.

127 Announced in 2009, this took place in March 2010 with the withdrawal of the Department of Energy’s application, after over $15 billion having been spent since 1983.
permission for the creation of the repository is applied for; this is to be examined in 2015.

In the nearer future, the group entrusted with project management by ANDRA was supposed to be suggesting a new costing around September 2012, following draft studies. According to ANDRA, this costing will itself have a 25 percent margin of uncertainty downwards and 50 percent upwards. This will be discussed in the ANDRA and operators’ working group, coordinated by the DGEC.

Generally speaking, for ANDRA, the architecture of the repository as presented in the 2009 dossier is not definitive. The repository is designed to operate for at least 100 years (the minimum legal duration for which reversibility must be ensured), allowing technical progress and the validation of processes carried out in the underground laboratory to be taken into account as they occur.

More specifically, as far as reversibility is concerned, the ministerial order establishing the cost evaluation cannot take fully into account the requirements relating to this aspect of disposal, in that according to article 12 of the 2006 law, the conditions of reversibility will not be determined by law until after 2015.

The extension of the operating period of the Bure laboratory could also have an indirect impact on the overall disposal cost, which includes research and study costs. ANDRA applied for permission to operate the laboratory until 2030; this permission was granted by a decree published on 20 December 2011, and does not rule out a further extension, if required by study and research work.

In addition, ANDRA’s particular tax position due to the status of the future repository as an INB has not yet been determined. The tax in addition to the INB tax known as the “disposal” tax calls for coefficients to be set by Council of State decree after having gathered the opinions of regional authorities.

Lastly, changes in regulations or economic and technical conditions could lead to certain radioactive substances being classified as waste or being removed from the list of waste; this would alter the volume and possibly the nature of disposal.

**D - Recovery and conditioning of old waste (RCD)**

The production of certain types of waste results from operations known as “recovery and conditioning of old waste” (RCD). This is old
waste from the reprocessing of spent fuel or other processes and operating waste, in liquid or solid form, of all types (from VLLW to HLW). Pending a conditioning route, these were stored provisionally in various facilities and containers (silos, pits and canisters).

The payment of balancing payments in 2005 and 2008 (cf. Annex 13 on balancing payments) enabled operators to clarify responsibilities and EDF to be fully released from its responsibility as regards RCD; the responsibility for the long-term management of waste from RCD has not however been altered. This means, for instance, that RCD operations involve only AREVA, mainly for the La Hague UP2 400 plant, and the CEA, notably in Fontenay-aux-Roses, Cadarache and Marcoule for its civil activities, given that the CEA’s most significant RCD operations are for its military activities (UP1 plant).

Insofar as the waste produced at present is processed, conditioned and disposed of on a continuous basis, RCD operations relate only to the past and should gradually decrease. There are many RCD operations, sometimes at relatively minor cost, but certain operations are in excess of €100 million. For ILW-LL, article 7 of the 2006 law set 2030 as the deadline for RCD operations.

### Costs for the recovery and conditioning of old waste as of 31 December 2010

<table>
<thead>
<tr>
<th>€ million</th>
<th>CEA (1)</th>
<th>AREVA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCD gross costs</td>
<td>531</td>
<td>1 458</td>
<td>1 989</td>
</tr>
</tbody>
</table>

*Source: Cour des Comptes, operators*

(1): The CEA’s amounts include approximately €79 million in costs for the long-term management of RCD waste: this should be booked as “long-term management of radioactive waste packages”, according to the regulations

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128 Except for HLW, ILW-LL and LLW-LL for which ultimate disposal solutions do not yet exist.
E - Unresolved issues

1 - “Orphan” waste

A certain amount of radioactive waste does not as yet have any existing disposal route or one being examined, given its rarity and chemical properties. The volume of this waste is low: about 1,000 m³, with a very disparate breakdown. According to ANDRA, it comes essentially from the nuclear power sector: only a very small quantity of it (around 10 m³) has been generated by research or industrial activities unrelated to this sector.

To respond to the demand of the 2010-2012 PNGMDR (French national management plan for radioactive materials and waste): “By the end of 2011, Nuclear operators and ANDRA shall establish management methods to suit the particular physical and chemical properties of this waste”, a working group was formed mid 2010 under the aegis of the DGEC to establish the long-term management methods for this waste.

A joint study by ANDRA, AREVA, the CEA and EDF, summarizing this investigation, was submitted to the French government in December 2011. No costing on the overall management cost for this orphan waste is yet available at this stage; this cost is therefore not taken into account in the operators’ provisions.

2 - Mining residues

The operation of uranium mines in France between 1948 and 2001 enabled 76,000 tonnes of uranium to be produced. Ore was processed in 8 plants only but 17 sites are now concerned by the disposal of residues, i.e. the products remaining once the uranium contained in the ore after processing has been extracted, with the quantity of residues evaluated at 50 million tonnes. These residues are VLLW and LLW. All these sites are under the responsibility of AREVA, which in accordance with the regulatory framework, has opted to manage this waste on site given the large quantities of waste produced: this is not compatible with disposal in ANDRA’s existing repositories.

In response to the circular from the Minister for the Environment on 22 July 2009, AREVA committed itself to “improving both knowledge of the environmental and health impact of former uranium mines and monitoring thereof”. Studies are in progress on the Jouac-Bernardan
site\textsuperscript{129}, which will be used to evaluate the funds required for the installation of additional overburden on mining sites in the event that the residues are re-classified as hazardous waste. The studies enabling more accurate costing will not however be completed until 2013, in accordance with the PNGMDR’s instructions.

3 - Recyclable materials

a) The case of depleted uranium and recycled uranium

In application of article L. 542-2-1 of the Environmental Code, uranium produced by reprocessing spent fuel (RU) and depleted uranium (DU) produced by enriching natural uranium and RU are “radioactive materials” and not waste\textsuperscript{130}. They are recyclable and are partly reused at the present time:

- recycled uranium can be enriched again (transformation into ERU) and is currently used as fuel in the four units at the Cruas nuclear power plant
- depleted uranium is used with plutonium to produce MOX fuel and can also be enriched again (this would create “secondary” stocks of depleted uranium to produce ENU fuel); the economic interest of this solution depends on the price of naturally occurring uranium and the availability of enrichment units. In the long term, the plan is to use depleted uranium to operate Generation IV fast neutron reactors, if this route comes into being.

In the meantime, the current fleet annually produces more depleted uranium and RU (approximately 7,100 tonnes and 1,000 tonnes) than it uses (approximately 600 tonnes of RU to produce ERU and 100 tonnes of depleted uranium to produce MOX). The stock of these materials is therefore increasing by 7,000 tonnes per year for depleted uranium and 400 tonnes per year for recycled uranium.

\textsuperscript{129} This mining complex was operated between 1987 and 2001 as an underground mine to a depth of 400 metres. The production rate was around 400 tonnes of uranium per year.

\textsuperscript{130} This distinction also allows regulated trade of uranium, which means that the stocks in France may come from foreign activities and conversely, French activities may generate stocks of materials abroad (particularly in Russia).
Forecast changes in the stocks of recycled uranium and depleted uranium in France (1)

<table>
<thead>
<tr>
<th>Tonnes</th>
<th>End 2007</th>
<th>End 2020</th>
<th>End 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycled uranium</td>
<td>21 180</td>
<td>36 000</td>
<td>49 000</td>
</tr>
<tr>
<td>Depleted uranium</td>
<td>254 820</td>
<td>332 324</td>
<td>452 324</td>
</tr>
</tbody>
</table>

Source: National inventory of radioactive materials and waste and PNGMDR 2010

(1): including radioactive materials of foreign origin.

If the production of RU and depleted uranium were to cease, the current stock of RU would be able to supply the fleet with enriched recycled uranium (ERU) for 36 years\(^1\), given current technical conditions. The current stock of depleted uranium would enable MOX to be produced for the current fleet\(^2\) for 2,300 years\(^3\). The PNGMDR’s reference solution for future recycling of these materials is to use them in Generation IV reactors; in this case this uranium would last for several thousands of years of consumption\(^4\).

In the absence of such reactors, large quantities of radioactive substances would be without use, whilst their level of radioactivity and lifespan prevents them from being accommodated in ANDRA’s existing repositories. Even with these reactors, it is still possible that part of the depleted uranium might never be used and at some point would be considered as waste, since the current stock could in principle supply a Generation IV nuclear fleet for several generations.

This issue is of particular importance, as stated by the PNGMDR 2010-2012: “in all cases, given the orders of magnitude of the volumes under consideration, if these materials were to be considered as waste, they are of a nature that would considerably alter the scope of disposal projects. It must therefore be emphasized that if these materials were at some point to be considered as waste, it would be necessary to take them

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\(^1\) The four Cruas units use 75 tonnes of ERU per year, made from 600 tonnes of RU.
\(^2\) The 22 authorized reactors use 120 tonnes of MOX per year, mixed with 2/3 of traditional fuel. The EPR is presented as being able to use up to 100 percent MOX fuel compared to 30 percent in current PWRs.
\(^3\) Alternatively, having a quantity of re-enriched uranium corresponding to the consumption of the current fleet over a period of about 8 years, although this solution would create a secondary stock of around 250 000 t of depleted uranium.
\(^4\) According to the 2010 opinion of the HCTISN: a Generation IV fleet as powerful as the current fleet would use around 100 t of depleted uranium per year.
into account when designing the corresponding long-term waste management; they could not be taken care of marginally, as has been the case for some historic waste.”

In current conditions, the disposal of depleted uranium represents around 76,000 m\(^3\). This corresponds to a quantity of the same order of magnitude as all the waste to be disposed of in the deep geological repository.\(^{135}\) A specific disposal solution should therefore be found in this case – a solution for which there is as yet no disposal concept or costing.\(^{136}\) Some 98 percent of the current stock of depleted uranium belongs to the AREVA group. These stocks of depleted uranium are kept at the Bessines and Pierrelatte sites. 60 percent of this total stock comes from enrichment for the benefit of EDF and 40 percent from enrichment for the benefit of foreign clients. It follows that if depleted uranium were to be considered as waste instead of as a recyclable material, France would have to dispose of radioactive waste of foreign origin\(^{137}\) which now belongs to AREVA under the terms of its commercial contracts\(^{138}\). Currently, storage of this depleted uranium costs the operator €1.8 million per year.

\(^{135}\) The characteristics of depleted uranium, the radioactivity per unit mass of which is around five times lower than that of natural uranium, would however make its disposal less complex and costly than that of HLW and ILW-LL in the CIGEO Geological Repository Project.

\(^{136}\) Conversely, for recycled uranium, EDF has made a provision corresponding to its oxidation and long-term storage (250 years). The gross costs amount to €3.3 billion and provisions to €602 million. According to EDF, this amount would be enough if this material were in the future to be considered as waste requiring final underground disposal of the type originally envisaged for ILW-LL.

\(^{137}\) Conversely, depleted uranium from enrichment by foreign operators for the benefit of EDF would continue to be taken care of in the country in which enrichment had taken place.

\(^{138}\) AREVA, *Interim study on the long-term management of depleted uranium*, December 2010: “According to internationally well-established commercial practice, the standard clauses of commercial contracts stipulate the option (practically almost always taken up) for the client to transfer ownership of the depleted flow to the enricher. In this respect, AREVA is the owner of depleted uranium”.

b) Plutonium

The stock of plutonium, from reprocessing and awaiting transformation into MOX, amounts to 82 tonnes, 60 tonnes of which are owned by France. The plutonium stored in a separate form in La Hague accounts for 29 tonnes of this total. This allows for production of MOX for 3 years at the current rate of consumption of nuclear power plants.

The question arises as to what would happen to it if the authorities were to discontinue the MOX sector. The long-term management strategy for spent fuel, based on reprocessing, could be called into question if no satisfactory ultimate disposal route is found for plutonium. A 10-year order for power plants using MOX would theoretically leave the choice between direct disposal of 26,000 tonnes of spent fuel (immediate shutdown of reprocessing and consumption of the existing plutonium in the form of MOX) and continuing reprocessing, which would generate approximately 2500 m³ of HLW and 260 tonnes of plutonium.

The PNGMDR does not raise the issue of the possible ultimate disposal routes for plutonium. It emphasizes its current status as a recyclable material, but does not plan for studies to be carried out for an alternative means of management should it be considered to be waste, as opposed to recycled uranium (RU) and depleted uranium, for which studies are recommended.

c) Thorium

Thorium is a naturally found radioactive material. AREVA has a stock of 2,265 tonnes of this, stored on the CEA’s site in Cadarache\(^\text{139}\). Thorium is not considered to be waste but as a radioactive material due to that fact that it is recyclable. According to the PNGMDR, thorium may “capture a neutron and transmute into uranium-233, which is fissile. A “thorium cycle” using thorium as a fuel may also come into being at some point, but not within the next few decades given the research and development work still required”; the PNGMDR therefore seems to be in doubt as to whether thorium is truly recyclable.

AREVA must therefore work with ANDRA to examine the consequences and costs of accommodating thorium in existing repositories or ones which are being studied, in the event of

\(^{139}\) RHODIA owns 7,134 tonnes of thorium stored in La Rochelle: this is unrelated to the nuclear power industry.
reclassification of thorium as radioactive waste. Moreover, AREVA must study the appropriateness and feasibility of a system to make the long-term management of these materials financially secure, should they be qualified as waste in the long term.

**F - Summary of gross waste management costs in the operators’ accounts**

The following tables present a summary of the quantities of waste committed as of the end of 2010 and the related gross costs and provisions. According to the order of 21 March 2007, “management costs for short-lived waste resulting from the operation of facilities in service” must not be booked as long-term waste management costs and no provision should be made for them. This waste is generally sent in real time to the ANDRA’s VLLW, LLW-SL and ILW-SS repositories.

**Volume of committed waste as of 31 December 2010**

<table>
<thead>
<tr>
<th></th>
<th>EDF</th>
<th>CEA (1)</th>
<th>AREVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>VLLW</td>
<td>815,000</td>
<td>222,000</td>
<td>273,000 t</td>
</tr>
<tr>
<td>LLW-SL</td>
<td>530,000</td>
<td>67,000</td>
<td>46,600</td>
</tr>
<tr>
<td>ILW-SL</td>
<td>52,000</td>
<td>1,940 t graphite + radiferous waste</td>
<td>2200</td>
</tr>
<tr>
<td>LLW-LL</td>
<td>36,141</td>
<td>16,080</td>
<td>9,924</td>
</tr>
<tr>
<td>HLW (2)</td>
<td>4,368</td>
<td>175</td>
<td>187</td>
</tr>
</tbody>
</table>

*Source: Cour des Comptes, operators*

(1) The volumes of VLLW, LLW-SL, ILW-SL and LLW-LL are given as of 31 December 2009, including any military waste.
(2) The HLW includes “hot” and “cold” waste (requiring a longer cooling period prior to disposal).

The gross costs for long-term management of the quantities of waste committed stood at some €25 billion at the end of 2010. Supplemented by expenses after closure of the repositories and expenses relating to recovery and conditioning of old waste, the total amount is €28.3 billion, €23 billion (81 percent) of which is to be paid by EDF.
Gross radioactive waste management costs:

<table>
<thead>
<tr>
<th>Gross costs, € million&lt;sub&gt;2010&lt;/sub&gt;</th>
<th>EDF</th>
<th>CEA</th>
<th>AREVA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Long-term waste management</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>including HLW and ILW-LL</td>
<td>19 791</td>
<td>1 555</td>
<td>1 069</td>
<td>22 415</td>
</tr>
<tr>
<td>including VLLW, LLW-SL and ILW-SL</td>
<td>1 440</td>
<td>0</td>
<td>269</td>
<td>1 709</td>
</tr>
<tr>
<td>including LLW-LL</td>
<td>727</td>
<td>56</td>
<td>23</td>
<td>806</td>
</tr>
<tr>
<td><strong>Costs following closure of repositories (1)</strong></td>
<td>1 056</td>
<td>261</td>
<td>40</td>
<td>1 357</td>
</tr>
<tr>
<td><strong>RCD</strong></td>
<td>531</td>
<td></td>
<td>1 458</td>
<td>1 989</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>23 014</td>
<td>2 403</td>
<td>2 859</td>
<td>28 276</td>
</tr>
</tbody>
</table>

Source: Cour des Comptes, operators

(1) Monitoring, maintenance of the centre’s overburden, taxation
(2) Contrary to regulatory requirements (order of 21 March 2007), the CEA does not book the charges relating to long-term management of waste from dismantling (€341 million) and RCD (€79 million) as waste management. These costs, which apply to all types of waste, are booked in the provisions for dismantling and RCD.

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**CONCLUSION – WASTE MANAGEMENT**

Although nuclear operators remain responsible for their waste, the disposal of this waste is entrusted to ANDRA, which manages three repositories. Waste management costs are invoiced by ANDRA to the producers, who take this into account in their operating costs.

- **Disposal of low-level and short-lived waste**

  Waste from the dismantling of INBs will eventually exceed the disposal capacity of the VLLW repository, which will need to be extended or supplemented by a new repository. The disposal capacity of the LLW-SL and ILW-SL repository may prove to be insufficient in the event of the operating period of power plants being extended to 50 years. By extrapolating past costs, the construction of two new repositories would generate an investment cost of around €260 million.

  For long-lived low-level waste, a dedicated repository was to be opened in 2013 but the project has been postponed due to difficulties relating to its location. Operators’ provisions are still based on an old costing of €806 million<sub>2010</sub> which will have to be changed in the light of the research work currently being conducted.
• **High-level and intermediate-level long-lived waste**

The disposal of HLW and ILW-LL in deep geological layers is the reference solution for France, Europe and internationally.

The revision of the 2005 estimate (€16.5 billion\textsubscript{2010}) for the deep repository differs for ANDRA (IS 2009 costing at €36 billion\textsubscript{2010}) and the producers (STI project at €14.4 billion\textsubscript{2010}). The STI project presented by the producers leads to a lower cost than the 2005 estimate, the basis on which they currently calculate their provisions. The official estimate of costs will be determined by ministerial order before 2015. If this estimate is higher than that of 2005 and close to the revised amount of the ANDRA estimate, the producers will have to make potentially significant adjustments to the amount of their provisions.

In all cases, the architecture and ultimate cost of the deep repository is liable to change due to technical and regulatory changes occurring during its operating period, which will be at least 100 years commencing in 2025.

In addition, the concepts currently being studied and costed by ANDRA do not plan for direct disposal of spent fuel assemblies. However, EDF’s accounts include the scenario of direct disposal for certain types of spent fuel, the cost of which is calculated on the basis of old ANDRA costings and concepts (2002). In the event of this type of disposal being chosen ultimately, it is not certain that the repository as it is currently designed could accommodate these fuels or that the provision made by EDF would be sufficient to cover the necessary developments. It would therefore be desirable for the cost of any direct disposal of the MOX and ERU produced each year to also be the subject of an estimate, and for this hypothesis to be taken into account in the future studies for the dimensioning of the deep geological repository.

• **Unresolved issues**

In the field of radioactive waste management, there are certain unresolved issues which could entail additional costs for the operators.

For orphan waste, the absence of costing and management solutions explains why these are not taken into account in the operators’ financial statements. The quantities concerned are small (1000 m\textsuperscript{3}) but they will require specific treatment.
In the case of AREVA mining waste and residue, the choice of on-site management appears to be consistent given the low radioactive nature of the materials and large quantities involved: these rule out disposal in ANDRA’s existing repositories. The additional overburden at the sites would entail costs for AREVA, but preliminary estimates still need to be consolidated.

Lastly, the currently recyclable nature of certain radioactive materials could be called into question in the future:

- depleted uranium is reusable and partly reused, but the stock continues to increase. According to the national inventory of radioactive materials and waste, this will reach 450,000 tonnes by 2030, compared to over 260,000 tonnes at the present time. Absorption of this stock will depend on the possible commissioning of Generation IV fast neutron reactors, which could theoretically operate for over 2,500 years with the current stock, or even longer should this stock continue to grow. Another solution would be to sell the stock to foreign enrichers or re-enrich it, but choosing these options depends on the price of natural uranium and the availability of enrichment capabilities. If these scenarios do not occur, a disposal solution must be found and funded. In current economic and technical conditions, it is probable that part of the depleted uranium stock will not be used. The scientific studies of the possible disposal of part of this uranium therefore need to be supplemented with financial studies in order to evaluate, albeit imperfectly, the possible liabilities for AREVA.

- with respect to plutonium, its recycling potential is linked to the existence of a recycling sector. Studies could be undertaken on the management of this material in the event of it not being recycled in the form of MOX.

- for thorium, recycling also depends on further technological developments, but the quantities in question are much smaller than for depleted uranium.
Chapter IV

Provisions and discounting

I - Balance sheet provisions

Future costs for decommissioning, management of spent fuel and management of existing waste are entered in operator accounts as they are inevitable, but potentially long-term, costs. They are therefore entered as provisions, calculated on the gross charges identified in Chapter III above and to which a discount rate is applied.

The total future costs of the nuclear power sector in the books of EDF, AREVA, CEA and ANDRA in 2010 were assessed at €79.4 billion in gross charges for decommissioning facilities, management of spent fuel and long-term management of radioactive waste. This sum is close to today’s value of the initial investment in currently operative facilities (€83 billion in overnight costs).

Taking account of discounting effects, these gross charges represented provisions of €38.4 billion in the 2010 financial statements of the main operators.
## Gross charges of the nuclear power sector

<table>
<thead>
<tr>
<th>Gross charges</th>
<th>EDF</th>
<th>AREVA</th>
<th>CEA</th>
<th>ANDRA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decommissioning</td>
<td>20 902.9</td>
<td>7 108.4</td>
<td>3 911.2</td>
<td>3 911.2</td>
<td>31 922.5</td>
</tr>
<tr>
<td>Management of spent fuel</td>
<td>14 385.8</td>
<td>419.9</td>
<td>14 805.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management of waste</td>
<td>23 016.9</td>
<td>2 859.1</td>
<td>2 402.8</td>
<td>83.5</td>
<td>28 362.3</td>
</tr>
<tr>
<td>• old waste retrieval and repackaging (RCD)</td>
<td></td>
<td>1 457.9</td>
<td>530.7</td>
<td>1 988.6</td>
<td></td>
</tr>
<tr>
<td>• LT waste package management</td>
<td>21 961.2</td>
<td>1 361.0</td>
<td>1 611.4</td>
<td>34.6</td>
<td>24 968.2</td>
</tr>
<tr>
<td>• post-closure costs of waste disposal facilities</td>
<td>1 055.7</td>
<td>40.2</td>
<td>260.7</td>
<td>48.9</td>
<td>1 405.5</td>
</tr>
<tr>
<td>Last cores</td>
<td>3 791.5</td>
<td></td>
<td></td>
<td></td>
<td>3 791.5</td>
</tr>
<tr>
<td>Other future charges</td>
<td>496.7</td>
<td>36.3</td>
<td></td>
<td></td>
<td>533.0</td>
</tr>
<tr>
<td>Overall total</td>
<td>62 097.1</td>
<td>10 464.2</td>
<td>6 770.2</td>
<td>83.5</td>
<td>79 415.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>78%</th>
<th>13%</th>
<th>9%</th>
<th>100%</th>
</tr>
</thead>
</table>

The costs of the nuclear power sector – January 2012

Cour des comptes
The costs of the nuclear power sector – January 2012
13 rue Cambon 75100 PARIS CEDEX 01 - tel : 01 42 98 95 00 - www.ccomptes.fr
Nuclear power sector provisions

<table>
<thead>
<tr>
<th>Provisions € millions</th>
<th>EDF</th>
<th>AREVA</th>
<th>CEA</th>
<th>ANDRA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decommissioning</td>
<td>11 030.9</td>
<td>3 421.4</td>
<td>2 944.0</td>
<td></td>
<td>17 396.3</td>
</tr>
<tr>
<td>Management of spent fuel</td>
<td>8 850.9</td>
<td>303.1</td>
<td></td>
<td></td>
<td>9 154.0</td>
</tr>
<tr>
<td>Management of waste</td>
<td>6 508.8</td>
<td>1 823.4</td>
<td>1 178.5</td>
<td>41.3</td>
<td>9 552.0</td>
</tr>
<tr>
<td>• inc. old waste retrieval and repackaging</td>
<td>1 209.2</td>
<td>446.7</td>
<td></td>
<td></td>
<td>1 655.9</td>
</tr>
<tr>
<td>• inc. LT waste package management</td>
<td>6 408.7</td>
<td>573.3</td>
<td>717.0</td>
<td>29.1</td>
<td>7 728.1</td>
</tr>
<tr>
<td>• post-closure costs of waste disposal facilities</td>
<td>100.1</td>
<td>40.9</td>
<td>14.8</td>
<td>12.2</td>
<td>168.0</td>
</tr>
<tr>
<td>Last cores</td>
<td>1 905.9</td>
<td></td>
<td></td>
<td></td>
<td>1 905.9</td>
</tr>
<tr>
<td>Other provisions for future charges</td>
<td>359.5</td>
<td>27.7</td>
<td></td>
<td></td>
<td>387.2</td>
</tr>
<tr>
<td>Overall total</td>
<td>28 296.5</td>
<td>5 604.3</td>
<td>4 453.3*</td>
<td>41.3</td>
<td>38 395.4</td>
</tr>
</tbody>
</table>

Source: Cour des Comptes from the financial statements of operators and reports on long-term nuclear charges and their financing

* including €158.8 million outside the scope of the 2006 law

Total provisions in the accounts therefore represent barely half (48 percent) of total gross charges, a proportion which varies widely between operators according to the scheduling of future costs. The future, partly significant, costs of the CEA are current costs (decommissioning, RCD), which limits the discounting effect, as its provisions represent 66 percent of its gross charges.
Comparison of charges and provisions per cost type

<table>
<thead>
<tr>
<th></th>
<th>Decommissioning</th>
<th>Spent fuel</th>
<th>RCD</th>
<th>Waste management</th>
<th>Post waste disposal</th>
<th>Last cores</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>€ millions 2010</td>
<td>31 922.5</td>
<td>14 805.7</td>
<td>1 988.6</td>
<td>24 968.6</td>
<td>1 405.5</td>
<td>3 791.5</td>
<td>533.0</td>
<td>79 415.0</td>
</tr>
<tr>
<td>Provisions</td>
<td>17 396.3</td>
<td>9 154.0</td>
<td>1 655.9</td>
<td>7 728.1</td>
<td>168.0</td>
<td>1 905.9</td>
<td>387.2</td>
<td>38 395.4</td>
</tr>
<tr>
<td>Provisions / gross</td>
<td>54%</td>
<td>62%</td>
<td>83%</td>
<td>31%</td>
<td>12%</td>
<td>50%</td>
<td>72%</td>
<td>48%</td>
</tr>
</tbody>
</table>

Source: Cour des Comptes from operators’ financial statements

II - Provision discounting

Given the major impact of discounting gross charges on the calculation of provisions for charges in operator accounts, the methods used and discount rate applied should be carefully considered.

A - The principle of discounting

1 - Converting future amounts to current values

Amounts entered as provisions by nuclear operators are intended to be spent over a long, sometimes very long, period. A long period in economic and financial terms means that a sum received or spent today is not strictly equivalent to or comparable with a sum to be received or spent in the future. Discounting involves taking account of the passage of time by recording these future costs in present values.  

140 Discounting is therefore "a mathematical operation which enables a comparison of financial values spread over time: it involves converting the future value of an asset or liability to the present value. Discounting is based on two essential factors: assessment of cash flows (scheduling of immediate and future real or notional expenditure and income) and the discount rate (coefficient to convert the future to the present). The discount rate is a rate of substitution between the future and the present; it represents the time value for a company or authority: it is a sort of "time price". Commissariat général du plan, Révision du taux d’actualisation des investissements publics, 2005 (Public investment discount rate review).
The discounting principle is also recognized in international accounting standards, specifically in the IAS 37 standard on provisions, contingent liabilities and contingent assets. This standard was implemented by EC Regulation No. 1126/2008 of 3 November 2008, which provides "Where the effect of the time value of money is material, the amount of a provision shall be the present value of the expenditure expected to be required to settle the obligation. Because of the time value of money, provisions relating to cash outflows that arise soon after the balance sheet date are more onerous than those where cash outflows of the same amount arise later. Provisions are therefore discounted, where the effect is material. The discount rate(s) shall be a pre-tax rate (or rates) that reflect(s) current market assessments of the time value of money and the risks specific to the liability. The discount rate(s) shall not reflect risks for which future cash flow estimates have been adjusted".

Future costs estimated by operators for the nuclear cycle back end are therefore based firstly on the gross value according to the current year’s economic conditions. These gross values are then discounted using a rate which enables determination of the amount to be budgeted today to cover future costs. It is the discounted value which is entered in the operator balance sheets.

This operation is very important for operators: any increase or decrease in the discount rate produces a change in the discounted provision and any matching asset, thereby having an impact on their balance sheets and profit and loss accounts. This change would apply even if the decommissioning or waste management estimates remain unchanged, i.e., at a constant gross value.

2 - No consensus on the right discount rate

Given long-term economic uncertainty and the inconsistent preference of economic players for the present, the choice of a discount rate necessarily includes an arbitrary component thereby rendering it questionable. A compromise solution may be to apply different discount rates according to the period in which the expenditure is made.
Such a solution was recommended in Annex 8 of the June 2000 nuclear sector economic forecast study\textsuperscript{141}. This report to the Prime Minister recommended two separate discounting phases: 30 years for the first phase with a discount rate of 6 percent and a second phase for the period over 30 years with a discount rate of 3 percent. The 2005 Lebègue report on review of public investment discount rates recommended use of a discount rate of 4 percent net of inflation, decreasing after 30 years and with an absolute limit of 2 percent net for very long-term investments. The British Finance Ministry also recommended use of a decreasing discount rate based on lapse of time\textsuperscript{142}.

This means that operators would have to use different discount rates according to the estimated provision maturity date: the rate could be higher for a facility decommissioning provision than for a long-term HLW and ILW-LL waste management provision which covers costs post-2100. However, implementation of such an approach implies that operators would have to justify the discount rate used for each individual provision. It could complicate matters further without fundamentally changing the value of the discounted provisions: operators would use a higher rate than at present for provisions maturing in less than 30 years, before reducing it gradually to reach a true rate of 2 percent for the most long-term costs pursuant to the Lebègue report recommendations.

\begin{center}
\textbf{B - Discount rate used}
\end{center}

The gross value of charges relating to the nuclear cycle back end for the three main operators was €79.4 billion at the end of 2010. These gross charges are expressed in provisions with a discounted value of about €38.4 billion. This latter figure is the one entered in the operators’ books and which determines the amount of dedicated assets for provisions which need asset coverage.

\begin{footnotesize}
\begin{itemize}
\item \textsuperscript{141} JM. Charpin, B. Dessus and R. Pellat, \textit{Nuclear sector economic forecast study: report to the Prime Minister, June 2000}.
\item \textsuperscript{142} HM Treasury, \textit{Intergenerational wealth transfers and social discounting}, July 2008: “This declining rate is based on uncertainty about the future values of time preference and calculates a certainty equivalent rate taking into account the range of this uncertainty”.
\end{itemize}
\end{footnotesize}
The choice of discount rate for provisions is an important one for operators: a reduction in the rate used entails an increase in the provision thereby worsening the net result for one or more financial years. An increase in discounted provisions also leads to increasing the portfolio of dedicated assets, reducing operator cash flow. However, an increase in the dedicated asset portfolio only concerns provisions requiring asset coverage. All other things being equal, a reduction in the discount rate would have the following consequences:

<table>
<thead>
<tr>
<th>Lower discount rate</th>
<th>Higher discounted provision</th>
<th>Reduced net result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Increase in dedicated asset portfolio</td>
<td>Reduced cash flow</td>
</tr>
</tbody>
</table>

1 - Regulatory rate framework

The discount rate used by operators is regulated by Decree No. 2007-243 of 23 February 2007 on securing the financing of nuclear sector charges, which provides that "the discount rate used in calculating the amount of provisions [...] may not exceed the confidently-expected yield rate of collateral assets managed with a degree of security and liquidity sufficient to meet their purpose. This discount rate may not exceed a cap fixed by order of the Ministers for the Economy and for Energy compatible with the applicable accounting standards. To calculate the discount rate mentioned in the first paragraph and assess the yield rate mentioned in the second paragraph, the operator will use a reliable and durable method"\(^{143}\).

\(^{143}\) This definition of the discount rate has practical interest and enables long-term equilibrium between the value of dedicated assets and that of the provisions they cover, but it isolates the discount rate from its reference definition in economic theory, i.e., "the time value for the community".
Operators must therefore choose a discount rate based on a documented and durable method, not exceeding the expected yield rate on their collateral assets while observing a rate cap laid down by regulations.

The rate cap is determined by the Order of 21 March 2007 on securing the financing of nuclear sector charges, which provides that the nominal cap value is equal to the arithmetical rate average over the last forty-eight months for State bonds with a constant thirty-year maturity (TEC 30), calculated on the closure date of the financial year concerned, plus 1 percent.

Subject to this cap, EDF, AREVA and the CEA use the same calculation method to fix their discount rate, by adding the running 48-month average of the TEC 30-year rate and the average of the running 48-month average of margins AA, A and BBB\(^{144}\). The contribution to the discount rate of the latter aggregate is limited to 100 basis points (1 percent). On 31 December 2010:

- the running 4-year average of the TEC 30-year rate was 4.24 percent;
- the running 4-year averages of margins AA, A and BBB were 0.87, 1.19 and 1.77 percent respectively. The simple average of these three margins being 1.28 percent, the limit of the 100 basis points fixed by the Order was reached.

On 31 December 2010, the theoretical rate was therefore 5.51 percent, capped by a rate of 5.24 percent. These rates have varied since 2006 as follows:

<table>
<thead>
<tr>
<th>31 December</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>running 4-year average TEC 30 (a)</td>
<td>4.38%</td>
<td>4.30%</td>
<td>4.24%</td>
<td>4.31%</td>
<td>4.24%</td>
</tr>
<tr>
<td>running 4-year average mrgn AA (b)</td>
<td>0.37%</td>
<td>0.38%</td>
<td>0.56%</td>
<td>0.77%</td>
<td>0.87%</td>
</tr>
<tr>
<td>running 4-year average mrgn A (c)</td>
<td>0.63%</td>
<td>0.60%</td>
<td>0.86%</td>
<td>1.06%</td>
<td>1.19%</td>
</tr>
<tr>
<td>running 4-year average mrgn BBB (d)</td>
<td>1.17%</td>
<td>1.01%</td>
<td>1.39%</td>
<td>1.34%</td>
<td>1.37%</td>
</tr>
<tr>
<td>running 4-year average Spread ((e= (b+c+d)/3))</td>
<td>0.72%</td>
<td>0.66%</td>
<td>0.94%</td>
<td>1.18%</td>
<td>1.28%</td>
</tr>
<tr>
<td>Theoretical rate (f = (a+e))</td>
<td>5.11%</td>
<td>4.96%</td>
<td>5.18%</td>
<td>5.49%</td>
<td>5.51%</td>
</tr>
<tr>
<td>Capped rate: (f \text{ or (a+1%)} \text{ if } f &lt; f)</td>
<td>5.11%</td>
<td>4.96%</td>
<td>5.18%</td>
<td>5.31%</td>
<td>5.24%</td>
</tr>
</tbody>
</table>

\(^{144}\) This is the variation between the rate for 30-year State bonds and the average rate of corporate bonds rated AA, A and BBB.
EDF, AREVA and the CEA all use the same formula and have adopted a **nominal value discount rate of 5 percent**, i.e., a slightly lower value than the capped rate. Based on a medium and long term inflation average of 2 percent, the true discount rate used by operators is thus **almost 3 percent** (2.94 percent to be exact).

This means that the confidently-expected yield rate on collateral assets should have a nominal value of over 5 percent per year or a true value of 2.94 percent (**below**).

### 2 - Rate sustainability

**a) Variation in the rate of 30-year State bonds**

Under current regulations, as the discount rate used by operators is held at the average over 4 years of 30-year State bond rates plus 100 basis points, if the rate of these bonds reduces and the reduction persists, the capped rate currently fixed at 5.24 percent could go down. This situation would force operators to adopt a lower discount rate once the capped rate fell below 5 percent, i.e., if the 4-year average of the TEC 30 was less than 4 percent. However, there has been a downward trend in this rate over the last twenty years, as the graph below shows:

**Rate variation of 30-year State bonds**

*Source: Cour des Comptes from Banque de France data*
The TEC 30 average was 3.74 percent in 2010 and 3.93 percent in 2011. If the rate level remains below 4 percent, the capped rate (the average TEC 30 rate over 48 months plus 100 basis points) would be reduced and could fall below 5 percent and force operators to reduce their discount rates.

### TEC 30 rate variation

<table>
<thead>
<tr>
<th>Year</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average TEC 30 rate</td>
<td>4.50%</td>
<td>4.60%</td>
<td>4.23%</td>
<td>3.74%</td>
<td>3.93%</td>
</tr>
</tbody>
</table>

Source: Cour des Comptes from Banque de France data

b) International comparisons

The rates used by the three French operators (nominal rate of 5 percent and true rate of 2.94 percent) are comparable with those used by German operators who work in similar economic conditions and in the same monetary zone: E.ON uses a nominal rate of 5.2, Vattenfall 4.75, RWE 5 and EnBW 5.5 percent.

In the United Kingdom however, the Nuclear Decommissioning Authority (NDA) which manages the nuclear cycle back end for redundant facilities uses a true value discount rate of 2.2 percent\(^\text{145}\) (2.94 percent for French operators). The choice of this rate complies with the instructions of the British Finance Ministry for which such rates must reflect the time value of very long-term liabilities (over 100 years). The true rate is 3 percent for the Nuclear Liabilities Fund (NLF) responsible for financing the back end of the cycle for existing facilities.

In Sweden, a different true discount rate is used according to the period concerned: 3.25 percent for the first 15 years and 2.5 percent for subsequent years.

Generally, the true discount rate of French operators is at an intermediate level in comparison with other countries of the European Union, as seen in this extract of a 2007 study carried out for the European Commission.

\(^{145}\text{Department of Energy and Climate Change: Consultation on an updated waste transfer pricing methodology for the disposal of higher-level waste from new nuclear power plants, December 2010; Nuclear Decommissioning Authority: Annual reports and accounts, 2010-2011.}\)
True discount rates used in the European Union

<table>
<thead>
<tr>
<th>Country</th>
<th>Spain</th>
<th>United Kingdom</th>
<th>France</th>
<th>Hungary</th>
<th>Sweden</th>
<th>Slovenia</th>
</tr>
</thead>
<tbody>
<tr>
<td>True rates</td>
<td>1.5%</td>
<td>2.2%: NDA*</td>
<td>2.94%</td>
<td>3%</td>
<td>3.25%&lt;15 years</td>
<td>2.5%&gt;15 years</td>
</tr>
</tbody>
</table>

Source: Wuppertal Institute, EU decommissioning funding methodologies

* NDA: Nuclear Decommissioning Authority; ** NLF: Nuclear Liabilities Fund

c) Adopted inflation basis

In their provision calculation for the nuclear cycle back end, the operators adopt an inflation basis of 2 percent with a nominal discount rate of 5 percent. This inflation basis corresponds with the long-term inflation objective of the European Central Bank (ECB) and not with average inflation over the period.

A memorandum dated 28 February 2011 and prepared by an insurance comptroller at the request of the DGEC considered that the chosen inflation basis does not take sufficient account of changes in costs specific to decommissioning or long-term waste management, although there is no evidence that they have kept pace with consumer prices. Another approach would be to use sectoral indices such as the civil engineering index whose recorded inflation has been well above average inflation. For example, from January 2002 – January 2008 consumer prices increased by 11.9 percent, whereas the national civil engineering index increased by 32.5 percent, the national underground works index by 26.1 percent and the national construction index by 28.5 percent. These types of cost represent an essential part of the provision for deep disposal of HLW and ILW-LL waste.

Given the lengthy maturity for these provisions, it is impossible to know whether such sectoral indices will continue to increase more rapidly than consumer prices. The choice of inflation basis nonetheless implies that the operators are confident in the absence of escalating costs associated with decommissioning and spent fuel and long-term waste management. By way of comparison, ANDRA uses a 2 percent inflation rate for its provisions unless the civil engineering index dominates costs; it then uses a price variation basis of 3 percent.
d) Comparison with other long-term liabilities

Few liabilities have a lifespan equivalent to that of the nuclear cycle back end and comparisons should therefore be treated with caution. Liabilities over a comparable period would include pension commitments. In the off-balance sheet notes to the government accounts, a net of inflation discount rate of 1.53 percent (1.63 percent at the end of 2009) is used for State pension and associated commitments. Standard No. 13 of the State chart of accounts provides that the discount rate is chosen with reference to State borrowing rates. In this case, the reference used is that of inflation-indexed State borrowing, and more specifically, the consumer price index excluding tobacco (OATi) maturing in 2029, given the period of pension commitments. Moreover, as the State has not set aside provisions for this sum nor established a portfolio of dedicated assets, annual modification of the discount rate has no effect on the State’s financial situation unlike that of AREVA, the CEA and EDF.

ANDRA also uses a different discount rate for its long-term provisions: 3.5 percent nominal rate or 1.47 percent true rate. There are several reasons for the choice of a much more cautious rate than that of other operators: a very long liability period (300 years), a less risky and less profitable portfolio of collateral assets (an annual average of 3.11 percent nominal profitability over 10 years). Finally, as the Agency stated in "Article 20" of its 2010 report, "no reference accounting organization recommends method(s) for calculating a cautious discount rate over a very long maturity period (300 years) for obligations requiring annual cash outflow which cannot be deferred in times of inflation and/or investment under-performance", which according to ANDRA justifies the choice of a lower discount rate.

e) Dedicated asset portfolio yield forecasts

The Decree of 23 February 2007 provides that the "discount rate may not exceed the confidently-expected yield rate on collateral assets managed with a degree of security and liquidity sufficient to meet their purpose".

In AREVA’s case, the structural composition of the collateral asset portfolio on 31 December 2010 was 60 percent Euro-zone rate products and 40 percent European shares, the company anticipating a yield of
3.5 percent from Euro-zone rates\textsuperscript{146} and a 7.5 percent yield from European shares. At the end of 2010, the anticipated yield rate on collateral assets was therefore 5.10 percent, barely above the discount rate. EDF considers that a portfolio comprising 50 percent shares and 50 percent bonds would produce an average annual true rate of 3.9 percent based on recorded yields over a century. Taking the last twenty years as a reference (including the 2007-2009 financial crisis), EDF considers that the profitability of such a portfolio would be 5.6 percent, a significantly higher yield than the true discount rate of 3 percent. The weight of share holdings in such a portfolio nonetheless increases volatility risks associated with this asset category.

Yield forecasts for dedicated assets are therefore an extrapolation assuming that past yields will continue in the future. The current financial situation demonstrates the fragility of these forecasts.

\textbf{C - Operator provision sensitivity to the discount rate}

In their report appended to the 2010 annual accounts, the EDF auditors drew the operator’s attention to the possibility of a major review of provisions: "\textit{Without prejudice to the opinion expressed above, we draw your attention to the valuation of long-term provisions associated with nuclear production. This valuation is sensitive to the hypotheses used for costs, inflation rates, long-term discount rate and expenditure schedules. A change in some of these parameters could lead to a significant review of the provisions entered.}" In their reference documents, the operators show the sensitivity of their provisions to a rate variation of +/- 0.25 percent (EDF) or +/- 0.5 percent (CEA).

The variation impact is greatest for provisions with a long maturity date. For example, the provision for direct disposal of MOX and Superphénix fuel is €5.8 billion gross value but only €565 million discounted value: EDF considers that while it must dispose of these fuels in the deep underground facility, this will happen between 2113 and 2124, which explains the discounted provision being ten times less than the gross charges.

\textsuperscript{146} These rate products are Euro monetary assets, Euro-zone Member State borrowing or private Euro bonds, and EDF and CEA debts.
If the discount rate varies – even slightly – it will have a significant impact on the operators’ accounts, especially for EDF.

**Sensitivity of provisions to discount rate variation: impact based on 2010 provisions calculated with a rate of 5 percent**

<table>
<thead>
<tr>
<th>Discount rate</th>
<th>3%</th>
<th>3.5%</th>
<th>4%</th>
<th>4.25%</th>
<th>4.50%</th>
<th>4.75%</th>
<th>5%</th>
<th>5.25%</th>
<th>5.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDF*</td>
<td>15 313</td>
<td>10 000*</td>
<td>5 936</td>
<td>4 300*</td>
<td>2 782</td>
<td>1 312</td>
<td>0</td>
<td>-1 206</td>
<td>-2 349</td>
</tr>
<tr>
<td>AREVA</td>
<td>2 000**</td>
<td>1 500**</td>
<td>1 059</td>
<td>761</td>
<td>491</td>
<td>243</td>
<td>0</td>
<td>-217</td>
<td>-420</td>
</tr>
<tr>
<td>CEA</td>
<td>1 198</td>
<td>821</td>
<td>507</td>
<td>368</td>
<td>237</td>
<td>115</td>
<td>0</td>
<td>-108</td>
<td>-211</td>
</tr>
<tr>
<td>Variation</td>
<td>+18 511</td>
<td>+12 321</td>
<td>+7 502</td>
<td>+5 429</td>
<td>+3 510</td>
<td>+1 670</td>
<td>0</td>
<td>-1 531</td>
<td>-2 980</td>
</tr>
</tbody>
</table>

*Source: responses to the Cour des Comptes by EDF, AREVA and the CEA
*Cour des Comptes estimates ** AREVA estimates

A reduction of 0.5 percent in the discount rate results in an increase in discounted nuclear provisions of over €3.5 billion out of a total of €38.4 billion. Such a reduction is foreseeable, for example in the event of a prolonged reduction in the true rates of State 30-year bonds, if expected yields on collateral assets decrease in a difficult financial context or increased inflation prospects for the nuclear cycle back end.

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147 For the 4.25, 4, 3.5 and 3 percent values, the variation in the EDF provision does not include the following provisions: (i) Dismantling first generation power plants: sensitivity of the provision for dismantling first generation power plants to a discount rate reduction of 0.5 percent is limited to + €86.1 million, (ii) AMI Chinon: sensitivity is not significant (iii) APEC: sensitivity of the provision to a discount rate reduction of 0.5 percent is limited to + €2.5 million, (iv) dismantling steam generator: sensitivity of the provision to a discount rate reduction of 0.5 percent is limited to + €11.9 million.
III - Profit & Loss Account provisions

Nuclear provisions are entered as liabilities in operator balance sheets. They change each year as a result of entries in the profit and loss account of each operator and differ according to whether they are provisions for spent fuel and waste management or decommissioning or last core management provisions. Gross charges for the former increase regularly according to the quantity of fuel consumed each year, while the others remain stable as gross charges (unless quotations change). For both types of provision, account must be taken each year of the shortened period to the expenditure date and their amount must therefore be "unwound".

A - EDF provisions for existing plants

The table below shows the provision amounts entered by EDF at the end of 2010 for its 58 operative reactors, both in gross and discounted values, and the allowances included in the profit and loss account charges; these allowances represent cost items additional to the other items of the annual cost of nuclear energy production identified in the report.

EDF nuclear provisions for existing plants at end of 2010 and charges entered in 2010

<table>
<thead>
<tr>
<th>2010 provisions € millions</th>
<th>Gross charge</th>
<th>Discounted provision</th>
<th>2010 annual charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Future spent fuel &amp; waste management</td>
<td>37 402</td>
<td>15 360</td>
<td>1 076</td>
</tr>
<tr>
<td>Last cores</td>
<td>3 791</td>
<td>1 906</td>
<td>91</td>
</tr>
<tr>
<td>Power plant decommissioning</td>
<td>18 398</td>
<td>9 227</td>
<td>461</td>
</tr>
<tr>
<td>Total</td>
<td>59 591</td>
<td>26 493</td>
<td>1 628</td>
</tr>
</tbody>
</table>

Source: 2010 EDF accounts

1 - Provisions for future spent fuel & waste management

In the balance sheet liabilities, these provisions represent the discounted amounts to cover the cost of future management of spent fuel and long-term management of radioactive waste.

Each year, charges in the profit and loss account contain two items:

- the discounted amount to cover the cost of spent fuel management and reprocessing waste produced by the year’s operations (€336
million in 2010 for EDF). This annual allowance increases the provision shown under liabilities in the balance sheet;

- an amount representing the financial charge for "unwinding": the purpose of this charge is each year to increase the stock of provisions recorded as liabilities in the balance sheet for reprocessing the waste of previous years as the period before such expenditure shortens (€740 million in 2010 for EDF).

The Cour des Comptes considers that both amounts (€336 and €740 million) should be added to the items of the annual costs of nuclear energy production\(^{148}\).

2 - Provision for future management of last cores

In the balance sheet liabilities, this provision represents the discounted amount to cover the cost of reprocessing the last cores. Unlike provisions for waste reprocessing, the initial contra-entry is not entered as a profit and loss account charge, but as a "matching" asset entered in the balance sheet.

Each year, the profit and loss account charges for the last core reprocessing provision contain two items:

- the depreciation allowance for the matching asset (€0.2 million in 2010 in the EDF accounts; this matching asset has now been almost completely written down);
- the "unwinding" financial charge which increases - according to the same process as above - the provision in the balance sheet liabilities (€91 million in 2010).

The Cour des Comptes considers that this charge should be included in assessment of the annual costs of nuclear energy production (i.e., (€91 million for 2010)\(^{149}\).

\(^{148}\) See "overall conclusion" in Chapter VIII, the different practices of the "Champsaur Commission" and EDF in calculating the CEC (cureant economic cost), which only includes the first of these two charges (€336 million) in costs of "purchases of fuel and energy", without the unwinding charge.

\(^{149}\) Contrary to the methods of the Champsaur Commission and the EDF CEC calculation: see Chapter VII.
3 - Provision for decommissioning existing plants

In the balance sheet liabilities, this provision represents the discounted amount to cover the cost of decommissioning existing power plants. As with the last core, the initial contra-entry has not been entered as a profit and loss account charge but directly entered as a matching asset in the balance sheet. Each year, the profit and loss account charges contain two items:

- The depreciation allowance, over 40 years, for the matching asset (an allowance of €22 million in 2010 in the EDF accounts);
- the "unwinding" financial charge which increases the provision in the balance sheet liabilities according to the same process as for the waste reprocessing provisions (€439 million in 2010).

The Cour des Comptes considers that all decommissioning charges recorded in 2010 should be included in the annual costs of nuclear energy production, i.e., €461 million (€22 million + €439 million)150.

B - Provisions of other sector players

Areva also includes nuclear provisions in its accounts, using the same accounting method as EDF. These costs are transferred to EDF operating charges for services invoiced by Areva as the invoices are presumed to cover at least all costs borne by the supplier (excluding any margins of the fuel supplier). To avoid counting the same costs twice, the amounts appearing as an Areva charge should not therefore be added to those paid by EDF in calculating the cost of nuclear energy production.

The CEA and ANDRA also make nuclear provisions, but use an accounting method mostly consisting in entering all as annual allowances for provisions and therefore as an operating charge, without using a matching asset, pursuant to the accounting regulations to which they are subject as public bodies.

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150 See in Chapter VIII the different methods used on this point by the Champsaur Commission and EDF in its CEC calculation.
CONCLUSION – PROVISIONS AND DISCOUNTING

Future charges for decommissioning, management of spent fuel and long-term management of waste (€79.3 billion in 2010) are entered in the accounts of EDF, AREVA and the CEA in the form of provisions amounting to €38.4 billion in 2010, by applying a discount rate of 5 percent.

This rate is subject to a legal cap which could reduce if the rates of 30-year State bonds remain at the average level recorded in 2010 and 2011.

The rate used by French operators (nominal rate of 5 percent, true rate of 2.94 percent) is at an intermediate level in comparison with the rates used in other European Union countries: other countries use lower net rates, as in Spain (1.5 percent). Some countries also use different rates depending on the provision maturity dates, e.g., 2.2 percent and 3 percent in the United Kingdom, 3.25 percent and 2.5 percent in Sweden.

The discount rate of French operators is based on bullish assumptions:

- a long-term inflation rate of 2 percent per year for nuclear cycle back end provisions, whereas there is no certainty that costs of decommissioning and management of spent fuel or waste will keep pace with consumer prices; an increase in the cost of work exceeding 2 percent would mechanically lower the true rate and thereby increase the value of the discounted provision;

- a yield from the dedicated asset portfolio of more than 3 percent in true value, implying repetition of past performances in the bond and share markets.

The sensitivity of provisions to the discount rate is important, even more so as the expenditure is well into the future, as is the case with long-term management of radioactive waste. By way of example, a reduction of one point in the discount rate would require an increase in the discounted provisions of the three operators of €7.5 billion, including €6 billion for EDF.
Chapter V

Dedicated assets

I - The regulatory and legislative framework

A - Assets dedicated to hedging part of the future costs of the nuclear sector

The nuclear sector is characterized by exceptionally long operating cycles, that may be as long as 70 or even 80 years, between the date of construction of a power plant and its dismantling and final disposal of the waste generated (fuels, dismantling wastes, etc.). Furthermore, a significant proportion of costs, that cannot be reliably estimated, is related to activities involving the back end of the cycle and will require the mobilization of substantial financial resources. These financial resources must be available in sufficient volume to successfully complete back end operations without a time lag and in a manner that meets both safety and industrial criteria.

Before 2006, operators of basic nuclear installations had already started to earmark assets intended to hedge the future costs for which provisions had been accrued under liabilities. However, these were relatively informal initiatives and more importantly were insufficient with respect to the future costs of the nuclear sector\(^{151}\).

\(^{151}\) Cour des Comptes, 2005, Special public report on the dismantling of nuclear facilities and the management of radioactive wastes
The French Act of June 28, 2006 on the sustainable management of radioactive materials and wastes set, for all nuclear operators, the conditions under which financial resources must be gathered and managed to hedge provisions. Article 20 of the Act specifically states the obligation for operators of basic nuclear facilities to accrue provisions for the future nuclear expenses and assign "solely the necessary assets solely for the purpose of hedging these provisions". The procedures for implementing the 2006 Act were specified by decree No. 2007-243 of 23 February 2007 on securing funding for nuclear costs.

### The provisions to be hedged by dedicated assets
at 31 December 2010

<table>
<thead>
<tr>
<th>Provisions in €M_{2010}</th>
<th>EDF</th>
<th>AREVA</th>
<th>CEA</th>
<th>ANDRA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dismantling</td>
<td>11 030.9</td>
<td>3 421.4</td>
<td>2 944.0</td>
<td>17 396.3</td>
<td></td>
</tr>
<tr>
<td>Spent fuel management</td>
<td>8 850.9</td>
<td>303.1</td>
<td>9 154.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recovery and conditioning of old waste</td>
<td>1 209.2</td>
<td>446.7</td>
<td>1 655.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long-term management of waste packages</td>
<td>6 408.7</td>
<td>573.3</td>
<td>717.0</td>
<td>29.1</td>
<td>7 728.1</td>
</tr>
<tr>
<td>Expenditure after shutting down disposal facilities</td>
<td>100.1</td>
<td>40.9</td>
<td>14.8</td>
<td>12.2</td>
<td>168.0</td>
</tr>
<tr>
<td>Last cores</td>
<td>1 905.9</td>
<td>1 905.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other provisions</td>
<td>359.5</td>
<td>27.7</td>
<td>387.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grand total</td>
<td>28 296.5</td>
<td>5 604.3</td>
<td>4 453.3</td>
<td>41.3</td>
<td>38 395.4</td>
</tr>
<tr>
<td>(\text{o/w provisions to be hedged by dedicated assets})</td>
<td>17 910.0*</td>
<td>5 456.0**</td>
<td>4 453***</td>
<td>41.3</td>
<td>27 860.3</td>
</tr>
</tbody>
</table>

* Source: Cour des Comptes, annual financial reports of operators and reports on long-term nuclear costs and their funding
* does not include the provision for spent fuel management (which is part of the operating cycle) and part of the provisions for last cores
** o/w. €214 million of provisions to be hedged by third parties
*** o/w. €158.8 of provisions outside the scope of the Act of 28 June 2006

The provisions to be hedged by these dedicated financial assets are provisions unrelated to the operating cycle: dismantling, management of
spent fuel that cannot be recycled in current facilities and long-term management of radioactive wastes. Provisions regarding current operation, in other words the provisions for the operating cycle do not require hedging by dedicated assets. These are mainly provisions for the recycling of spent fuel which are expensed as the spent fuel is generated and therefore recognized in operating costs.

**B - Characteristics of the French system of securing future nuclear costs**

1 - Dedicated assets consolidated on operator balance sheets

The funding system set up is based on the principle of hedging all accrued costs, excluding the operating cycle, by dedicated assets instead of simply posting them as liabilities on the balance sheet.

A five-year deadline was set for achieving this hedging target which had to be completed by June 2011. In 2010, the legislator extended this deadline to 2016.

Furthermore, in 2006, it was decided that these assets should be maintained on the balance sheet of each company concerned, as opposed to creating an external funding structure, separate from the accounts of operators. Such a structure could then have been run by financial management professionals in various forms, similar to the practice in many countries.

These financial reserves are required to meet specific obligations: they must be clearly identified and separated from the operator's other financial assets. They must meet specific quarterly reporting obligations set out by the administrative authority. The financial reserves are described as "dedicated assets" or "hedging assets".

2 - Dedicated assets in the form of financial investments portfolio

As required by Article 20 of the Act of 28 June 2006 these assets must present "a sufficient level of security and liquidity to meet their goal". The recitals explaining the reasons for the law indicated that "in order to prevent and limit the costs that will be borne by future generations, the dedicated assets must present a sufficient level of security, diversification and liquidity. (...) It is also a question of ensuring that the operators adopt an asset-liability management capable of reducing the risks of a mismatch between liability flows and asset-generated flows (...)".

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This requirement resulted, through the application decree of 23 February 2007, in defining a restrictive list of asset types: Government bonds, shares of companies with their corporate head office in a European Union or OECD country, rights in rem, units in UCITS funds and other undertakings for collective investment, and money-market deposits.

Caps have been set by asset type to ensure a diversified portfolio. The caps are expressed as a percentage of the total of hedging assets and are defined by texts. They state that the same company or same group cannot issue securities that represent more than 5 percent of the realizable value of the hedging assets, or the realizable value of a building held as a hedging asset, and cannot exceed 2 percent of the realizable value of hedging assets. These limits are comparable to those set by the insurance code to regulate life assurance investments.

A number of securities were explicitly excluded in 2007 from the scope of hedging assets. Such was the case of "securities issued by the operator or by a company belonging to the same group as the operator", in other words, securities representing capital stocks or liabilities of the nuclear operator’s subsidiaries should be excluded\textsuperscript{152}, indeed these securities do not meet the diversification obligation as they are used in the very activity of the group concerned by the future costs. Exceptionally, operators who had already used this type of security at 31 December 2005 were allowed to retain them, provided they received specific permission from the administrative authority and within limits subsequently set by the latter.

Lastly, these reserve assets can neither be transferred nor loaned. The State has sole rights over the assets and exclusively for ensuring compliance with dismantling and waste management obligations \textsuperscript{153}.

\textsuperscript{152} Similarly, operators are not allowed to recognize their own real estate assets as dedicated assets.

\textsuperscript{153} These assets cannot be seized even in the event of bankruptcy.
3 - Financial investments that must yield sufficient returns

The purpose of setting aside financial assets as reserves is to ensure that operators will have sufficient financial reserves to cope with their future costs when they result in actual payments. These investments must therefore "bear fruit" and generate sufficient returns (dividends and expected higher value for shares, interests received for bonds and money-market investments) between their accrual date and payment date, to ensure that at the right time, the accrued assets match the payable costs.

As the dedicated assets should be equal to provisions, this increase in the value of the (asset) portfolio is to be compared with the discount rate used to calculate the present value of future charges. For this "fruit bearing" logic to work, it is actually important for recognized returns to be equal or greater than the discount rate in the long term. The largest operators in terms of volume, namely EDF, AREVA and CEA, who opted for nominal discount rate for their future charges of 5 percent, their placements must generate returns at least equal to 5 percent each year. In the opposite case, the portfolio must be increased to maintain equality between the assets and provisions.

We recall that the decree of 23 February 2007 states that "the discount rate cannot exceed the rate of return, expected with a high confidence level, from hedging assets managed with a sufficient degree of security and liquidity to meet their goal".

II - Different and evolving application procedures

A - Management of EDF's dedicated assets

1 - A steep increase in the portfolio

According to the Government-EDF plan, EDF was required to earmark dedicated assets for hedging its long-term nuclear commitments since 1997. The required amount was €1.2 billion in 2000. The financial investments portfolio now represents €13.5 billion (net asset value, excluding RTE) at 31 December 2010. Every year it receives cash allotments from the company's free cash flow, in other words the operating cash flow, from which investment-related flows are deducted.
Cash allotments to the EDF dedicated assets portfolio
(excluding securities of EDF subsidiaries)

<table>
<thead>
<tr>
<th>In €million current</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash allotments for the year</td>
<td>2 397</td>
<td>1 785</td>
<td>1 902</td>
<td>1 343</td>
</tr>
</tbody>
</table>

Source: EDF

For financial year 2010, the cash allotment to EDF’s dedicated assets portfolio amounted to €1.3 billion. This amount, reduced in relation to previous years, is supplemented by the incorporation, as dedicated assets, of half of the securities of the French national grid (RTE), subsidiary of EDF. In 2007, the year of maximum allotments, a total of around €200 million was allotted every month.

For the four year period ranging from 2007 to 2010, the recognized annual average performance was 1.90 percent. For a longer period ranging from 2003 to 2010, this annual average performance would be 5.76 percent. These results are necessarily very variable depending on the date selected to start the calculation and the level corresponding to stock market prices.

Annual performance of EDF’s dedicated asset portfolio, with coupons and reinvested dividends (excluding EDF subsidiaries)

<table>
<thead>
<tr>
<th>In €million</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change by using a 100 base at 1 January 2007</td>
<td>103</td>
<td>87.6</td>
<td>99.1</td>
<td>107.8</td>
</tr>
<tr>
<td>Recognized performance</td>
<td>+3%</td>
<td>-14.92%</td>
<td>13.08%</td>
<td>8.79%</td>
</tr>
</tbody>
</table>

Source: Reports on the long-term costs of the basic nuclear installations of operators and calculation by the Cour des Comptes.

154 We assume a sum of 100 invested as of 1 January 2007, that would change according to the annual performance rates recognized in 2007, 2008, 2009 and 2010. The amount obtained as of 31 December 2010 can be used to calculate an average annual return.

155 Source: Reports on the long-term charges of basic nuclear installation of operators and reference documents: calculation by the Cour des Comptes.
2 - The target composition of the portfolio

The organization of governance on this theme was reviewed after the Act of 28 June 2006. EDF created specific governance structures to monitor this assets portfolio. Several board of directors’ committees are concerned; the Comité de Suivi des Engagements Nucléaires (CSEN - Nuclear Commitments Monitoring Committee) composed of members of the board of directors and representatives of the company and which meets three times a year, the audit committee, which can give an opinion on this theme. Furthermore, a Comité d’Expertise Financière des Engagements Nucléaires (CEFEN- Nuclear Commitments Financial Expertise Committee), made up of independent persons from the company (market finances specialists), are tasked with helping the company and its corporate bodies on issues of investment choices, match between the assets held and the liabilities to be funded.

For example, EDF defined a "strategic allocation" of its portfolio, in other words a breakdown of investments between shares, bonds or other financial (money market) or investment (real estate) products, that meet legal constraints, namely hedging liabilities on a specific date, and which must normally allow EDF to obtain the expected annual rate of return of 5 percent (2.94 percent in real terms), in line with the selected discount rate. The baseline strategic allotment, thus defined, consists of investing in bonds or fixed-income products for a proportion ranging from 46 percent to 58 percent of the total, and investing in shares for a percentage ranging from 42 percent to 54 percent. This choice was based on the yields of equity and bond markets in the 20th century.

Annualized real return of financial assets

<table>
<thead>
<tr>
<th></th>
<th>Money market</th>
<th>10-year bonds</th>
<th>Shares</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>0.6%</td>
<td>2.5%</td>
<td>1.3%</td>
</tr>
<tr>
<td>Canada</td>
<td>1.6%</td>
<td>2.7%</td>
<td>2.0%</td>
</tr>
<tr>
<td>Denmark</td>
<td>2.3%</td>
<td>3.5%</td>
<td>3.0%</td>
</tr>
<tr>
<td>France</td>
<td>-2.9%</td>
<td>1.2%</td>
<td>-0.3%</td>
</tr>
<tr>
<td>Italy</td>
<td>-3.8%</td>
<td>-0.3%</td>
<td>-1.8%</td>
</tr>
<tr>
<td>Japan</td>
<td>-2.0%</td>
<td>0.4%</td>
<td>-1.3%</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.7%</td>
<td>1.8%</td>
<td>1.3%</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>1.0%</td>
<td>1.9%</td>
<td>1.3%</td>
</tr>
<tr>
<td>Sweden</td>
<td>1.9%</td>
<td>2.4%</td>
<td>2.4%</td>
</tr>
<tr>
<td>Switzerland</td>
<td>0.8%</td>
<td>0.4%</td>
<td>2.1%</td>
</tr>
<tr>
<td>USA</td>
<td>1.0%</td>
<td>1.3%</td>
<td>1.9%</td>
</tr>
</tbody>
</table>

Sources: Morningstar and Dimson, Marsh and Staunton, (2002); C. Gollier (2011)
3 - The consequences of the financial crisis

However with the occurrence of the financial markets crisis (collapse of Lehman Brothers in September, fall of equities markets), EDF no longer strictly complied with this baseline strategic allocation of assets between equities and bonds\textsuperscript{156} in 2008; thus, instead of the recommended strategy of a minimum of 42 percent of equities in the total portfolio, they had been reduced to just 33 percent at the end of 2008.

In April 2009, after several months of interruption in allotments to the dedicated funds\textsuperscript{157}, a decision was made \textsuperscript{158} to resume these allotments at an amount of €2,783 million by supplementing them with an additional allotment of €5.2 billion in mid 2011 in an attempt to meet the regulatory deadline for matching the value of dedicated assets to that of provisions, which had been set at June 2011. This supplement was to make up for the several months of interruption in allotments and the impact of the crisis. The potential loss in the portfolio’s value in 2008 can be estimated at €1.5 billion.

In reality, this scenario was not applied to the end since it was decided, with the agreement of the governing authority and the legislator, to extend the deadline from June 2011 to June 2016. Indeed, the French electricity market reform law (NOME), of 7 December 2010, granted to operators (but in practice only EDF can take advantage of this extension) an additional five-year period to accrue sufficient assets to fully hedge their liabilities, i.e., an objective date of June 2016.

Until 29 June 2016, the annual average allotment for dedicated assets must be positive or zero, after deducting projected cash outflows for ongoing dismantling operations and allotments for new expenses to be hedged by the dedicated funds.

EDF’s portfolio has been affected by other developments linked to the various financial crises. For instance, the 2007 decree limited the holding of currency-denominated assets to 20%, the CSEN and CFEN

\textsuperscript{156} This allocation was validated by the board of directors in July 2008 and was supposed to be regularly reviewed every three years barring any special circumstances.

\textsuperscript{157} Between October 2008 and July 2009, EDF stopped all allotments to this portfolio since the continued drop in stock prices would have have led to near instantaneous recognition of capital losses on the purchased securities.

\textsuperscript{158} Minutes of the Nuclear Commitments Monitoring Committee (CSEN) meeting on 9 April 2009.
committees accepted the principle of holding such assets as a full-fledged components of the financial risk diversification plan.

4 - Using the RTE's securities as dedicated assets

In 2011, EDF, which fully owns RTE, assigned half of RTE's securities to its portfolio of dedicated assets, for a value of €2.3 billion, i.e., the net book value of these securities. Yet, until 2010, the regulatory framework had explicitly discarded the possibility of considering the securities of a nuclear operator's subsidiary as dedicated assets.

A decree was therefore enacted, on 29 December 2010, to amend certain provisions of the decree of 23 February 2007. This decree, specifically enacted to make such securities admissible as dedicated assets, introduces an exception to article 4-III, for the units of the "company provided for by article 7 of Act no. 2004-803 of 9 August 2004", in other words RTE, on condition that the closest future costs (cash outflows in the next five years) are already hedged by equity and bond type financial assets.

The admissibility of these assets was approved by the administrative authority, the DGEC. It also approved exceeding the 2 percent threshold limit set for the capital of a single company, which is the consequence of this exception for RTE units159.

According to EDF and its governing authorities, the assignment of RTE securities, with regular and foreseeable returns in the long term, has the beneficial effect of "reducing volatility" of the portfolio.

However, in terms of diversification and of liquidity, the use of RTE securities for constituting the dedicated funds is debatable.

On one hand, the 2007 decree had explicitly excluded the assets accrued by the subsidiaries, since they are involved in the very activity of the relevant group, which is not a measure of risks diversification. It is however true that the characteristics of RTE and its independence with respect to its parent, in the context of European directives, make it a subsidiary with a very special status.

159 The decree also introduced other changes, especially the possibility of taking receivables from European Union Members States as dedicated assets.
On the other hand, given that RTE is a fully regulated company, the liquidity of its assets is highly debatable. It implies that EDF would not hesitate to sell the French national grid company to finance the dismantling its nuclear installations. Yet, under French constitutional law\textsuperscript{160}, the buyer has to be a public entity, or the State itself, which amounts to making the State guarantee these assets, even if, in exchange, the State would become the owner of a long-term asset; from a budget standpoint, this "reacquisition" by RTE would have a visible impact.

EDF specified to the Cour des Comptes on this point that the "assignment of [RTE securities] does not mean that EDF does not rule out the possibility of selling the French national grid company, which is impossible in the current state of the legislation. It means that the dividends paid by RTE will be assigned to the portfolio of assets dedicated to the full amount of the percentage of assigned securities. This flow of dividends represents the economic advantage of this assignment". Yet, in the texts, it is indeed the sum of the value of the dedicated assets and of the profits of the investment thereof that should hedge the provisions as a whole, and taking the value of RTE's securities into account means that EDF does not have to invest in other assets.

5 - The management costs of the dedicated assets portfolio

Management costs correspond to the payment of custody, reporting and custodial fees for the securities (BNP-Paribas is the custodian) as well as the management fees and expenses paid to the management companies, calculated as a percentage of the total managed asset, of 0.24 percent in 2008, then 0.25% in 2009 and 0.31% in 2010. Therefore holding and managing this significant securities portfolio has a high price where the amount has clearly gone up in 2010, particularly due to the increase in management costs that year.

\textsuperscript{160} Cf. preamble to the French Constitution (paragraph 9): "Any property, undertaking, whose operation has or acquires the characteristics of a national public service or de facto monopoly, shall become the property of the community". The situation is different in other countries, in the United Kingdom for example.
Management costs and custody costs of the portfolio of dedicated assets from 2008 to 2010

<table>
<thead>
<tr>
<th>In €million current</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Custody costs of securities, custodial fees and reporting services</td>
<td>0.7</td>
<td>0.8</td>
<td>0.9</td>
</tr>
<tr>
<td>Management fees collected by the management companies</td>
<td>21.6</td>
<td>21.9</td>
<td>38.7</td>
</tr>
<tr>
<td>Total costs linked to the securities portfolio</td>
<td>22.3</td>
<td>22.7</td>
<td>39.6</td>
</tr>
</tbody>
</table>

Source: EDF

6 - Situation of the portfolio at 31 December 2010

At the end of 2010, there was a gap of around two billion between the realizable value of the dedicated assets portfolio and the provisions to be hedged. This gap doubles if RTE’s securities are not taken into account.

EDF summary of amounts in 2010

<table>
<thead>
<tr>
<th>€million 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total provisions for end-of-lifecycle operations to be hedged by dedicated assets</td>
</tr>
<tr>
<td>Carrying amount</td>
</tr>
<tr>
<td>Total assets corresponding to these provisions</td>
</tr>
<tr>
<td>Total excluding RTE securities of which</td>
</tr>
<tr>
<td>Bonds (Governments and private sector)</td>
</tr>
<tr>
<td>Directly-held shares</td>
</tr>
<tr>
<td>Reserved investment funds</td>
</tr>
<tr>
<td>Money-market UCITS</td>
</tr>
<tr>
<td>The subsidiary's securities (RTE)</td>
</tr>
</tbody>
</table>

Source: EDF reference document

* value of RTE securities in EDF’s corporate accounts corresponding, for the book value, to 50 percent of the contribution value of RTE in 2005 and for the realizable value to 50 percent of the net asset value of RTE as at 31 December 2010
B - Management of AREVA's dedicated assets

1 - Changes in and organization of the AREVA portfolio

The first cash reserves were accrued by COGEMA from 1993 onwards, in equities (French, then European as from 1997), directly held and representing significant interests in the capital of the companies concerned. The first investments in bonds to hedge future expenses were made in 2003 and 2005 for the subsidiary AREVA NC. In the same way, EURODIF, a subsidiary started building from 1999, funds composed of European equities, then it added bonds in 2004.

Today, for the AREVA group, dedicated assets are classified in three subsets corresponding to combinations of subsidiaries: AREVA NC, AREVA NP and EURODIF.

For these three sub-sets of the group, there are two separate portfolio managements. Indeed, the so-called AREVA NC portfolios (€3,463 million at 31 December 2010) and AREVA NP (€23 million) are managed by the AREVA parent company, while the dedicated assets of the EURODIF portfolio (€618 million as of 31 December 2010), which corresponds to the commitments and the assets of subsidiaries Eurodif Production and Socatri, are managed by Eurodif, subsidiary of AREVA. This separation can be explained primarily by the special nature of Eurodif's shareholding structure which includes several foreign shareholders, namely Synatom (Belgium), Enusa (Spain), Sofidif (Iran), and Enea (Italy).

Among the dedicated assets earmarked to finance future costs and entered against provisions under liabilities, the AREVA group recognizes

\[\text{AREVA NC} \quad \text{(Nuclear Cycle) is the AREVA subsidiary which took over the activities of the former COGEMA in 2006 around uranium as a nuclear fuel: operation of mines, fuel production and enrichment, spent fuel processing and recycling and cleaning-up and dismantling of facilities. In France, AREVA NC runs the Hague reprocessing plant, the Marcoule and Pierrelatte nuclear sites (the Tricastin nuclear site).}
\]

\[\text{AREVA NP} \quad \text{(Nuclear Power) is the subsidiary of AREVA which since 2006 has been pursuing the activities of the former FRAMATOME: construction of reactors and large components for nuclear plants, services to nuclear operators (outage, preparation of nuclear fuels).}
\]

\[\text{EURODIF} \quad \text{is the AREVA subsidiary specialized in uranium enrichment on the Tricastin site (Georges-Besse I plant).}
\]
several receivables as well as funding expected from third parties, for a total amount of €1,475 million.

**Composition of the AREVA group's three portfolios of dedicated funds as at 31 December 2010**

<table>
<thead>
<tr>
<th>€million 2010</th>
<th>AREVA NC</th>
<th>EURODIF</th>
<th>AREVA NP</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Securities</td>
<td>3,463</td>
<td>618</td>
<td>23</td>
<td>4,104</td>
</tr>
<tr>
<td>CEA receivable</td>
<td>550</td>
<td>-</td>
<td>-</td>
<td>550</td>
</tr>
<tr>
<td>EDF receivable</td>
<td>648</td>
<td>-</td>
<td>-</td>
<td>648</td>
</tr>
<tr>
<td>Other receivables</td>
<td>63</td>
<td>-</td>
<td>-</td>
<td>63</td>
</tr>
<tr>
<td>Third-party share</td>
<td>211</td>
<td>-</td>
<td>3</td>
<td>214</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>4,935</td>
<td>618</td>
<td>26</td>
<td>5,579</td>
</tr>
</tbody>
</table>

Source: Annual update note (2010) of the AREVA report on the long-term costs of AREVA basic nuclear installations and on the management of dedicated financial assets; Cour des Comptes calculation

Until 31 December 2010, there was receivable due from EDF, which was settled in June 2011. In fact, EDF had agreed to bear a fraction of the costs of dismantling the La Hague site. The value of the commitment was calculated and EDF paid the corresponding sum (cash payment) in four instalments to AREVA. Meanwhile, this sum was considered as a receivable and admitted by the administrative authority as a hedging asset. The cash payment was made in three instalments: €1,272 million in 2009, €633 million in 2010 and €648 million in 2011 (1 July), representing a total of €2.6 billion.\(^{163}\)

Different investment strategies are used to manage the various portfolios of the group's subsidiaries. This is because the hedged entities have different expenditure profiles: the weight of equities in the portfolio is adjusted up in proportion to the time frames of the expenditures to be financed. For example, since the Georges Besse 1 (uranium enrichment through gaseous diffusion) is scheduled to shut down in 2012, the EURODIF portfolio is made up of liquid assets (fixed income products) that can be rapidly used.

---

\(^{163}\) All spent fuel management operations for power plants in France are carried out in the AREVA group plant in La Hague. These operations are performed in the context of the EDF-AREVA framework agreement of 19 December 2008. The framework agreement led to the signature with AREVA on 12 July 2010 of the processing-recycling agreement and the waste recovery and conditioning protocol and the shut down and dismantling of the La Hague plant (RCD-MAD-DEM protocol). This protocol defines EDF's contribution to the deconstruction costs of facilities in La Hague, and sets the amount of a final balancing payment to be paid by EDF to AREVA.
For AREVA NC and AREVA NP, the "end-of-lifecyle operations monitoring committee" has recommended since 2007, based on the studies of AXA Investment Managers and Mercer investment consulting, to adopt in the long term an allocation consisting of 40 percent of so-called "diversified" assets (namely equities\textsuperscript{164}, as well as emerging and high-yield bonds, investment properties) and 60 percent so-called « backing » assets, in the form of government bonds whose maturities would be aligned with the expenditure schedules. Structurally, the "diversified" portfolio is slightly riskier than the asset-backed portfolio, but the expected return is higher.

Overall, at year end 2010, the amount of dedicated assets (€5,578 million in net asset value) was slightly higher than that of the provisions to be hedged (€5,456 million). The portion of assets held in the form of listed financial securities, immediately realizable, amounted to €4,103 million, which represents 74 percent of the amount of accrued charges (scope of the Act of 28 June 2006). The outstanding portion comprises commitments taken by third parties to finance these future costs, the substantial part of these commitments is borne by the CEA and EDF.

AREVA - summary of amounts in 2010

<table>
<thead>
<tr>
<th></th>
<th>£million 2010</th>
<th>2010</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total provisions to be hedged by dedicated assets*</td>
<td></td>
<td>5 456</td>
<td></td>
</tr>
<tr>
<td>Total assets corresponding to these provisions</td>
<td></td>
<td>5 579</td>
<td></td>
</tr>
<tr>
<td>Financial investment securities</td>
<td>Carrying amount (3 805), Net asset value (4 104)</td>
<td>550</td>
<td>648</td>
</tr>
<tr>
<td>CEA receivables</td>
<td></td>
<td>3 805</td>
<td>550</td>
</tr>
<tr>
<td>EDF receivables**</td>
<td></td>
<td>648</td>
<td></td>
</tr>
<tr>
<td>Other receivables (ANDRA)***</td>
<td></td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>Share of third-parties in provisions (receivable)</td>
<td></td>
<td>214</td>
<td></td>
</tr>
</tbody>
</table>

Source: Annual update note (2010) of the AREVA report on the long-term costs of AREVA basic nuclear installations and on the management of dedicated financial assets.

* o/w some provisions outside the scope of the Act of 28 June 2006

** receivable settled in 2011

*** more specifically, this is a receivable from the other nuclear operators due to the disagreement between operators on the breakdown of expenditures linked to the disposal project for ANDRA's long-lived high-level waste (LLHLW)

\textsuperscript{164}AREVA includes its receivable due from CEA which bears a 5 percent interest rate.
2 - Return on the portfolio and management cost

The profitability of the securities portfolio fell sharply due to the 2008 crisis, even more so than the EDF portfolio.

**Average profitability of the group's securities portfolio* (AREVA and Eurodif)**

<table>
<thead>
<tr>
<th></th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>Annual average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start index 100 on 1 January 2007</td>
<td>103.80</td>
<td>75.88</td>
<td>86.65</td>
<td>92.20</td>
<td>-</td>
</tr>
<tr>
<td>Performance of dedicated assets (dividends and reinvested coupons)</td>
<td>3.80%</td>
<td>-26.9%</td>
<td>14.20%</td>
<td>6.40%</td>
<td>-2.01%</td>
</tr>
</tbody>
</table>

*Source: AREVA and Cour des Comptes calculation
* therefore excluding remuneration of the receivable held by AREVA on EDF

By extending the period under observation, the average annual performance improves. In 2005, the performance of the asset portfolio was +20 percent and in 2006 +14 percent. Thus, by retaining the 2005+2010 period, the annual average performance would be +5.22 percent.

However, the report on the long-term charges of AREVA’s basic nuclear installations and on the management of the dedicated financial assets stresses that since the beginning, the dedicated funds excluding receivables have reported an annual average performance of +8.6 percent.

**Comparison of the historic values and market values for AREVA’s securities portfolio (all subsidiaries)**

<table>
<thead>
<tr>
<th></th>
<th>€million</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>The portfolio’s historic acquisition value on 31/12</td>
<td>2 022</td>
<td>2 019</td>
<td>3 242</td>
<td>3 806</td>
<td></td>
</tr>
<tr>
<td>Net asset value on 31/12</td>
<td>2 623</td>
<td>1 767</td>
<td>3 314</td>
<td>4 104</td>
<td></td>
</tr>
<tr>
<td>Difference between acquisition value and net asset value on 31/12</td>
<td>601</td>
<td>- 252</td>
<td>72</td>
<td>298</td>
<td></td>
</tr>
</tbody>
</table>

*Source: Annual update note of the AREVA report on the long-term costs of AREVA’s basic nuclear installations and on the management of dedicated financial assets and calculation of the Cour des Comptes.*
C - Management of CEA's dedicated assets

The CEA created a dedicated fund for financing the end-of-lifecycle obligations of civil facilities in 2001, at the time where the AREVA group was created from CEA subsidiaries. In March 2002, the first study of backing between the liabilities to be financed and the hedging assets had resulted in selecting a portfolio composed of 70 percent eurozone bonds and 30 percent eurozone equities. The principle of monetizing AREVA shares had already been adopted.

Just as EDF and AREVA, from 2006 onwards, the CEA continued allotments to a portfolio of financial assets, intended to hedge its long-term nuclear costs 165. However, at the end of 2009, the dedicated funds showed a depleting cash position and a legally non-compliant balance sheet. This was because the CEA had begun its dismantling operations several years ago and therefore needed to pay for the related expenditure.

Thus, in 2009, the CEA paid its suppliers for the dismantling works carried out by raising part of the dividend received from AREVA (€104 million) and a fraction of the cash payments received from other nuclear operators. But it also had to dip into the depleting resources of its dedicated funds (both civil and defence funds).

In light of this situation, the Nuclear Policy Council met on 12 February 2010 and decided to prepare a budget to finance the CEA's long-term nuclear costs instead of granting it the means, through subsidies, to rebuild its dedicated assets up to the full amount of its provisions.

This change of approach was set out in a framework-agreement between the State and the CEA, signed on 19 October 2010. Through this agreement, the State pledged to guarantee the equilibrium of the balance sheet of the CEA's long-term nuclear costs through a receivable from the State to the CEA, for an amount of €904.5 million under the civil fund as of 31 December 2010. Comparatively, the equivalent receivable for the Defence fund amounts to €6,017.2 million. The two funds have separate accounting and management systems. However, the CEA's potential cash needs may concern either of the funds. The other point consisted in recording under the assets of the civil fund, a greater portion of AREVA's capital held by the CEA. This portion was 15 percent and an additional

165 From 2007 to 2010, the dividend collected by AREVA, subsidiary of CEA, was assigned to a civilian fund for an amount of €104 million a year. The total dividend collected was €319.6 million in 2007, €314.2 million in 2008, €375.4 million in 2009, and €176.1 million in 2010.
15 percent was added to it. After AREVA's capital increase at the end of 2010, the securities assigned to the civil and defence funds therefore represented 27.83 percent of AREVA's capital. The State and the CEA agree on the required financing for a three-year period. This allows the CEA to draft contracts to cover operations with its suppliers.

In the event of foreseeable insufficient funds for the next twelve years, and taking account of the contributions already planned by the government to the CEA, the CEA may sell AREVA shares to the State, at a price corresponding to the "fundamental value of the corporation", in this case defined by the stock market price of AREVA shares.

However, in a period of significant decline in the share price, the mechanism in place requires revaluation of the amount of the receivable from the State depending on the change in the value of AREVA shares. Basically, through one mechanism or other, the State is the sole guarantor and payer of the dismantling costs of the CEA public institution.

**Average profitability of CEA's marketable securities**

<table>
<thead>
<tr>
<th></th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>Annual average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start index 100 on 1 January 2007</td>
<td>103,0</td>
<td>88,8</td>
<td>99,1</td>
<td>100,8</td>
<td>-</td>
</tr>
<tr>
<td>Performance of dedicated assets (dividends and reinvested coupons)</td>
<td>2,97%</td>
<td>-11,87%</td>
<td>11,61%</td>
<td>1,69%</td>
<td>+0,74%</td>
</tr>
</tbody>
</table>

*Source: CEA and Cour des Comptes calculation*

The return on the CEA’s investments in marketable securities for the last years and which now represent €576.3 million has been fluctuating as shown by the table above, but rather better than those of AREVA. Indeed, following a study conducted in March 2002, an asset allocation for the civil fund had been adopted consisting of 70 percent bonds and 30 percent eurozone equities. In July 2009, considering the uncertainties about the future of the fund, the share of equities was lowered to 25 percent. Reducing the sensitivity of these assets to interest rate risks and equity market risks has been completed since January 2010 and the fund is now fully composed of money-market products. The reduced exposure to equity market risk during the period explains the relatively high performances of the CEA’s portfolio compared to those of other operators.

166The AREVA investment certificate was worth €37 on 30 December 2010 and €30 on 20 October 2011.
In its 2009 report, on the evaluation of dismantling and cleaning-up charges for its nuclear facilities, the CEA indicated that since the beginning, namely 2001, the annualized performance of the civil fund's investments was 3.98 percent in nominal value and 2.2% in real value.

**CEA – situation of dedicated assets at 31 December 2010**

<table>
<thead>
<tr>
<th>€million</th>
<th>Civil fund</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total provisions to be hedged by dedicated assets</td>
<td>4 453</td>
</tr>
<tr>
<td>Realizable value</td>
<td></td>
</tr>
<tr>
<td>As of 31/12/2010</td>
<td></td>
</tr>
<tr>
<td>Total assets corresponding to these provisions</td>
<td>3 131</td>
</tr>
<tr>
<td>Receivable from the State</td>
<td>905</td>
</tr>
<tr>
<td>Receivables from third parties</td>
<td>10</td>
</tr>
<tr>
<td>AREVA stock</td>
<td>2 295</td>
</tr>
<tr>
<td>Marketable securities</td>
<td>576</td>
</tr>
<tr>
<td>( o/w unrealized capital gains)</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3 786</strong></td>
</tr>
<tr>
<td>Debt towards AREVA NC</td>
<td>-550</td>
</tr>
<tr>
<td>Settlement for the 2010 financial period</td>
<td>-105</td>
</tr>
</tbody>
</table>

*Source: CEA update note of the report on the evaluation of dismantling and cleaning-up charges for CEA nuclear facilities, position as of 31 December 2010.*

### III - Thoughts on the current situation

Despite the different situations for each of the operators, the general development of the system, especially in the recent period of the global financial crisis, has raised many questions about the future of the sector.

International comparisons show moreover that the solutions adopted by the various countries to guarantee the financing of future expenditures linked to the nuclear sector are very different. They often make a difference between dismantling expenditures and spent fuel and waste management expenditures (see Annex 19).
A - Moving away from the initial goal

As of 31 December 2010, the portion of assets held in the form of immediately realizable listed financial securities, amounted to €18,170 million out of a total of €27,819 million of discounted accrued charges slated to be hedged by dedicated assets, i.e., 65.3 percent of the total.

Apart from a portion for which hedging was not yet mandatory on that date (€2,745 million), other types of hedging assets were recognized for a total of €6.9 billion. The bulk of this amount (€4.6 billion) is directly or indirectly is the responsibility of the State, the rest comprising RTE's stock (€2.3 billion) the nature of which has already been reviewed above (II-A-4).

Summary with figures for all operators as of 31 December 2010

<table>
<thead>
<tr>
<th>Emillion</th>
<th>27 819</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total provisions for end-of-lifecycle operations</td>
<td></td>
</tr>
<tr>
<td>of which EDF</td>
<td>17 910</td>
</tr>
<tr>
<td>of which AREVA</td>
<td>5 456</td>
</tr>
<tr>
<td>of which CEA (civil fund)</td>
<td>4 453</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Financial securities and investments</th>
<th>18 170</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDF’s financial securities and investments portfolio</td>
<td>13 491</td>
</tr>
<tr>
<td>AREVA’s financial securities and investments portfolio</td>
<td>4 103</td>
</tr>
<tr>
<td>Portfolio of securities held by CEA</td>
<td>576</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other hedging methods</th>
<th>6 904</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTE stock</td>
<td>2 324</td>
</tr>
<tr>
<td>AREVA stock held by CEA</td>
<td>2 295</td>
</tr>
<tr>
<td>CEA’s receivable from the State</td>
<td>905</td>
</tr>
<tr>
<td>AREVA’s receivables from EDF</td>
<td>648</td>
</tr>
<tr>
<td>AREVA’s receivables from CEA</td>
<td>550</td>
</tr>
<tr>
<td>AREVA’s receivable from ANDRA*</td>
<td>63</td>
</tr>
<tr>
<td>Other AREVA receivable from third parties</td>
<td>214</td>
</tr>
<tr>
<td>CEA receivables from third parties</td>
<td>10</td>
</tr>
<tr>
<td>CEA adjustment with funds defined for 2010</td>
<td>-105</td>
</tr>
</tbody>
</table>

| Outstanding hedging to accrue | 2 745 |

Source: Reports on the long-term charges of the basic nuclear installations of operators

*** receivable from other nuclear operators about the breakdown of expenditures linked to ANDRA’S LLHLW disposal project.
Schematically, we can consider that the hedging assets now have two distinctive forms and different nature: a first category comprises financial investments (fixed-income products or equity) made from cash allocations. The second category brings together all other asset types: receivables, investment securities (in AREVA for the CEA or in RTE for EDF). For this category, there is no organized and permanent market where the assets can be converted into cash. However, the State appears directly or indirectly as the lender of last resort. The State is the shareholder of three operators and the debts owed by one to the other are ultimately the State's debts to itself. In the same way, when the State undertakes to buy AREVA stock, in order to finance the CEA's costs, it is in fact buying the stock from itself.

The changes observed, especially for EDF and CEA, show that the initiative of building a portfolio of financial assets intended to cover the entirety of future charges has been stagnating. Two factors are particularly significant:

- **The increasingly frequent use of exceptions to accept the equity stock of operators' subsidiaries as hedging assets.**

  The decree of 2007 already allowed some operators to use the value of the securities of their subsidiaries as hedging assets. But this possibility was supposed to be regulated by the State. These exceptions have been beneficial to the CEA since the beginning, allowing it to use AREVA's stock.

  By accepting these exceptions, allowed by the 2007 decree (registration of debts between operators, registration of AREVA's securities for the CEA), the State has gradually confirmed that the assets initially accepted on an exceptional basis and in proportions to be defined, were comparable to the other assets (shares, diversified bonds) described by the texts.

  However, it is obvious that the "consanguinity" of the stocks in the area of electricity is neither a factor of diversification, nor a limitation of risks with respect to the change in the value of securities.

- **Partial re-budgeting of the funding**

  The State-CEA framework agreement drawn up in October 2010, which translates the State's commitment to guarantee the equilibrium of the balance sheet of the CEA's long-term nuclear costs, replaces the obligation for the institution to hold a securities portfolio.
Similarly, various crossed receivables, between corporations in the nuclear or energy sector and the State, are now considered as assets intended to secure future financing costs. This development goes against the legislator’s wish as expressed in the Act of 2006.

By making the State the last-resort financer of the long-term nuclear costs, this development postpones over time and transfers substantial future charges to public finances, around €6.9 billion (using the calculation assumptions and future charges updates and evaluation currently adopted by operators). This estimate also assumes that allotments that have not been made yet would be done for a total of €2.7 billion.

**B - The financial crisis reveals the weaknesses of the system**

The financial and stock market crisis reveals the weaknesses of the system:

- The law entrusted operators themselves with the management of their dedicated assets but financial investment is not part of their core business

In France, unlike other countries, the choice was made to entrust operators with the management of their dedicated assets. This choice, which results in asking industrial operators to manage substantially large assets (€18 billion for EDF and AREVA) is based on the presumption of strict governance of these funds for the State to be able to ensure their adequate management in highly unstable markets. All operators have tried to set up ad hoc structures to properly handle the management of these funds, and yet the financial and human resources that can be harnessed for this purpose vary from one operator to another. The particularly turbulent and complex stock market situation that has persisted over the past years underlines the need for the right skills.

- Uncertainties on the portfolio’s value

Investments intended to finance future costs present risks that have sharply increased in recent years. For EDF, half of its securities portfolio is made up of equities, and their value is subject to price fluctuations. The risks of a decline in the portfolio’s value were realized between 2008 and 2011 when stock prices fell sharply.
The other fifty percent consists primarily of government debt securities. Given the current difficulties of a number of European Union member countries to redeem their loans, such bond investments can no longer be considered risk free.

As indicated by EDF in its reference document in the chapter on group risks, one of the risks nuclear operators have to cope with is that "the investments might not be sufficient and this could lead to the need for additional cash outflows", namely buying additional securities to ensure equality between the assets and the provisions which the return on the currently-held assets cannot do. Uncertainties on the portfolio's return and its consequences on the discount rate

The regulation requires that the discount rate used to calculate provisions must be lower than the rate of return "expected with a high confidence level, from hedging assets managed with a sufficient degree of security and liquidity to meet their goal"167.

In the past four years, this condition has not been met, neither for AREVA, nor for EDF. In the case of AREVA, which lost nearly 27 percent of the value of its investments in 2009, the average annual performance was -2 percent for the last three years. This performance is improved if the time horizon under consideration is longer: thus, reckoned from the very first share purchases made in 1993, it would be equal to +8.6 percent a year. But since the 2008 economic crisis which continues to linger, it is rather difficult to guarantee the profitability of a portfolio, especially if we want to avoid taking too many risks.

Furthermore, on a like-for-like mechanism, if this change were to lead to a downward adjustment of the discount rate for provisions, the volume of provisions to be accrued under liabilities would be higher and the financial assets hedge would have to grow by the same proportions. This necessary increase in the portfolio will further increase the long-term investment of capital in a financial investment activity which, as explained earlier, is not the prime profession of a nuclear facility operator.

• Uncertainties about the exact time of the cash outflows for these costs

As mentioned earlier during the board of directors meeting of 21 January 2011, one of the arguments used to request for an extension of the deadline for building EDF's dedicated asset portfolio, which had to be initially completed in June 2011, was the possibility of postponing these cash outflows over time if the plan to extend the term of operation had been implemented and accepted by the Nuclear Safety Authority. But the converse assumption could also be envisaged for all or part of the current 58 reactors.

C - An imperfect system of governance

The Act of 28 June requires the creation of a National Committee for the Evaluation of Funding for the costs of dismantling basic nuclear installations and spent fuel and radioactive waste management, the CNEF, specifically in charge of monitoring the financial aspect of future costs. The committee is tasked with checking that the provisions match costs and checking the management of dedicated assets, and can "at any time, forward its opinion on issues within its purview to Parliament". The committee's opinions can be rendered public.

Details of the committee's membership were published two years later by a decree dated 20 June 2008. It includes the presidents of ad hoc energy or finance parliamentary and Senate commissions or their representative, four qualified key people designated equally by the Assemblé Nationale and the Senate and four qualified people appointed by the Government for six years.

The law requires that the committee submits to Parliament and to the committee for the transparency and information on nuclear safety, every three years, a publicly disclosed report in which it presents its observations. In fact, this commission sat for the first time in June 2011, five years after its creation.

In light of its limited room for action, since it is not empowered to control the level of provisions that require hedging by dedicated assets, the committee has limited capacity to provide governance adapted to the need to clearly and accurately analyse these subjects.
CONCLUSION – DEDICATED ASSETS

Operators had started accruing financial reserves to finance their provisions before the introduction of the 2006 legislative framework. At the end of 2010, the aggregate provisions of the three operators to be hedged by dedicated assets (i.e. excluding the operating cycle) amounted to a total of €27.8 billion. This amount mainly covers the provisions for dismantling installations and those for medium/long-term waste management. There are various schedules for cash outflows.

The amount of these provisions is based on assumptions and estimates and on the choice of a nominal discount rate, currently 5 percent. These €27.8 billion are composed of portfolios of financial assets, as initially stipulated by the decree of 23 February 2007, around €18.2 billion (equities, bond and money-market investments).

Exceptions were gradually introduced which now allow the recognition of other types of assets for securing the financing of future costs, especially receivables between operators and receivables from the State. This development is far from the initial spirit of the legislative framework and leads for example, in the case of CEA, re-budgeting the required funding. It postpones future costs in time and transfers them to public finances.

In a period of global financial crisis, management of these assets involves a greater investment risk. For EDF for example, half of its securities portfolio is made up of equities, and their value is subject to price fluctuations. Admittedly, the performance of such portfolios must be considered over a very long period in light of the expenditure schedules. However, the risks of a decline in the portfolio’s value may materialize, as it did between 2008 and 2011 with the steep fall in stock prices. The other half comprises bonds which are not totally risk-free, as shown by the current difficulties of a certain number of European Union member States to repay their debt. If the returns on their investments prove to be insufficient, this would require additional cash outflows to raise the portfolios.

Furthermore, the texts require the discount rate to be modelled on the portfolio’s return; for the last four years, the return obtained has been lower than the discount rate used. The return gets better over a long period, and the ratio between the two rates are reversed but the current framework does not specify how an adjustment of the discount rate should intervene with respect to the insufficient financial performances, especially concerning the period over which the comparison must be made.
The mechanism created by the Act of 2006 had provided for the creation of a commission specifically in charge of monitoring financial commitments. It did not meet between the year of its creation (2006) and June 2011, even though this period was marked by substantial hazards on financial markets, leading to huge consequences on investments in dedicated assets. Accordingly, operators implemented their asset portfolio management method, public authorities granted exceptions to the principles initially set out in the legislative and regulatory texts, without this commission having the right to present an external and independent view on the governance of funds and the balances between assets and liabilities.

The Cour des Comptes recommends that this subject should be re-examined and amended if necessary, because a system where the initial structure and logic of the mechanism are amended by various exceptions each time a new difficulty arises is not very productive.
Chapter VI

Possible developments in future expenditure

The figures for future spending by operators are based on various assumptions that might be called into question. Two items are particularly structuring: plant service life and the spent-fuel management related to setting up a Generation IV sector. In addition, investment costs and operating costs for the reactors that are to replace the existing reactors, i.e. for EPRs, are also major factors in how expenditure might develop over the coming years.

Depending on how these parameters progress, various variants are imaginable and can constitute food for thought, with the figures still being very uncertain today.

I - Two major factors in expenditure development

A - Plant service life

The current nuclear power plant fleet had an average age of 25 years at the end of 2010. During the period from 2017 to 2019, six of the oldest units will reach their fortieth year in operation (on the Fessenheim and Le Bugey sites), and then 18 other units will join them during the period from 2020 to 2022; in all, ten years from now, 24 of the 58 reactors will have clocked up service lives of 40 years. The particular characteristics of operating a nuclear reactor, in terms of
corrosion, irradiation, or pressure, for example, mean that the components are subjected to extreme stresses. The resulting ageing affects both the “replaceable” components (steam generators, electricity generators, condensers, and primary and secondary circuit piping), and also the non-replaceable components of the plant, namely the reactor pressure vessel, and the containment buildings (seen Annex 14). In addition to the ageing of the facilities, safety knowledge is changing as are the instructions and requirements that the Autorité de Sûreté Nucléaire (ASN, French Nuclear Safety Authority) may issue to operators in the course of its inspection and monitoring duties, pursuant to the French Nuclear Security and Transparency Act (“TSN” Act) of 13 June 2006.

These various constraints on EDF, not only as regards compliance with regulations and respect for safety, but also as regards optimizing its operation (by preventing malfunctioning/failures and unscheduled outage that drags availability down), presupposes a maintenance investment programme whose scale depends in part on the service lives of the power plants.

1 - What is the service life of a power plant?

a) French regulations

French regulations do not make provision for any limitation over time in the authorization to operate a nuclear power plant. Instead, they are based on periodic safety reviews on which continued operation depends.

Operators are obliged, at regular intervals of a maximum of ten years\(^{168}\), to review the safety of each facility. This rule was established formally by the “TSN” Act of 13 June 2006 (Article 29)\(^{169}\), which specifies that: “the review should make it possible to assess the situation of the facility as regards the rules that are applicable to it, and to update the assessment of the risks or drawbacks that the facility has, while taking into account, in particular, the state of the facility, the experience acquired during operation of it, and developments in knowledge and in the rules applicable to similar facilities”.

\(^{168}\) These reviews may also be referred to as “ten-yearly inspections” but a different frequency may be decided if the specificities of the facility so warrant.

\(^{169}\) Article 29 1 “For application of the decree of authorization, and in compliance with the general rules laid down in Article 36, the ASN defines the requirements that it deems necessary relating to design, construction, and operation of the facility”.


At the end of the review, and in a report to the ASN and to the relevant ministers, the operator presents the findings and the measures envisaged for remedying “the observed anomalies, or for improving the safety of its facility”. After analysing the report, the ASN gives its opinion to the relevant ministers, and it may require new technical specifications or requirements.

The French regulations make provision for the safety requirements not to be set permanently, but rather for them to change over time, depending on the progress of knowledge and on the return on experience relating to operating or to incidents in reactors across the world, with a view to achieving the best international practices\textsuperscript{170}. This principle now also appears in the Directive 2009/71/Euratom of 25 June 2009 establishing a Community framework for the nuclear safety of nuclear installations. That directive provides (Article 4) that “Member States shall ensure that the national framework is maintained and improved”.

Thus, since the reactors making up the current fleet were commissioned, safety requirements have changed significantly. The EPR, in particular, has safety characteristics superior to those of the rest of the nuclear power plant fleet.

\textit{b) The service lives of the power plants in the EDF accounting system}

The 58 reactors of the “Pressurized Water Reactor” (PWR) sector were built to operate for a period that, when the programme was designed, was estimated at 40 years. Originally, that period was assessed with regard to the physical properties of the steel of the reactor vessel and to the anticipated ageing thereof: the 40 years correspond to the duration determined by the models available at the time for which the walls of the vessel could be irradiated, with a load factor of 80%, without the metal losing its essential safety characteristics (toughness, breaking strength in the event of cold thermal shock). Assuming that the load on the core is continuously at its maximum (100%), that period would be 32 years, measured in “equivalent full-power days”\textsuperscript{171}.

\textsuperscript{170}Article 29 III of the French “TSN” Act: “Operators of basic nuclear installations shall periodically review the safety of their installations while taking into account the best international practices”.

\textsuperscript{171}ASN Document, January 2010 “Le contrôle des équipements sous pression des réacteurs nucléaires” ("Inspecting the pressure equipment of nuclear reactors"). Measuring maximum fluence, i.e. total quantity of neutrons the vessel can receive.
Economically, the reference period that was initially chosen in the accounts for calculating depreciation was 30 years. It was increased to 40 years on the initiative of the firm in 2003, and has not been changed since.

In July 2009, the ASN gave a partial opinion on the subject, indicating that it had not identified any generic problem calling into question the capacity of EDF to secure the safety of its 900-MW reactors for up to 40 years, with it being necessary for the capacity of each reactor taken individually to be examined during the course of the ten-yearly inspections of each reactor\textsuperscript{172}. It has not, as yet, given any opinion on the reactors of the other series.

\textbf{2 - What is the expected future expenditure for continuing to operate the power plants?}

The future costs related to maintenance of the nuclear power plant fleet are, by design, not known with certainty. Furthermore, they are highly dependent on the ageing of the components and of the installations, and on the probable developments in safety and operating requirements. Economically and financially, the subsequent potential return on those investments will depend on the residual service lives of the facilities.

Estimating such costs is therefore based on anticipation at a given time, and includes multiple uncertainties, in particular regarding the regulatory authorizations from the ASN.

\textit{a) The forecasts prior to the ASN report of January 2012}

As indicated in Chapter I-B-4, the investments for maintenance of the nuclear power plant fleet underwent a significant slowdown from 2003 to 2006, and the resulting slippage in maintenance is, according to EDF, having repercussions on current operation. EDF considers that maintenance was insufficient in the early 2000s, when the power plants were starting to reach the ages of about fifteen or twenty years, that deficient maintenance having been a source of malfunction or failure, and of falling performance levels.

\textsuperscript{172} Letter from the president of the ASN to EDF dated 1 July 2009: the ASN position on the generic aspects of continued operation of the 900-MW reactors after the third ten-yearly inspection.
Maintenance investment in millions of current euros

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<th>Year</th>
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Source: EDF

Investment spending is now steadily increasing, in particular due to the acceleration in the programme for changing the steam generators of the 900-MW series. In 2010, the ten-yearly inspections, the programme for replacing the large components, and the other investments related to operating the power plants accounted for €1.7 billion in investment. In 2011, that figure reached €2.1 billion.

b) The forecasts prior to the ASN report of January 2012

Thus, prior to publication on 3 January 2012 of the ASN report and opinion “sur les évaluations complémentaires de la sûreté des installations nucléaires prioritaires au regard de l’accident survenu à la centrale de Fukushima Daiichi” (“on the additional assessments of the safety of priority nuclear facilities in view of the accident that occurred at the Fukushima Daiichi plant”), EDF foresaw major investments on the historic nuclear power plant fleet.

On various occasions, EDF supplied estimates for the investments it deemed necessary for obtaining an extension to the service life. Thus, in December 2008, EDF indicated that “the financial stakes involved in significantly lengthening the service life of the nuclear power plant fleet beyond 40 years were estimated at €2008400 million per plant unit, spread over several years”, i.e. about €23 billion (gross value) for the entire fleet.

It was then specified that the €400 million represented an average amount. In certain units, in particular the 900-MW ones, major operations such as replacing the steam generators had already taken place, whereas they still needed doing in others. That average investment was then earmarked in part for replacing components, such as the steam generators or the turbine generators, and in part for improving the safety level.

More recently, in May 2010, before the French National Assembly’s Economic Affairs Commission, the Chief Executive Officer of EDF advanced a figure of €2010600 million per unit, i.e. about €201035 billion for the fleet as a whole.
Finally, in the course of preparatory work for the French Act on the New Organization of the Electricity Market (“NOME” Act), and of work for the Champsaur Commission, and more recently, in January 2011, in a letter to its supervisory ministry, EDF assessed the scale of the foreseeable investment costs for the fleet over the coming 15-year period at €50 billion, i.e. €58 billion in current non-discounted euros, with inflation assumptions ranging, depending on the years, from 1.5 percent to 2 percent.

This amount, which is higher than the previously given figures, appears to cover a broader spectrum\(^\text{173}\); the plan also includes the end of the investment programmes undertaken in the preceding years, and expenditure made necessary by the ageing of non-nuclear components (tertiary property for the power plants). It is organized around the following focuses:

- replacing large components such as steam generators, electricity generators, condensers, or cooling tower elements. All of these parts are essential both for the safety and for the availability of the power plants\(^\text{174}\). Other projects are longer-term and regulatory such as, for example, civil engineering work for reinforcing the sealing of certain containment buildings for the 1,300-MW series and for the 1,450-MW series, and are performed at the time of the ten-yearly inspection for the units concerned. This first volume of work represents several tens of billions of euros;

- operations for bringing the facilities into compliance with the fire standards, from 2008 to 2017, including the new design for the fire detection system for all facilities (dealing with the obsolescence of the equipment and homogenizing the sites);

- refitting the fuel storage pools so as to increase their volume capacity. These pools, located in the immediate vicinity of the reactor building, receive the new fuel reloads, and the irradiated fuel assemblies from the core until they are cool enough to be transported to the processing facility of La Hague. On average, the pools have a

\(^{173}\) To the best of the Cour des Comptes’ knowledge, the initial figures were not calculated as precisely and comprehensively as for the €50 billion plan.

\(^{174}\) For example, until 2005, EDF organized steam generator replacement at a rate of one unit per year. However, in view of the changing situation regarding steam generators, in view of their importance to safety, and in view of the risks of malfunctioning/failure (new mode of accelerated ageing discovered in 2006), that rate appeared insufficient, and, in 2005, the decision was made to double it. But, given the manufacturing time of about four years and the production capacities of the suppliers (AREVA, in this case), that decision was applicable only as from 2010.
capacity that is lower than those of operators outside France, and that is becoming insufficient since the developments in the fuels used (increase in the burnup fraction, introduction of fuel based on mixed oxides: Mixed Oxide (MOX) fuels) have led to lengthening of the minimum cooling time in the pool prior to transport. However, this is subject to authorization from the ASN, and the assessment that will be made of this project will necessarily take into account the return on experience from the Fukushima accident;

- the “extreme heat” plan that includes the changes made necessary to take into account, at the ASN’s request, the return on experience from the 2003 heat wave, and global warming, such changes involving replacement of chiller units, and air-conditioning of premises and equipment. This plan spans the period from 2006 to 2017;

- projects excluding nuclear buildings, e.g. renovation of the tertiary buildings (bringing them into compliance with sanitation and safety standards, changing roofs, and improving insulation) or making accommodation available for staff close to the nuclear power plants (4,300 dwellings to be funded from 2012 to 2017).

A programme intended to increase the electricity generating capacity of the existing reactors is also planned. It would need an operating application to be filed with the ASN and a new decree of authorization to be obtained for the installations in question.

These estimates open up two avenues for thought.

* The level of future expenditure

This amount of €201050 billion in investment over the next 15 years can be compared to the €201073 billion of the cost of initially building the fleet of power plants (cf. Chapter I).

This represents an average annual amount of maintenance investment of €20103.3 billion, whereas the average annual maintenance investment from 2008 to 2010, already considerably higher than the average annual amount for the early 2000s, was only €1.5 billion. It is almost double the maintenance investment for 2010 (€1.75 billion).

* The real nature of these maintenance investments

This investment programme was prepared with the aim of achieving a service life of 60 years. However, EDF is not able to indicate

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175 The increased overall size of the pools was noted as of 2002 by the ASN.
the share of the foreseen expenditure that would specifically make it possible to lengthen the service life from 40 to 50 years or from 40 to 60 years.

In particular, certain large components, such as the steam generators, are being replaced for safety and performance reasons; they need to be replaced even with a power plant service life of 40 years, so to continue operation and so as not to degrade availability as it has been degraded in recent years. For other investments, they are essential for safety reasons and not for reasons of extending the service lives of the power plants. A significant share of the investments presented thus appears necessary to “proper” continuation of operation regardless of the service life of the power plants.

Clearly, for EDF, so long as some of the investments are necessary, it is economically desirable for the period of use of the equipment or of the work in question to be as long as possible.

However, that in no way guarantees that the life of the facilities will be extended:

− firstly, the authorization to continue operation may be given only after the ASN has given its opinion, on the basis of the findings of the periodic reviews, every ten years;

− secondly, the authorization to continue operation is based not only on the state of the ancillary components, but also on the ageing of the non-replaceable elements (vessels and containments), no amount of investment providing a full technical answer to the observed ageing phenomena (cf. Annex 14). However, these elements are being given particular attention. As regards ageing of the vessels, EDF, based on research programmes, is changing the mode of operation of the reactors to slow down the irradiation to which they are subjected, and is seeking, by modelling methods other than those initially used, to show the existence of new safety margins. These new methods are based on a probabilistic approach to margins, unlike the tougher current methods that are based on a deterministic approach (i.e. on assessing the risk per se, independently of its probability of occurrence). The ASN has so far indicated that it is opposed to this type of method. As for the containment buildings of the existing fleet of power plants, they are of designs that differ depending on the series in question, and proposals have been made to improve their sealing, but it is not, as yet, possible to guarantee their leaktightness in the event of a serious accident with core meltdown, unlike what is planned for the EPR (no radioactive release in the event of a core-melt down accident).
It would thus appear difficult or even impossible, contrary to the details given in EDF communications, to isolate expenditure that is specifically earmarked for extending the service life, and that offers no guarantee of achieving such an extension.

3 - The uncertainties

In addition to all of the considerations addressed above, two major subjects of uncertainty are particularly sensitive issues today.

a) Safety compared with the EPR

The decree of authorization for building an EPR requires technical and safety specifications that are tougher than for the power plants currently in operation. The safety reviews, which include major and in-depth technical checks on the most essential components of the nuclear installation, have two objectives: to check that the initial safety baseline document is still complied with, and to detect weakness and non-compliances; and to compare the applicable requirements with those in force for facilities having safety practices and objectives that are more recent.

177 The figure of €2010600 million per unit was indicated by EDF’s CEO on 12 May 2010 before the French National Assembly’s Economic Affairs Commission. In June 2010, the press kit “L’énergie nucléaire : pivot d’une production d’électricité sûre, efficace et sans CO2” (“Nuclear energy: the linchpin of safe and competitive electricity generation without CO2 emissions”) mentioned a non-costed industrial plan relating to the technical improvements making it possible to continue operation beyond 40 years.

178 Decree No. 2007-534 of 10 April 2007, Article 2 “Accident prevention: The reactor should be designed, built, and operated in such a manner as to prevent the following situations from occurring: II-1. Rupture or blowout of the components of the primary circuit and of certain pipes under pressure (...). II-2. Accidents with the core melting down that can give rise to major early radioactive release (...). The accidental situations identified to date are: - core meltdown situations occurring while the primary circuit is at high pressure; core meltdown situations in the spent fuel pool; reactivity accidents resulting from cold water or water that is insufficiently rich in soluble neutron absorber rapidly entering the primary circuit; core meltdown situations with the containment being bypassed (...); - global hydrogen detonations and steam explosions inside and outside vessels that might damage the structural integrity of the containment building”
and while taking into account progress of knowledge and national and international return on experience\textsuperscript{179}.

The latter point leads to various interpretations depending on whether it is considered that the re-assessment surveys should be conducted “with regard to” the safety objectives applicable to the new reactors, or that the objective of the re-assessment surveys should be for the safety baseline document of the facility in operation to be “as close as possible” or indeed identical to the safety baseline document of the third generation reactors. This change in requirements for the ten-yearly reviews is the subject of debates between the operator and the ASN, given that the differences between the safety requirements of the various reactors can be sources of public debate and can raise questions of acceptance.

Depending on the interpretation that will be made by the ASN, and on the requirements it will draw from that interpretation, the amount of the investments necessary for continued operation of the current fleet of power plants could be significantly different, and indeed significantly higher than the programme mentioned above.

\textit{b) The consequences of the Fukushima accident}

It is currently very difficult to put a figure on the additional investments that will result from the return on experience from the accident at the Fukushima power plant. While risks that were already known were realized at that accident, it also requires new accident scenarios to be integrated, such scenarios being characterized by combined contingencies or combined concomitant negative events (loss of electrical power combined with a loss of cooling source). The programme initially planned by EDF cannot therefore be maintained as it stands. While the ASN has established its report on the first complementary safety assessments (ECSs), it appears that various changes are going to combine:

\textsuperscript{179} Cf. Annex to ASN Opinion No. 2011-AV-0120 of 4 July 2011 on continued operation of reactor No. 1 of the Fessenheim nuclear power plant: “The safety review is an opportunity firstly to examine in depth the situation of the facility in order to check that it complies fully with all of the rules that are applicable to it, and secondly to improve its level of safety by, in particular, comparing the applicable requirements with those in force for facilities having safety practices and objectives that are more recent, and while taking into account progress of knowledge and national and international return on experience”.

\textsuperscript{179} Cour des comptes
The costs of the nuclear power sector – January 2012
13 rue Cambon 75100 PARIS CEDEX 01 - tel : 01 42 98 95 00 - www.ccomptes.fr
certain expenditure is going to be incurred faster than scheduled in the schedule of operations for the programme mentioned above; replacements of parts or investments that were planned at the time of the fourth ten-yearly inspections are probably going to have to be brought forward;

additional investment programmes, some of which could be for large amounts, will be needed compared with the plan. This applies, for example, to construction of a crisis management building on each site, the experience of Fukushima having shown that such a building is useful for receiving the numerous intervention teams under emergency intervention and radiation-protection conditions. Based, for example, on a very first estimate of €100 million per building and per nuclear site, the cost would be €2 billion in all;

investments scheduled in the €50 billion programme will be made, but with greater safety requirements that will increase their cost. This applies to installation of station-blackout diesel generators on all sites, and to creating a second water reserve for feeding the emergency injection circuit.

The precise and detailed costing of the programme incorporating the consequences of Fukushima180 will be able to be established only once the safety objectives have been set by the ASN and once sufficient progress has been made with the design & engineering work and with establishing the construction schedule for the changes made to achieve them.

However, according to EDF, it would appear that the investments that are directly consequent upon implementation of the ASN recommendations, following the Fukushima accident, could represent about €10 billion, approximately half of which was already foreseen in the initial maintenance investment programme for €50 billion181. Therefore, the total programme could reach €55 billion, which would take the annual maintenance investment forecast from the pre-Fukushima estimate of €3.3 billion on average for the next 15 years to €3.7 billion, but possibly with an acceleration at the beginning of the 15-year period, depending on the future requirements and instructions of the ASN as regards doing the work.

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180 By way of illustration, if, for the first proposal, an investment of €100 million were to be expected per building and per nuclear site, that would represent a total cost of €2 billion; for the second point, the total cost could reach €3.8 billion, as the estimates currently stand, those estimates not yet being very detailed.

181 For the items whose cost can already be approximated, the estimated amount lies in the range €5 billion to €6 billion.
International comparisons

The power plants that are shutdown across the world

In June 2011, worldwide, 113 nuclear power generating units were shut down (including 39 pressurized water reactors), according to the statistics of the World Nuclear Association \(^{182}\). 14 reactors ceased operating following an accident or a serious accident, 22 were shut down due to political choices made by the relevant governments, and 97 were shut down for reasons of economic cost effectiveness. Of the latter, most of which were commissioned prior to 1980, 62 were operated briefly, and 35 had service lives close to what was originally scheduled, namely in the range 25 years to 30 years. It is difficult to know whether the shutdowns for reasons of insufficient cost effectiveness were the result of the equipment ageing (and of the excessive cost of replacing it), or the result of more demanding safety or environment protection requirements.

Graph: Ages of the reactors in operation

\(^{182}\) The WNA is an association that groups together nuclear power producers.
Service life of civil reactors in the United States

The legal framework is laid down by the federal Atomic Energy Act enacted in the United States in 1946 and amended in 1954. The Nuclear Regulatory Commission (NRC) grants licences for operation of civil reactors for terms that may not exceed 40 years. However, those licences are renewable for additional terms of up to 20 years through a relatively lengthy procedure\(^{183}\) and based on a decision by the NRC. Reactor owners are free to apply for renewal of the licence. Today, there are 104 reactors in service in the United States that were initially authorized to operate for 40 years, and the NRC has granted an extension of the operating term for 60 of those reactors. Since 2009, 8 reactors in the United States have now been operating for periods in excess of 40 years since they were commissioned.

Operation of about thirty reactors has been discontinued in the United States. For example, the Maine Yankee reactor was shut down for reasons of insufficient economic cost effectiveness with regard to the environmental criteria with which the facility would have had to comply after 25 years in operation.

Service life of reactors in Germany

Before the Fukushima accident, Germany had ten electricity-generating reactors shut down. Eight more were shut down in March 2011 after the Fukushima accident. Of the “commercial” reactors shut down pre-2011, two were closed for reasons of “lack of cost effectiveness” (Hamm-Uentrop and Stade), two were closed following accidents (Gundremmingen A in 1977 and Greifswald 5 in 1975). For another reactor, Wurgassen, it was a defect detected in 1994 on the reactor body and deemed too costly to correct that led to it being shut down. As for the Mulheim-Karlich power plant, a structural design fault (location of an ancillary building) led to termination of its period in operation, which lasted only two years in all. Nine reactors are now still in operation. The oldest was commissioned in 1982.

\(^{183}\) The procedure can last 3 years. It includes involving or consulting the public (locally held information meetings), and an environmental review (examination of the operating compliance of the facility with regard to the regulations on environment protection), a review of the safety of the facilities, and inspections and hearings by the Commission.
B - Future research

Future research may have highly structuring consequences for the future of the sector in the middle-to-long term, and impacts on short-term costs, depending on the changes made to research spending and on the working focuses selected for the research.

1 - The “nuclear sector of tomorrow” programme

The funding through subsidies of the research conducted by the Commissariat à l’Énergie Atomique et aux énergies alternatives (CEA, French Alternative Energies and Atomic Energy Commission) is to change significantly as from 2011, due to the “Investissements d’avenir” (“investments for the future”) scheme that has allocated €1 billion to the “ncléaire de demain” (“nuclear sector of tomorrow”) programme.

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Source: reference schedule of funding for the CEA Objectives and Performance Contract (amounts exclusive of VAT)

Two projects structure this programme: the Generation IV pilot reactor ASTRID and the experimental Jules Horowitz Reactor (JHR). The French revised budget act of 2010 earmarked €900 million for these projects, the payment schedule for which is given in the above table exclusive of VAT. In addition, to these amounts, €100 million has been allocated to the Agence Nationale pour la gestion des Déchets Radioactifs (ANDRA, French National Radioactive Waste Management Agency) for disposing of and treating waste. After the Fukushima disaster, €50 million was allotted to safety and to radiation protection, taken equally from the CEA budget allocation and from the ANDRA budget allocation.

2 - Generation IV and the ASTRID programme

Research into Generation IV nuclear reactors is co-ordinated at international level by the Generation IV International Forum (GIF), in which the following countries are participating: France, the United States,
Japan, South Korea, and, more recently, China and Russia. One of the main objectives of the GIF is, ultimately, to diversify the fuels used, uranium-235, used by current power plants, only accounting for 0.7 percent of the extracted ore, and running the risk of ultimately being produced in insufficient quantities if nuclear power develops globally, in particular in emerging countries. Furthermore, the generation-IV reactors should pave the way for recurrent recycling of the uranium and plutonium contained in spent MOX fuels, thereby making it possible to reduce the longer-term harmfulness of certain very-high-level radioactive wastes.

Various reactor designs have been selected for the R&D phase. With ASTRID (the Advanced Sodium Technological Reactor for Industrial Demonstration), France has decided to design an industrial prototype of a sodium-cooled fast-neutron reactor. The French revised budget act of 2010 has earmarked €650 million for this project so that it can be funded up to the stage including the detailed design, the feasibility studies or design engineering for the facilities for the associated cycle, and the construction or renovation of technological facilities for qualifying the components. The aim is to make it possible in 2017 to decide to build a pilot for industrial deployment as of 2040 if the relevant political decision is taken. The cost of building the pilot, which is not currently known, is thus not included in the current ASTRID programme.

The other countries in the Forum are further upstream, in phase with the originally planned schedule. The project to build a prototype in Japan has been put back to an unspecified date. Korea is at the upstream design stage. Russia is developing reactors, but of older design.

The “Investments for the Future” Convention is urging the CEA to bring the industry into the programme before the end of the first preliminary design phase, i.e. by the end of 2012, so as to share the costs and guarantee commitment from manufacturers, builders, and operators. The aim is for the industry to bear 20 to 30 percent of the costs of first preliminary design phase, i.e. of €75 million, and then to fund up to a half of the costs of the second preliminary design phase and of the pilot, if the decision is taken in 2017 to build it. Collaboration agreements involving financial participations were set up at the end of 2010 with AREVA, EDF, ALSTOM. COMEX Nucléaire and other industrial partners.

184 In November 2010, AREVA committed itself to funding 20% of the costs of the first and second preliminary design phases for the programme.
185 Agreement on the specific areas such as safety or operating experience feedback from Superphénix. The collaboration agreement on the R&D contributions from EDF to the ASTRID project has been signed.
The project remains essentially focused on a sodium-cooled reactor like Phénix (Phoenix) and Superphénix (Supерphoenix). But, the aim is for Astrid to constitute a technological breakthrough in safety, availability, keeping investment costs under control, and transmutation of minor actinides such as americium. The CEA is also researching alternative cooling possibilities, in particular helium gas cooling, particularly through partnerships with the GIF and with various Central European countries. But spending on such research remains limited.

3 - The Jules Horowitz Reactor

The aim of the experimental Jules Horowitz Reactor (JHR) is to analyse the behaviour of fuels and materials under irradiation. It is to replace the Osiris reactor and also other reactors in Europe that are of advancing years, and it will soon be the only irradiation reactor in Europe that is available for research. Finally, beyond the nuclear power sector, it will also make it possible to produce nuclides for medical use, in quantities satisfying 50% of European needs if necessary.

The definition and development research was conducted from 2003 to 2007; the construction, which began in 2007, should enable the reactor to be commissioned at full capacity in 2018. The cost of completing the work is estimated at €2005670 million, exclusive of medical-use radionuclide production, and including €2005250 million funded by the partners (€100 million by EDF, €50 million by AREVA, and €100 million by the European Union and by international partners who wish to have guaranteed access rights). The appropriations earmarked by the revised French budget act of 2010 cover €160 million, and the balance is funded by the CEA from ordinary subsidies and external resources. The participations from EDF and from AREVA in the construction, entered as investments on the balance sheets, have not been taken into account in the two parts of this report devoted to research spending (Chapter I – II and Chapter II – II A).

4 - Disposal of waste

The French revised budget act of 2010 allocated €100 million (reduced to €75 million since) under the “Investments for the future” scheme, firstly for setting up solutions for recycling low-radioactive metal waste from dismantling nuclear facilities, so as to reduce the volume to be stored, and secondly for developing innovative processes for treating chemically reactive radioactive waste (organic waste, sodium-bearing waste, asbestos waste, polluted waste, etc.) by plasma torch or pyrolysis with a view to rendering it inert and to making it easier to store.
Research into treating graphite waste, aiming to reduce storage volume and radiotoxicity has also been attached to this programme.

5 - Safety and radiation protection

After Fukushima, the French Government announced on 27 June 2011 a reinforcement of research into nuclear safety and radiation protection, with €50 million being devoted to that research field from the “nuclear sector of tomorrow” “investments for the future” programme.

On 27 October 2011, the Atomic Energy Committee decided that the €50 million would be spent through a call for projects, steering of which is to be delegated by the Commissariat général aux investissements d’avenir (general commission for investments for the future) to the Direction Générale de la Recherche et de l’Innovation (DGRI, Directorate General for Research and Innovation) of the French ministry for research, and to the Direction Générale de la Prévention des Risques (DGPR, Directorate General for Risk Prevention) of the French ministry for the ecology; it will be implemented by the Agence Nationale de la Recherche (ANR, French National Research Agency). The call for projects covers the fields of accident prevention, improvement of tools and methods relating to serious accidents, human and environment protection, and crisis management tools.

A more distant and more hypothetical future: Fusion

The International Thermonuclear Experimental Reactor (ITER) programme differs from the above-examined programmes. Its aim is not heavy isotope fission, but rather controlled fusion of light atoms in a magnetic confinement facility. The materials for controlling the process, the type of reaction to be produced, the rectors (particle accelerators and not power plants) are specific. The framework is also very specific because the programme was decided in 1985 by the Soviet Union, the United States, the European Union (via Euratom) and Japan as a manifestation of peaceable cooperation. In November 2006, the member states of the organization, today also including Korea, China, and India, set up an international legal entity for building and operating a research centre at Cadarache.

The related costs are described here since the long-term aim of ITER is to generate civil electricity using a method acting on the atomic structure of matter. However, the current stage of the research can still be considered to be fundamental research because it has yet to be demonstrated that thermonuclear fusion can be controlled for long enough to be certain that this technology will work.
The cost of the programme is estimated at €201013 billion for construction, €20106.3 billion over a 20-year period for operation, and €20101 billion for final shutdown of operation and dismantling. The direct contribution from France to the construction cost is €20101.1 billion, including €480 million borne by eight local authorities in the Provence-Alpes-Côte d’Azur (PACA) Region, the balance being borne by the French State. The work to develop the site and build the facilities is being managed by ITER France, an agency set up within the CEA. From 2007 to 2010, laying on services to the site and developing the infrastructures cost 208 million current euros.

The tokamak\textsuperscript{186} building will, by the end of 2019, make it possible to test the fundamental technologies designed for fusion reactors. Its reinforced concrete structure will comprise a 13-metre deep underground portion and an over-ground portion. It will be surrounded by ancillary structures, chiller cooling towers, electrical installations, control room, waste management installations and laboratories.

In February 2007, Euratom and Japan signed an additional research agreement for the materials testing, the advanced simulations and experiments on the plasma, and the design engineering for the preindustrial demonstrator DEMO that is to succeed ITER from 2030 to 2050.

\section*{II - Costs of the EPR}

Insofar as it is desired to continue with nuclear power, and regardless of their service life, current reactors may, ultimately, be replaced only by “3\textsuperscript{rd} generation” reactors, whose safety conditions offer higher performance than the safety conditions of current reactors. Today the only 3\textsuperscript{rd} generation model available for construction in France is the EPR at Flamanville. Leaving aside the two EPRs being built in China\textsuperscript{187}, through lack of accurate information and also because their costs will not be reproducible in France, only the EPRs under construction in Finland and at Flamanville can serve as a basis for estimates of investment and production costs.

However, since those two reactors are still being built, the cost figures can but be estimates. Furthermore, in the same way as for 2\textsuperscript{nd} generation reactors, it is probable that the “first-of-their-kind” reactors will cost significantly more than the reactors built subsequently.

\textsuperscript{186} Tokamak: magnetic confinement chamber designed for controlling plasma.

\textsuperscript{187} The Taishan site appears to be progressing to cost and to schedule.
As regards the construction costs for the Flamanville 3 EPR, on 20 July 2011 EDF announced a revised cost, including engineering, of €6 billion (€3.7 million per megawatt (MW) for 1,630 MW) and an objective of first saleable output in 2016. It might be recalled that in December 2008, the cost was estimated at €4 billion for construction in 54 months, and then reassessed in December 2010 at €5 billion for construction in 78 months. The Cour des Comptes has not audited these items that are, as yet, but forecasts. However, it is possible to compare this construction cost with the construction cost of the latest pressurized water reactors built in France at Chooz for a cost of €20104.8 billion (commissioned in July 2000, with 2,910 MW for 2 reactors, i.e. €1.63 million per MW and €2.06 million per MW inclusive of engineering), and at Civaux for a cost of €20103.7 billion (commissioned in May 2002, with 2,945 MW for 2 reactors, i.e. €1.25 million per MW and €1.37 million per MW inclusive of engineering).

In addition to the difficulties of building a first-of-a-kind, AREVA explains the difference in cost per megawatt by different technologies making it possible, in particular, to satisfy more stringent safety requirements better. It is also probable that reactors similar to Chooz or to Civaux would be more costly to build today, due to raw material prices and civil engineering prices rising more steeply than the general GDP price curve that was used for calculating the construction costs in 2010 euros. In addition, the EPR is supposed to have operating costs lower than the operating costs of the Chooz and Civaux reactors, making it possible to compensate for the extra investment costs (excluding the “first-of-a-kind” effect), which, according to AREVA, would make it possible to have full production costs similar to those of the most recent reactors in the current fleet, built under today’s economic conditions. This will not be possible to verify until the operating stage of the EPR.

EDF has not officially revised its production cost forecasts on the basis of its latest announcements regarding the construction cost of €6 billion. But, in the same way as the investment costs, the production cost forecasts have risen over time.

In 2007, the Direction Générale de l’Energie et du Climat (DGEC, Directorate General for Energy and Climate) proposed an estimate of €44.9 per megawatt hour (MWh) (i.e. €201046.6 per MWh) for a recurrent EPR. The latest EDF forecasts from December 2008 give a cost of €54.3 per MWh (i.e. €201055 MWh), for construction, engineering, and dismantling, on the basis of a construction cost of €4 billion in 54 months.

In view of the lengthening lead times, which would suggest a higher amount for the interest during the construction, and in view of the increase in the cost of the construction since then, it can be estimated that
the future production cost of Flamanville will be from €70 per MWh to €90 MWh, with a service life of 60 years. However, these items should be taken with considerable precaution because they are not based on an analysis conducted by the Cour des Comptes on a precise estimate proposed by EDF. It should also be remembered that these costs are not the costs for a standard EPR, for which costs should be lower but are even more difficult to forecast.

III - The variants

Depending on the assumptions that are made about the service lives of the power plants, about Generation IV, and about the development of EPRs, the future expenditure can be significantly different. A few variants can be imagined in order to understand how the orders of magnitude of the dismantling costs, spent fuel management costs, and waste management costs might develop.

As indicated in the introduction, it is not the business of this report to propose energy mix scenarios or to make assumptions on how demand will develop; the following analyses are thus based on an assumption of nuclear power of the same order of magnitude as that generated by the current fleet.

A - The baseline situation

The baseline situation underpinning the calculation of the future costs is, if we restrict ourselves to the current accounting details, based on the following assumptions:

- a service life for the reactors of 40 years, used for the current calculation of depreciation, and the current calculation of the provision for dismantling, given that, as already emphasized, extending operation of the reactors to 40 years and possibly beyond is subject to a favourable opinion from the ASN after in-depth ten-yearly inspections;

- maintenance investments that currently account for about €1.7 billion per year and that should double in the future, on the basis of an investment budget envelope of €50 billion at least from 2011 to 2025. As indicated above, although these investments are presented as being essential for extending the service life of the power plants to 50 or 60 years, they are also probably to a large degree necessary for continuing operation and for reaching with acceptable availability the 40 years envisaged up to now in the accounts, and for satisfying the
requirements and instructions of the ASN following the Fukushima accident;

- Generation IV reactors ultimately being built, making it possible to recycle a large fraction of the stocks of spent fuel (MOX, ERU) and also a fraction of the depleted uranium currently stored, pending re-processing in these future reactors. However, as emphasized above, in the absence of a currently available industrial solution for recycling such spent fuel, the calculation of the forecasts for spent ERU and MOX fuel management is based on an assumption of it being stored directly, without reprocessing, in the deep geological repository currently under study but that does not incorporate this assumption. Realization of the development of Generation IV would increase the provisions for spent fuel management because it would then be necessary to make provision for reprocessing the spent MOX and ERU fuels. These costs (and the cost of developing Generation IV reactors) will need to be compared with the savings that could be made by avoiding direct disposal of the waste (more costly than storing it or disposing of it after treatment or processing).

   Industrially, this “baseline situation” is partly fictitious. If we assume that all of the reactors stop at 40 years, a large number of replacement power plants will need to be commissioned in quick succession in the coming years. In particular, if the power plants are to be nuclear, construction of several EPRs should already be under way in order to maintain the current level of output, given that six to ten years elapse between the decision to launch an EPR and commissioning of it.

   By the end of 2020, 12 reactors representing 10,900 MW will have reached a service life of 40 years, while probably only the Flamanville EPR (1,630 MW) will be able to be commissioned at that date, since the Penly EPR project has not yet been launched officially.

   With output remaining constant, the assumption is thus for the service lives of at least some of the power plants to be extended to 50 years, which pre-empts the decisions that the ASN might take.

**B - Variant: service life of 50 years**

The variant based on a service life of 50 years could thus be considered as a “real baseline situation”, from an industrial viewpoint if not from a bookkeeping viewpoint. In order to simplify estimating the consequences of lengthening the average service life of the fleet, it is assumed that there is a uniform extension to 50 years even though, in reality, the safety requirements and the need to stagger replacement would likely lead to differing life spans.
In order to sustain current nuclear power output, this variant assumes that the following economic and financial conditions are satisfied:

- the EDF maintenance investment programme of €50 billion (plus the investments resulting from the ASN’s post-Fukushima opinion) is fully implemented by 2025;

- 6 EPR projects are launched and funded by the year 2030; in addition to the financial investment cost that that represents (in the range €201030 billion to €201036 billion), questions are raised as to the industrial conditions for completing the projects in question within short lead times;

- however, if the amount of the EDF gross dismantling costs were to remain unchanged (€201018.1 billion for the reactors), the provision would decrease by €20102.3 billion, going from €20109 billion to €20106.8 billion; the extension would lead to a significant shift in the schedule of disbursements over time;

- the consequences of the extension in terms of fuel management\(^\text{188}\) would be limited; this variant would ultimately require the capacity of the pools at La Hague to be increased, but at a date that would depend on the steps taken for storing the fuel for the current fleet (cf. Chapter III-II-A-3-b);

- as regards waste, the consequences would be more significant: the power plants would produce excess operating waste (very low-level waste (VLLW), and low- and intermediate-level short-lived waste (LILW-SL)) that was not taken into account for dimensioning the current repositories; under current conditions (compression of waste, annual volume produced), it would probably be necessary to build a new repository for LILW-SL (the construction of a new VLLW repository already being foreseeable without extending the service life);

conversely, the additional waste from the spent fuel (waste from reprocessing the spent fuel or fuel assemblies to be stored directly) should be able to be stored in the deep repository operated by ANDRA, because the scenarios developed by ANDRA make provision for dimensioning margins that make it possible to

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\(^{188}\) No assumption is made here on the consequences of the construction and operation of the above-mentioned 6 EPRs.
accommodate additional waste resulting from operating the current fleet for 60 years;189

− in addition to the above-listed maintenance and replacement EPR construction investments, there would also be the cost of extending the research and development for Generation IV, in particular the funding of the ASTRID pilot project to around 2020, if that project goes ahead, and the cost of the subsequent industrial phase; none of these projects that are probably costly can be costed at the current time.

C - Variant: “discontinuing reprocessing”190

A foreseeable consequence of discontinuing reprocessing would be for the AREVA La Hague plants UP2 800 and UP 3 to close. That would probably bring forward the date of the start of dismantling of them, which was scheduled to begin in 2040. AREVA would therefore have to disburse much earlier than scheduled €20104.2 billion as of the date of closure and over a period of 20 years, which is the total time scheduled for the dismantling operations, while, at the same time, it would have to cope with retraining the staff and, with the loss of revenue from the reprocessing.

Discontinuing reprocessing of the spent ENU fuels would also involve disposing of them directly.191 At 31 December 2010, there was already a stock of 16,540 tonnes of spent ENU fuels. Added to that, there would be the assemblies irradiated since that date. It is generally accepted that the cost of direct disposal in clay is about twice as high as the cost of storage after reprocessing.192 That extra cost would essentially concern EDF, the main producer of spent fuels. It would also require new storage pools to be built, because the net flow of spent fuels would then increase six times (1,200 tonnes per year as against 200 today).

The provisions for managing spent fuel would be very considerably reduced because they would then concern only storage of

189 Cf. dimensioning scenario (SD) of the 2009 ANDRA file.
190 The comments on this variant do not take account of any contractual penalty clauses that might change the distribution of the financial impacts between AREVA and EDF. This variant measures, above all, the overall impact on the sector.
191 In calculating such a provision, EDF is already assuming that the other spent fuels (MOX, ERU, Superphénix, Brennilis) will be stored/disposed of directly.
192 ANDRA’s scenario S2 (direct storage) was assessed in 2002 at lying within the range €33.2 billion to €55 billion.
the recycled uranium (RU) already extracted and construction of the new storage pools.

This reduction would be attenuated to an extent by the increase in the provisions for long-term waste management. However, the unit costs used today by EDF for calculating its provisions for MOX and ERU remain significantly less, in discounted value, than the reprocessing costs.

In a subsequent stage, this scenario would also have an impact in terms of fuels used, the end of reprocessing also discontinuing production of plutonium and therefore progressively drying up the MOX channel, requiring an increase in consumption of natural or reprocessed uranium.

**D - Variant: “without any fourth generation”**

This scenario would have a major impact in terms of fuel management strategy because, in this case, the vast majority of uranium 238 (99.3 percent of the ore) could sooner or later be considered as waste. In particular, that would influence the economic balance of the mines and of the enrichment function because the depleted uranium produced by these activities would then acquire a negative value.

In terms of provisions related to spent fuel management, this scenario would not have any medium-term influence, because the calculation of the provisions is already based on storing spent ERU and MOX fuels without reprocessing them, and thus on the assumption of absence of a fourth generation.

But, beyond the bookkeeping dimension, as regards waste management, it would really be necessary to store spent MOX in the future deep geological repository. The provision constituted for that purpose by EDF, for a gross amount of €20106.3 billion is based on fragile assumptions. Since the deep repository project is currently not designed to receive spent MOX, it is impossible to know whether the provision would actually be sufficient to cover the extra cost related to storing/disposing of spent MOX directly, following the abandonment of a fourth generation of reactors.

As regards AREVA, the current reference solution for recycling 250,000 tonnes of depleted uranium is to use it as fuel in the Generation IV reactors. In the absence of such reactors, two existing channels nevertheless enable depleted uranium to retain its status as a recyclable
material: re-enrichment, and production of MOX fuel\textsuperscript{193}. This material should therefore not be re-classified as waste. This reasoning also applies to the 20,000 tonnes of RU for which EDF is responsible.

Furthermore, it can be emphasized that the absence of a fourth generation does not necessarily mean that reprocessing will be discontinued. Reprocessing makes it possible to reduce the volume of ultimate waste to be disposed of\textsuperscript{194} and to make savings in the relatively rare raw material that natural uranium represents. The existence of reprocessing can be justified by advantages that are specific to it, independently of a fourth generation of reactors.

Conversely, Generation IV reactors operate with plutonium, and that requires spent MOX fuel to be reprocessed so as to extract plutonium from it. A scenario in which reprocessing is discontinued and in which Generation IV reactors are developed is therefore meaningless.

\section*{Conclusion – Possible Developments}

Numerous factors can have consequences for the amount of future spending on nuclear power, even assuming that the current output level is maintained.

The service life of the power plants is a decisive element. The industrial scenario implicitly adopted today, without any assurance of it being accepted by the ASN, is one in which the service lives of the reactors are extended beyond 40 years, since the substitute output capacities made necessary by a 40-year scenario have not been launched or even scheduled.

Assuming a service life extended to 50 years, then, from a solely financial viewpoint, massive investments are necessary for extending the service lives of the power plants, for building the EPRs that are supposed

\textsuperscript{193} However, these channels come up against the drawbacks of lack of cost effectiveness and of absence of the channel in France (this applies to re-enrichment) and of low usable volume (this applies to MOX production).

\textsuperscript{194} Re-use of recycled plutonium in MOX and the absence of reprocessing of such MOX after irradiation requires, however, partial use of direct storage, which is less economical with volume.
to take over from the current reactors, and for developing the Generation IV programme.

In addition to the uncertainties about the technical difficulties and about the acceptability of the fourth generation, its cost is currently unknown. Only the cost of taking the ASTRID project, which is an experimental tool with no industrial dimension, up to the end of the detailed design stage (APD) is currently costed at €650 million.

It would be advisable to work on alternative solutions, in the event that the assumption of the fourth generation proves not to be feasible on a large scale, in particular by incorporating a variant making provision for spent fuel to be stored in the deep geological repository that is currently a project being studied. That would make it possible, in particular to cost more accurately the provision for spent fuel management that is already based on that assumption.
Chapter VII

Costs which are difficult to quantify

The previous three chapters present analyses of identified past, present and future costs relating to nuclear power generation. Some of these costs are easy to measure and quantify, while calculating others can be a matter of complex hypothesis, involving a number of uncertainties. But in any event, these are all costs which will have to be paid, monetarily, one day or another.

There are other costs, however, which are not currently counted as an identified expense, but which are nonetheless consequences of nuclear power generation.

Among these related costs, or “externalities”, are those of particular concern, such as the consequences of a major accident and the current insurance situation in the nuclear sector.

I - Externalities

Any human activity has unmonetized consequences on the community or the environment which can be difficult to measure and often difficult to translate into monetary costs (or profits), which would allow them to be added to (or subtracted from) the “conventional” costs of the effective expenses. They are referred to as negative or positive externalities; neither producers nor consumers bear the cost of these consequences, which means that they remain at the expense (or profit) of the community, whether it is aware of them or not.
Power generation is particularly concerned by externalities, first because as a structuring activity, essential to human development, its impact is often massive, and second, because the negative and positive externalities of different forms of energy are very different. Consequently, it is often easier to compare the externalities of different forms of energy than to measure them or put a monetary figure on them per se.

Within the scope of this report, the Cour des Comptes cannot fill the gaps in current knowledge on the impacts of nuclear power generation. Nor can it put monetary figures on these impacts, which would require making basic assumptions as to the price of human life, the value of nature and the applicable discount rate.

Furthermore, this report addresses only the costs of this activity (which means taking only negative externalities into account) and does not attempt to compare its advantages and disadvantages with those of other forms of electricity or power generation. Thus, we will limit our scope here to discussing the externalities most often identified, and indicating any potential factors for quantifying them. This will show that a single externality can be seen as positive or negative depending on who is considering it and how it is being compared to other energies.

Externalities can be broken down into several main categories depending on whether one is considering the impacts on the environment or health, but when it comes to energy, there are more economic or “political” impacts which are also qualified as externalities. They must be taken into account over the entire life cycle of the generation chain, including the fuel cycle.

A - Impacts on the environment

As a general rule, impacts on the environment are viewed as negative externalities, which come at a cost to the community. Thus, the low level of some of these impacts can be seen as an advantage, but only by comparison.

The impacts on the environment mainly concern the climate, water consumption, the release of material into the water and air, and the direct effects on nature and landscapes.
1 - Greenhouse gas production

The impact of the nuclear power sector on the climate is generally viewed as insignificant, as the generation of electricity in nuclear power plants does not produce CO₂. This differentiates this form of energy from electricity produced using fossil fuels, but not from renewable energies.

Depending on the value determined per tonne of CO₂, the positive externality which can be measured by comparison with other energies may vary considerably.

- From a community perspective, it is noted that the Quinet report, drafted in 2009 within the scope of the Strategic Analysis Council (CAS) project, defines a recommended value per tonne of CO₂ which increases from €32/t in 2010 to €100 in 2030 and €200 in 2050; the Stern report, on the other hand, published at the end of October 2006, estimated that each tonne of CO₂ emitted today would cost €85 in damages.

- From a corporate perspective, the cost per tonne of CO₂ can be measured by its price on the carbon market, which depends on the quota allocated by the European Commission overall and per country, and the level of economic activity which determines the restrictiveness of this constraint. For the recent period, the price per tonne of CO₂ on the market in 2010 was steady at around €15, as demand remained low given the economic situation and the allocated quota. Starting in 2013, the quotas will no longer be granted free of charge, but will be sold through an auction system, which will allow the price to be determined according to greater exchanges.

- The price per tonne of CO₂ can also be calculated based on the cost of the carbon capture and storage methods used for power plants, i.e. between €15 and €80/t CO₂ (in 2008).

The CO₂ emissions from nuclear power generation in France are estimated at 15 g of CO₂ per kWh\(^{195}\). This value includes construction of the plants and supply systems. At the 2010 market price (€15/t), the annual generation of approximately 400 TWh (15 g/kWh = 15,000 t/TWh) represents a “cost” of €90 million for 6 Mt of CO₂ equivalent. Using the value from the Quinet report (32€/t), the cost is slightly more than double, at €190 million.

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\(^{195}\) Source: 2nd strategic energy review by the European Commission.
By way of comparison, the same electricity generation obtained with combined-cycle gas power plants, which emit 420 g of CO$_2$eq per kWh, would produce 168 Mt of CO$_2$ at a cost of €2.5 billion (at €15 per tonne) or €5.4 billion using the Quinet 2010 shadow price.

Thus, without a doubt, greenhouse gas emissions from nuclear power generation are very low, which is a positive externality. The value of its emissions is calculated as a small additional cost, determined using a cost per tonne of CO$_2$ which is not so easily defined.

2 - Material released into the water and air

Like any industrial activity, nuclear power generation causes the release of various materials into the air and water. The authorizations granted for each facility specify the acceptable limits for this radioactive and chemical discharge into the water and air, with penalties for exceeding the limits; cases of underground water pollution have been found at Tricastin or Golfech, for example. The limits for released materials have gradually become more stringent. Nevertheless, this externality may presumably be quantified monetarily.

Again in this case, the gross values taken alone are not very telling, as other means of electricity generation (such as carbon- and fuel-based generation) are much greater sources of pollution, particularly due to their nitrogen oxide or sulphur emissions which cause acid rain, eutrophication, or the formation of ground-level ozone.

3 - Impacts on aquatic environments, landscapes and biodiversity

Water consumption

For the generation of nuclear power, large amounts of water are needed to cool the facilities and spent fuel. This is why power plants are located near rivers and streams or along the sea.

Power plants therefore have a perceptible impact on the aquatic environment that they use, and which they warm by several degrees by releasing water at a higher temperature than that the water they take in. This has an impact on the plant and animal life, which is why limits for water intake have been stipulated according to the flow rate of the rivers in question.

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196 The authorized levels of released material for the La Hague power plant (notably tritium, iodine and carbon 14) are slightly higher than for nuclear power plants.
This negative externality is amplified during dry spells and low water periods when the impact of the differences in temperature between the intake water and the discharge water is not as easily “diluted” due to the rivers’ lower flow rate. This also factors into the “fragility” of this means of generation: the Fukushima accident illustrated the strategic importance of water in the generation of nuclear power, which oriented location choices facilitating access to water, but which are also risk factors in the event of flooding. In addition, this requires special efforts in order to adapt to the consequences of climate change, an initiative undertaken in France after the wave of 2003.

Other means of electricity generation, such as the production of hydroelectricity, have notable impacts on the aquatic environment, which vary depending on the facilities in question and their location.

Impact on the landscape

Power plants and the extra-high voltage power lines that accompany them have a very strong impact on the landscape, especially since, for safety reasons, they are often built in undeveloped areas where they are highly visible and alter the landscape considerably. However, it is very difficult to calculate this impact, which is fairly subjective. The real impacts differ from one facility to another, and the methods for quantifying these externalities are still under debate.

Extraction activities, like all mining activities, also have a massive impact on the environment.

B - Impacts on human health

The impacts on human health are just as difficult to quantify as the impacts on the environment, but in some ways they are related, and can be broken down into three categories:

- for the populations living in the areas around nuclear facilities (including mines), the impact of the low-level radiation resulting from the released materials mentioned above. Although it is far from underestimating the very serious human aspects of this issue, the Cour des Comptes is not competent to choose between the opposing expert opinions on this subject, with regard to the correlation between leukaemia and cancer rates and living in proximity to power plants. These aspects are under study by researchers at the Institut National de la Santé et de la Recherche Médicale (INSERM French National Institute of Health and Medical Research);
the health impact of working in radiation environments, which is aggravated by the fact that maintenance work, during which the levels of radiation received by staff are the highest, is almost always carried out by subcontractor staff who are generally not as well trained and monitored as EDF staff. For health reasons and to ensure the reliability of the tasks performed, it has been requested, notably by OPECST, that there be less reliance on subcontracting and especially cascade subcontracting. At present, the necessary data do not seem to be available for calculating the cost of this “chronic” impact on staff, beyond the “occupational accidents” resulting from accidental overexposure;

- the public health consequences of a serious accident, including risks of contamination of the food chain by certain radioelements, such as caesium 137 and strontium 90. The potential figures for these health risks, which depend notably on the quantity of material released outside the confinement, are included in the discussion of the consequences of the nuclear accidents examined in the second part of this chapter (accidents and insurance).

C - Other externalities

The notion of externality, meaning a cost which is not borne by the producer or consumer, does not apply only to environmental or health issues. The various forms of power generation also have externalities of an economic nature, or relating to land use planning, which are taken into account for energy policy decisions.

However, one may ask whether it is relevant and possible to quantify these externalities in terms of monetary cost (or profit) considering that, first, political choices are not solely the result of economic reasoning; and second, the evaluation methods are still far from allowing these externalities to be directly included in the overall optimization calculations based on the different energy policy goals.

Thus the Planning Act of 13 July 2005 sets out the guidelines on the energy policy, which, it states, “is based on a public energy service which guarantees the nation’s strategic independence and promotes its economic competitiveness [...] This policy aims:
COSTS WHICH ARE DIFFICULT TO QUANTIFY

− to contribute to national energy independence and guarantee security of supply;
− to ensure a competitive price for energy;
− to preserve human health and the environment, particularly by working to slow global warming;
− to guarantee social and territorial cohesion by ensuring access to energy for all.’’

In comparing the various forms of energy, each of these factors weighs in to varying degrees, but this is difficult to quantify in monetary value. In the case of nuclear power:

− its impact in terms of security of supply and energy independence is viewed as a positive externality, even though its fuel, uranium, is now produced abroad. Indeed, the percentage of its added value which is produced within the national territory is very high compared with other energies, notably those generated using fossil fuels. This externality can be measured as the impact on the trade balance, for example by replacing nuclear power generation with gas generation and comparing it to the current situation. The calculation will of course be different using renewable energies, depending on whether the calculations would part from the current situation with a very large fleet of nuclear power plants and embryonic renewable energies or use the hypothesis of an already existing fleet

− unlike other sources of energy, it is not intermittent and is generally predictable, except in the event of unscheduled outage. Nevertheless, even though it is suited to basic generation, and in France is subject to load following, it needs to be supplemented with other forms of electricity generation to meet erratic fluctuations and peaks in demand,

− it also requires having a centralized network, with measurable economic effectiveness and consequences in terms of security or fragility in the event of exceptional, climatic or other incidents, compared to other types of networks better suited to decentralized, local power generation;

− it requires massive financial resources which can be hard to find and pay in an unstable economic and financial climate. However, once the investment has been made, the cost of generation is fairly low,
− it requires major research efforts and relies on cutting-edge technologies which are then disseminated throughout the entire industry, notably in robotics, materials, software security, etc. This favourable impact on innovation is a positive aspect in terms of economic competitiveness, in addition to the nuclear industry’s direct impacts on employment and export capacities, which depend on its share in the global energy mix.

− as for the economic impact of nuclear facilities on the communities in their vicinity, the Cour des Comptes does not know of any specific studies on this subject, but their location in often isolated areas, the taxes paid to local authorities, and the economic activity and jobs that they create locally suggest this impact is positive and does not have much effect on property values.

All of these considerations illustrate that while trying to put a figure on all of these externalities is an impossible task, they must be taken into account when comparing different forms of power generation.

II - Nuclear risk and insurance

From a cost perspective, a serious nuclear accident raises two types of questions: 1) how much do the potential damages total, and who pays for them, and 2) are the insurance systems set up to cover this specific risk adequate and comprehensive?

A - Nuclear risk

The civil liability system for players in the nuclear industry follows specific rules relating to the nature of the risk covered: i.e. occurrence of the risk is highly unlikely, but in the event of a major incident the consequences could be catastrophic.

1 - The specific nature of nuclear risk

a) What is the risk of a nuclear accident occurring?

Assessing a risk usually involves a combination of two factors: the probability of the accident occurring and the severity of the consequences. In the nuclear industry, this approach is not applicable because the overall body of safety measures aims to ensure a near-zero probability of the accident occurring. The probability of occurrence of an accident which would release significant radioactivity into the atmosphere is to the order of $10^{-6}$ per reactor per year for those currently
in service, and may be as low as $10^{-8}$ for EPR type generation\textsuperscript{197}. But as low as the calculated accident probabilities are, risks still exist, as proven by the examples of Three Mile Island, Chernobyl and Fukushima, and they can have serious consequences.

Over the last 35 years, three major nuclear accidents have occurred in the civil nuclear electricity generation industry, two of which have caused major damage. The rarity of these events means that insurers cannot use models based on a risk’s rate of occurrence. Moreover, the damage caused would be on a scale exceeding the insurance market’s means for paying compensation. This basic information explains the nature of the insurance system and its limits.

\textit{b) How to evaluate the harmful consequences}

It is very difficult to evaluate the medium and long-term consequences of a nuclear accident: few examples exist and they are each highly specific (for example, the consequences of the accident at Three Mile Island were confined to the reactor containment and cannot be compared to the consequences of Chernobyl). Moreover, the consequences to consider depend on many complex factors: the urbanization of the disaster area, meteorological conditions affecting the dissemination of the radioactive material released into the atmosphere, direct and indirect losses, etc. In fact, for the past accidents and some of the financial consequences, no exhaustive evaluation exists. However, the IAEA did attempt to evaluate the cost of the Chernobyl accident, which totalled hundreds of billions of dollars\textsuperscript{198}.

In France, accident scenarios have been created and are used for regular safety exercises. However, the financial evaluations of the consequences of these scenarios are still inadequate\textsuperscript{199}.

\textsuperscript{197}These figures, which correspond to French power plants, are not systematically applicable to all foreign countries, as the designs for power plants can differ significantly. Moreover, they do not take into account probabilities for discharge resulting from internal faults, with the exception of human error or external attacks.

\textsuperscript{198}Source: “Chernobyl’s Legacy: Health, Environmental and Socio-Economic Impacts”, available on the IAEA website.

\textsuperscript{199}The ASN ordered a study on this subject in 2011.
The IRSN has launched an initiative to evaluate a scenario based on the main assumption of a “controlled” release of radioactive material. These studies do not postulate the probability of this type of scenario occurring in France. This scenario is liable to vary according to the accident location, the metrological conditions, etc. It includes the following:

- the cost of the direct damages on the accident site (including site decontamination and dismantling and supplying a replacement power source);
- the short and long term effects of the radiological contamination (medical care, evacuation and assistance for the population groups concerned);
- the cost of the contaminated territories (decontamination and compensation measures granted to the population groups);
- the numerous indirect costs (such as restrictions on exports and agricultural production, cost overruns for generating or purchasing electricity, and decreased tourism).

This research still needs to be backed up scientifically. It roughly estimates the cost of damages to be as high as €70 billion\textsuperscript{200} with 10 percent in direct damages and 90 percent in indirect damages, which are quite uncertain and very difficult to put a figure on. This figure is extremely sensitive to different assumptions, which can increase or decrease the indirect costs considerably.

This figure is roughly comparable to the costs of a natural catastrophe such as the Kobe earthquake in 1995 ($100 billion\textsuperscript{201}) or hurricane Katrina in 2005 (cost of damages estimated at $125 billion, $60 billion of which were covered by insurance providers\textsuperscript{202}, and with the indirect consequences, a total cost of over $200 billion). In addition, the damage caused by an oil spill can represent a cost of several billion euros and affect multiple countries\textsuperscript{203}. Another comparable disaster is the breaking of the Banqiao Dam in China in 1975, which caused almost 30,000 immediate deaths, in addition to the later deaths due to epidemics and famine.

\textsuperscript{200} The IRSN estimates give an average cost of between €70 billion for a moderate accident on a reactor, such as the Three Mile Island accident in 1979, and €600 billion to €1,000 billion for a very serious accident such as those at Chernobyl or Fukushima.
\textsuperscript{201} Source: World Bank.
\textsuperscript{202} Source: US National Oceanic and Atmospheric Administration.
\textsuperscript{203} The oil which spilled from the tanks on the Prestige in 2002 soiled the coasts of Portugal, Spain and France.
In terms of the known consequences, the nuclear industry appears safer than many other energy sectors. In particular, direct mortality as a result of the civil nuclear sector is much lower than that with fossil fuels\textsuperscript{204}. It must not be overlooked, for example, that the oil industry counted over 20,000 deaths between 1969 and 2000.

Indirect mortality is more difficult to evaluate, both in the nuclear industry (early death due to limited doses of radiation, for example) and other industries (e.g. due to the fine particles produced by coal-fired power plants).

However, the consequences of a major nuclear accident would potentially be much more serious than for major accidents in other energy sectors. With regard to earthquakes and hurricanes, there are at least two characteristics of nuclear accidents that must be considered: the contamination of the territories affected lasts for extremely long periods (counted in centuries); and such accidents have a significant impact on public opinion and may call into question the continued operation of nuclear power plants at the global level (citizen responses, political decisions, a domino effect at the international level). In addition, since the French fleet is very homogenous, a design defect could result multiple consequences.

The characteristics of nuclear risk – very low probability but consequences which may be catastrophic – explain why the liability of nuclear operators is capped, so that the limited civil liability can be insured. Moreover, the operator is automatically held liable, without any fault on their part needing to be established.

\textsuperscript{204} Source: "Comparing Nuclear Accident Risks with Those from Other Energy Sources", OECD/NEA, 2010.
2 - Civil liability for nuclear damage: a derogation from general law

Generally speaking, civil liability covers the damages incurred by a third party who suffers a loss which gives rise to compensation. In this sense, the damages differ from those caused to the operator’s facilities as a result of the accident, which are generally covered by a separate “damage insurance” policy.

The development of nuclear power generation since the 1950s has led a number of governments in territories in which these facilities were built to set up an insurance system covering the risks involved in operating these power plants. The characteristics of nuclear risk, as indicated above, naturally led the governments concerned to organize a special civil liability system, in a supranational framework.

According to the preamble of the Paris Convention (1960):

“The generation and use of atomic energy involve potential risks which are far-reaching and specific in nature. Despite the high level of safety which has been achieved in this sector, accidents which could cause considerable damages do remain a possibility."

“A special civil liability system for nuclear damage is required, as general law is not adapted to the particular issues in this sector."

Indeed, under general law on civil liability, compensation for victims hinges on proving that one or more third parties were at fault, and demonstrating the causal link between the fault and the damage.

For nuclear power plants, on the contrary, the international conventions and their legislative translations into national law provide for the liability of the operator alone, without any fault on their part having been established, and without the operator being able to claim the liability of a third party, such as their supplier, except in extremely limited cases. The liability is based on the risk and is directed at the operator.

Moreover, whereas civil liability is generally unlimited, that of a nuclear operator is capped by defined limits, which prevent an excessive burden on the operator and enable him to insure this risk (and therefore to guarantee their solvency for the purposes of paying compensation).
Hereinafter, the term “civil liability for nuclear damage” (CLND) will be used to cover both the notions of “third party nuclear liability” (TPNL) and “nuclear transport civil liability” (NTCL).

3 - The French landscape

Several aspects make France a unique player in the landscape of countries which generate nuclear power. First, nearly all of its operators are government-controlled, since the Government is, by a large margin, a majority shareholder in EDF and AREVA, and CEA and ANDRA are public establishments.

Moreover, unlike in other countries, there is only one producer of nuclear power (which represents the vast majority of electricity generation in France). This makes it impossible to set up a balanced risk sharing system between multiple economic players, such as that implemented in the United States, for example.

However, one must not conclude from this situation that the civil liability system is futile and that society has to bear the burden of all of the costs: after all, there is a difference between the costs and responsibilities borne by the operator, and which are therefore ultimately paid by electricity consumers, and the costs borne by the Government, i.e. the taxpayers.

B - International conventions on civil liability for nuclear damage

1 - The conventions

a) Paris Convention of 29 July 1960 (OECD/NEA)

The economics of the system

The convention on civil liability in the nuclear energy sector (negotiated within the framework of the OECD Nuclear Energy Agency [AEN] and signed in Paris on 29 July 1960) set out the bases for the special system of coverage for civil nuclear risks. This system was intended to balance the interests of potential victims with those of the emerging nuclear industry, which it was important to preserve.
This convention, to which there are currently 16 contracting parties\textsuperscript{205}, entered into force on 1 April 1968 and was successively amended in 1964, 1982 and 2004 (the last amendment has not yet entered into force). It provides for a special civil liability system intended to facilitate the compensation of victims for damages incurred on the territory of the country in which the accident occurred and other countries parties to the convention.

\textit{The basic principles of the civil liability system for nuclear damage introduced by the Paris Convention}

The special system provided by the Paris Convention of 1960 is based on five principles which have largely been maintained in all subsequent conventions. The operator of a nuclear facility is responsible for all damage caused during operation or during the transport of radioactive material to or from this facility. This liability is called into play under the following conditions:

- \textbf{objective liability without fault}. The operator is responsible for any personal or property damage caused by an accident which has occurred at their facility or during the transport of radioactive material to or from their facility without the victim having demonstrated fault on their part. To invoke the operator's liability, the victim need only establish a causal link between the event which caused the damage and the loss incurred;

- \textbf{exclusive liability} “directed” solely onto the operator of the nuclear facility, intended to ensure quick processing of compensation disputes and preventing any attempt by the victims to invoke the liability of their suppliers and/or sub-contractors;

- \textbf{limited liability} which is limited in duration and capped at the amount of compensation for damages to be borne by the operator;

- a \textbf{compulsory financial guarantee} for the operator in order to prevent their insolvency;

- a \textbf{jurisdiction unit} conferring competence to evaluate compensation solely to the courts of the state in whose territory the accident occurred, or in the case of transport, the state in which the facility for which the operator is responsible is located.

\textsuperscript{205} Germany, Austria, Belgium, Denmark, Spain, France, Greece, Italy, Luxembourg, Norway, Holland, Portugal, the United Kingdom, Sweden, Switzerland and Turkey. Switzerland ratified the Paris Convention as amended in 2009 but it will only enter into force for Switzerland when the amendment Protocol of 2004 enters into force. Thus, it is currently effective in 15 countries.
The damages covered under the civil liability system for nuclear damage include:

- personal damage. A principle of non-discrimination applies to victims of a nuclear accident, irrespective of their nationality, domicile or place of residence;
- property damage (to equipment) with the exception of (i) the nuclear facility itself and other nuclear facilities, including those under construction, which are located on the site of this facility, and (ii) property on the same site which are or have to be used in connection with any of these facilities.

**The limits placed on civil liability for the operator of a nuclear facility**

The Paris Convention significantly limited the operator's civil liability, notably with very low upper limits of liability.

**The upper limits of compensation for damages**

Under Article 7 of the Convention, the maximum for which the operator may be held liable for damage caused by a nuclear accident was set at 15 million Special Drawing Rights (SDR), i.e. approximately €17.25 million\(^{206}\). Under certain conditions, this amount can be modified by a contracting party’s legislation. A guaranteed minimum of 5 million SDR (€5.75 million) is also provided for, to be paid by the operator for damages caused by the transport of nuclear material or damages resulting from “reduced-risk nuclear facilities” recognized as such by a contracting party.

**Ten-year statute of limitations for claims for damages**

Claims for damages must be initiated within ten years of the date of the nuclear accident. However, the national legislation of a contracting party, on the territory in which the facility for which the operator is responsible is located, may provide for a time limit of longer than ten years.

\(^{206}\) With an equivalence rate of 1 SDR = €1.15. The SDR is an international reserve asset created in 1969 by the International Monetary Fund.
Exceptions to the operator’s liability

The provisions of the Paris Convention do not apply to nuclear accidents which occur on the territory of non-contracting states nor to damages suffered on these territories, unless the contrary is stipulated by the legislation of the contracting party to which the liable operator is subject.

The operator is not held liable for damage caused by a nuclear accident if this accident is the direct result of armed conflict, acts of hostility, civil war, insurrection or exceptional natural cataclysms\(^\text{207}\). The national legislation of the contracting party on whose territory the nuclear facility is located may, however, exclude natural cataclysms from the exemptions to the operator’s liability.

b) The Brussels Supplementary Convention of 31 January 1963

The compensation system set out by the Paris Convention quickly proved inadequate in terms of covering the damages which could be caused by a nuclear accident, even one limited in scope. Most states parties to the Paris Convention have acceded to the Brussels Supplementary Convention of 31 January 1963\(^\text{208}\) in order to ensure better compensation for victims through a system of higher upper limits comprising three tiers of cumulative compensation to be paid by the operator, the state in which the facility is located, and the states parties to the Convention. The supplementary nature of this Convention is set out in its 1st Article, which specifies that the system in place is subject to the provisions of the Paris Convention: a state cannot become or remain a party to this convention unless it is a party to the Paris Convention.

The three-tiered cumulative compensation system:

- the **first tier** corresponds to the amount of compensation to be paid by the operator as established by the Paris Convention, i.e. a minimum of 5 million SDR, the equivalent of €5.75 million;

\(^{207}\) Damage caused by terrorist acts is, however, covered by the agreement.

\(^{208}\) Twelve states are currently parties to the Brussels Supplementary Convention: Germany, Belgium, Denmark, Spain, Finland, France, Italy, Norway, Holland, the United Kingdom, Sweden, Slovenia and Switzerland (Switzerland has ratified the Brussels Convention but it has not yet entered into force). The three states which are parties to the Paris Convention but not the Brussels Supplementary Convention are Greece, Portugal and Turkey.
− the second tier corresponds to the compensation paid by the “facility state”, i.e. the state in which the liable operator’s nuclear facility is located, in an amount (cumulated with the first tier) limited to 175 million SDR (€201.25 million);

− the third tier, cumulated with the first two tiers, provides an allocation of compensation of up to 300 million SDR, i.e. €345 million. This compensation is to be paid by the contracting states according to a breakdown scale based on the relative GDP levels and heat ratings in place in each state.

The Paris and Brussels Convention set out the principles of international law on civil liability for nuclear damage on which positive French law is based. At present, the parties to these conventions mainly include the nuclearized countries of Western Europe.

c) Reciprocal application of two conventional systems for civil liability for nuclear damage

The Vienna Convention on civil liability for nuclear damage was adopted on 21 May 1963 under the auspices of the IAEA and within the framework of the United Nations. It entered into force on 12 November 1977, with 38 states parties209, and has the unique characteristic of counting equivalent numbers of nuclear and non-nuclear countries among its members.

Negotiated at the same time, the Vienna and Paris Conventions are inspired by the same basic principles and present comparable methods for implementing civil liability for nuclear damage, with the exception of a few details, but in significantly different amounts for the different countries. France is not a signatory of the Vienna Convention.

In 1986, in the absence of a single international system of civil liability for nuclear damage, the Chernobyl accident led the parties to the Paris and Vienna Conventions to establish a legal bridge ensuring better compensation for victims, guaranteeing them the reciprocal benefits of the provisions of each convention.

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209 Saudi Arabia, Argentina, Armenia, Belarus, Bolivia, Bosnia and Herzegovina, Brazil, Bulgaria, Cameroon, Chilli, Croatia, Cuba, Egypt, Estonia, Federation of Russia, Hungary, Kazakhstan, Leetonia, Lebanon, Lithuania, Macedonia, Mexico, Moldova, Montenegro, Niger, Nigeria, Peru, Philippines, Poland, Czech Republic, Romania, Saint-Vincent, Senegal, Serbia, Slovakia, Trinity and Tobago, Ukraine and Uruguay.
This was the purpose behind the Common Protocol on Application of the Vienna and Paris Conventions, signed on 21 September 1988 and put into force on 27 April 1992.

This common protocol extends the geographical coverage of the liability systems through a system of reciprocal advantages, which allows the victims of a state party to one of the two conventions to obtain compensation for an accident occurring on the territory of a state which is party to the other convention.

It must be pointed out that France has not ratified the common protocol (although it did sign it on 21/06/1989) due mainly to the fact that it does not adequately ensure reciprocal application of the two systems given the differences in compensation amounts for certain countries. Nevertheless, an interministerial decision of 3 October 2011 provides for its future ratification with a reservation regarding reciprocity.

\[d) \text{ Substantial revision of the liability system, pending ratification for the past eight years}\]

\textit{The Protocols of 2004 amending the Paris Convention and the Brussels Supplementary Convention}

The signing of the protocols amending the Paris Convention and the Brussels Supplementary Convention, on 12 February 2004, brought these two conventions contextually very close to the Vienna Convention after its 1997 amendment. The main changes implemented were:

- a very substantial increase in the nuclear operator’s liability (raised to €700 million), the compensation amounts to be paid by the state in which the accident facility is located, and the amounts to be paid through solidarity between the states (bringing the overall compensation provision to €1.5 billion);

- a broader definition of “nuclear damage”;

- an enlarged geographical scope of coverage for both conventions.
Comparison of the compensation amounts provided by the Paris / Brussels Conventions with those provided by the Protocols of 2004

<table>
<thead>
<tr>
<th>Categories</th>
<th>Amounts provided by the conventions in force in France</th>
<th>Protocols of 2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operator</td>
<td>€91.5 million</td>
<td>€700 million</td>
</tr>
<tr>
<td>Operator’s state</td>
<td>+ €109.8 million i.e. a total of: €201.3 million</td>
<td>+ €500 million i.e. a total of: €1,200 million</td>
</tr>
<tr>
<td>States parties</td>
<td>+ €143.7 million i.e. a total of: €345 million</td>
<td>+ €300 million a total of: €1,500 million</td>
</tr>
</tbody>
</table>

Source: Conventional and legislative measures and Cour des Comptes

The rules imposed by the European Union for the ratification of the Additional Protocols of 2004

One must note that the amended Protocols of 2004 have not yet gone into force. Indeed, the aim of the Additional Protocol to the 2004 Paris Convention is to intervene in legal matters by transferring jurisdiction to the courts of the coastal state, in the event of nuclear damage in the exclusive economic zone of a contracting party. Consequently, under the principle imposing the rule of unanimity of Member States in judicial matters, the European Union required that the instruments of ratification of this protocol be deposited simultaneously by the Member States parties to the conventions in question.

Three Member States of the European Union (Belgium, Great Britain and Italy) are concerned in particular, since the domestic law provisions needed to authorize ratification of the protocols have not yet been implemented.

2 - The limits of international law

a) The insurance market’s difficulties covering certain extensions

As the insurance market was thus able to cover the financial guarantee provided by the legal provisions currently in force, the alternative solutions, such as creating a mutual, captive or partial risk retention insurance system, have seldom been used. However, the limits of the insurance market’s abilities may be tested with the entry into force of the Protocol of 2004 amending the Paris Convention. Whereas raising the upper limit for insured compensation to €700 million does not appear to pose a problem, the insurance market would not be able to cover the
some of the extensions of the scope of damage covered. The main difficulties would be:

- covering the costs of restoring a damaged environment, for which it is difficult to objectively determine the limit of reasonable measures to implement;
- financing protective measures if there is a “serious and imminent threat of nuclear accident”, for the same reason, the precautionary principle applied by the local public authorities may involve measures more costly than those recommended by the experts;
- the extension of the statute of limitations for physical injury from 10 to 30 years, notably due to the difficulty of establishing a causal link between the nuclear accident and damage in the case of diseases appearing many years after the event.

These points must not prevent the entry into force of the Protocols of 2004. On one hand, we have seen that the reticence of insurance providers evolves over time, and on the other hand, as with other risks, the state can provide coverage, in exchange for payment of a premium, if the insurance market proves inadequate.

\[b\text{) Some major nuclear countries are not parties to any conventions}\]

Several countries with developed nuclear power industries are not parties to any international conventions on civil liability for nuclear damage. Japan (54 nuclear reactors in operation in 2010), China (14 reactors in service) and Korea (20 reactors in production) have domestic legislation on civil liability for nuclear damage (adhering to the same general principles introduced by the international conventions), but have not signed any international conventions. Thus, the case of cross-border damage due to a nuclear accident in these countries is not covered.

The United States is also a special case. The system of civil liability for nuclear damage in the United States, which is governed by the Price Anderson Act, dates back to 1957. Based on objective liability in a limited amount, it covers nuclear reactors, research reactors, the Department of Energy (DOE) nuclear facilities and transport activities, and it provides for a victim compensation system based on the operator. In terms of international conventions, the United States is only party to the 1997 Convention on Supplementary Compensation for Nuclear Damage, which has only been ratified by 4 countries and has not entered into force.
C - Positive French law

1 - The legal provisions in force

a) Act No. 68-943 of 30 October 1968

The legal system of civil liability for nuclear damage applicable in France is based on the provisions in force of the Paris Convention, the Brussels Supplementary Convention and their additional protocols; these provisions have been repeated and supplemented by Act No. 68-943 of 30 October 1968, which constitutes the positive French law.

The main provisions of the Act of 1968, amended by Act No. 90-488 of 16 June 1990, cover the following points:

− the maximum civil liability is increased to €91.5 million per accident occurring at a nuclear facility and limited to €22.9 million when the accident concerns a reduced-risk facility or the transport of nuclear material;

− beyond this amount to be paid by the operator, the state pays the remaining compensation due to the victims, under the conditions and within the limits provided by the Brussels Supplementary Convention, up to a maximum of €345 million.

− every nuclear operator must hold and maintain an insurance policy or other financial guarantee approved by the Ministry of Economy and Finance for the amount of their liability per accident. Failing which, the state acts as the alternate guarantor of compensation for damages up to a maximum of €91.5 million;

− if the guaranteed amounts are not enough to provide compensation for the damages, or if this appears to be risk, a Council of Ministers decree published within six months of the accident will document the resulting exceptional situation and determine the procedure for compensation, providing for priority compensation for physical injury;

− the state provides compensation for damage the effects of which appear more than ten years after the date of the accident if it occurred on the national territory. However, the claim for compensation must be initiated within five years of the 10th anniversary of the accident;

− transporters of nuclear material in transit on French territory must have an insurance policy or other financial guarantee covering the damage that could be caused by a nuclear accident during transport, in the amount of €22.9 million for transport governed by the Paris Convention, and €228.7 million in other cases.
It seems apparent that the current upper limits are far too low and would not cover the damage occurring from an accident, even of limited scope. The provisions of the Protocols of 2004 set out above attempt to make up for this inadequacy, at least in part.

b) The provisions of the Protocols of 2004 appear in the Act of 2006, but remain inapplicable

Article 55 of Act. No. 2006-686 of 13 June 2006 on transparency and safety in nuclear matters sets out the implementation measures for the Revision Protocols of 2004 and therefore amends the Act of 1968; however, it stipulates that these measures shall only be applicable when the protocols enter into force.

This Act authorized acceptance of the Additional Protocols of 2004 in France; the deposit of the instrument of ratification must include a reservation on reciprocity with regard to non-contracting parties whose national legislation does not offer reciprocal advantages in an amount equivalent to that introduced by these protocols.

c) Implementation of the financial guarantee by operators under the system currently applicable in France could be improved on

There is no list of the operators concerned

The amended Act of 1968 on civil liability in the domain of nuclear energy applies to natural and legal persons, public or private, who operate a nuclear facility falling within the scope of application of the Paris Convention. However, there is currently no list kept up-to-date by either the ASN or the DGEC, of the operators required to have the provided financial guarantee. Consequently, it is currently impossible to ensure that all operators of nuclear facilities on French territory have the mandatory guarantee of compensation for potential victims of nuclear damage.
The guarantees are not systematically subjected to approval as stipulated by law

Article 7 of the amended Act of 1968 stipulates that the financial guarantee put in place by each operator must be approved by the Ministry of Economy and Finances. This legal requirement is currently not observed in France, as the General Subdirectorate of Insurance (Directorate General of the Treasury) does not systematically issue approvals for guarantees regarding civil liability for nuclear damage.

Therefore, at present, it is not possible to certify the reliability of the financial guarantees put in place by operators. Considering the complexity of the financial mechanisms involved\(^{210}\), this failing makes it impossible to certify the operators’ ability, via their insurance providers, to meet their obligations in terms of civil liability coverage. The necessity of this approval system will become even more acute once the upper limit for liability has been increased to €700 million.

2 - Difficulties and limits

a) Excessively low upper limits of civil liability

As explained above, the provisions for compensation currently in force are limited to a maximum of €345 million, which is clearly not enough to ensure compensation for damages, even for physical injury alone, in the event of a major accident. Regarding the amounts stipulated by the Protocols of 2004 amending the Paris and Brussels Conventions, which are considerably higher, they are still not applicable.

b) A flawed nuclear insurance market

Coverage of civil liability for nuclear damage is mainly provided the world over by insurance or reinsurance pools. EDF is an exception to this rule, as it uses a mutual insurance system and a captive reinsurance system. The creation of these pools of insurance providers, each of which operates in a single national territory, automatically leads to a quasi-monopolistic situation and a lack of transparency which raises questions about the system’s ability to cover future risks.

\(^{210}\) Operators are not eligible to join the agreements between the insurance providers in the ASSURATOME group, nor for the outcome of the reinsurance premiums paid each year, nor to join the agreements guaranteeing the safety and availability of compensation funds.
c) Implementing these guarantees could prove difficult in the event of a serious accident

The main goals of the specific rules on civil liability for nuclear operators, and the obligation to have and maintain a guarantee, are to ensure quick compensation for victims. However, this may be impeded by several factors when it comes to implementing the provisions.

Priority given to compensation for physical injury

Should the damages to be compensated surpass the authorized upper limit for compensation, French law provides that priority be given to compensation for physical injury. The problem, however, is that this is the damage which takes the longest to reveal itself; the consequences may appear several years after the exposure to radioactivity and it is difficult to establish the relationship between certain diseases and the nuclear accident. Compensation for damages other than physical injury may therefore be delayed or subjected to a fairly low upper limit so that compensation funds can be kept in reserve.

Solutions other than “conventional insurance” pose the problem of effectiveness when it comes to managing accidents

In the event of a major nuclear accident, managing the claims for compensation is a major task. An insurance provider, with its network of agencies, is particularly well equipped to handle this task, which is one of the primary facets of its profession. But when the financial guarantee is provided by a dedicated mutual, captive or risk retention insurance system rather than an insurance company, this raises the question of whether they will be able to handle the influx of damage claims. The option of an agreement with an insurance provider must be carefully examined in order to ensure that it is a suitable solution. In this regard, verification of these aspects should be included in the conditions for issuing the approval as stipulated by law.

It should also be said that the administrative costs at the expense of the insurance providers is currently capped at €30 million and that the question of who would assume the additional costs remains unanswered.
The state as guarantor: a guarantee which is currently at no cost to operators

The Paris and Brussels Conventions and their translation into French law limit the civil liability of nuclear operators. In the current system of covering the cost of an accident (compensation and economic cost), the state participates at 4 levels:

- it finances the 2nd third of the compensation for damages, up to the current maximum of €126.5 million, to be raised to €500 million after the entry into force of the version amended in 2004;
- it contributes to the 3rd third of funding (solidarity between states) according to the installed capacity. This contribution totals €143.75 million, approximately 34 percent (i.e. currently €49 million) of which is contributed by France. In the version of the Convention amended in 2004, as per the new breakdown between states, France’s contribution will represent 40 percent, i.e. approximately €120 million;
- in the event of a major accident, in the highly probably case that the three tiers of compensation were not enough to cover all of the damages, the state could (although this is currently not provided by law) find itself having to pay compensation for certain damages, such as physical injury, beyond the upper limit provided by law, for an amount not previously determined. Moreover, separately from any decision to pay compensation beyond the predefined maximum, part of the economic cost of the damages would be borne by the French economy, due to reduced tourism or exports, for example;
- similarly, in the event of default on the part of the insurance providers (or alternative guarantees) or operators (which seems fairly improbable for an upper limit of civil liability of €91.5 million, but considerably more realistic when the upper limit is raised to €700 million), the state would have to compensate for this default on the basis of subsidiarity.

Of course, not all of these different levels of participation constitute a guarantee, per se, but overall, they result in the state covering all of the costs resulting from the accident, at no cost to the operator (beyond the first compensation limit), whereas in a conventional system of reparation of damages caused to a third party, they would be at the responsible party’s expense, without limits.
e) Financing the state’s coverage of part of the compensation for damages

Thus, what we have seen, is that in the event of a major nuclear catastrophe, the state would have to cover a significant share of the damages which should have been borne by the producer under their civil liability.

The compensation for damages borne by the state, in place of the operator’s civil liability, for the 2nd and 3rd thirds of the compensation, currently comes at no cost to the operator. Moreover, the insurance market could be unable to cover certain extensions of guarantee stipulated by the Protocols of 2004, which means that the state’s guarantee would have to replace the defaulting market.

In both of these cases, the state could legitimately demand payment of a premium for covering these risks. For the 2nd third of compensation, under the terms of the Brussels Convention, the national law can also raise the upper limit of the operator’s liability and consequently reduce or eliminate the tier of additional funding provided by the state.

The cost of the risk covered by the state is very difficult to evaluate. However, we can arrive at an approximate figure for this risk by comparing it to the cost of fictive creation of a compensation fund, like those which exists in other domains.

As stated above, the probability of an accident occurring is very low, and the accidents which occurred at Chernobyl and Fukushima cannot be compared to the French context. However, in order to estimate the cost of a potential risk insured by the state without a consideration, one needs to work from an accident cost figure. This is why the nuclear accident cost of €70 billion, based on exploratory research conducted by the IRSN, has been used in the following calculations. Excluding any probabilistic approach in the name of simplicity, the creation of a fund endowed with this amount over the average operating life of a nuclear fleet (here, based on the assumption of 40 years) would translate into an annual endowment of €580 million (with the annual yield for the fund estimated at 5 percent). The nuclear power generated in France is to the order of 410 million MWh per year, which means that endowing this type of fund with €70 billion would cost €1.41 per MWh, i.e. 3.52 percent of the ARENH price211 fixed at €40/MWh on 1 July 2011, and to be raised to

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211 ARENH: price for regulated access to historical nuclear electricity
€42/MWh on 1 January 2012. This represents an annual “endowment” of €83 million (i.e. €0.20/MWh) per €10 billion of the accident cost.

This being an illustrative example, which is highly sensitive to the assumptions made (particularly the accident cost figure and the fleet’s operating life, and without taking a probabilistic approach), it gives only an estimation of the cost of the risk assumed by the state. The funds and the selected accident cost are only “calculation variables” used to indicate a cost for the risk, since a well-founded statistical approach is not possible. The information developed here must not be interpreted as arguments in favour of creating this type of fund.

Comparisons with other economic activities and other energy sources

The system of civil liability for ship owners with regard to damage resulting from oil pollution is similar to the system for nuclear damage: it is based on the principle of objective liability “directed” at the tanker, imposes a system of mandatory liability insurance, limits liability (under certain conditions) to an amount defined according to the vessel’s tonnage, and specifies the jurisdiction of the courts.

A fund (FIPOL) has also been created to provide additional compensation beyond that to be paid by the ship’s owner, which is financed through contributions charged to any person having received more than 150,000 tonnes of oil over the course of the year\(^{212}\). The maximum amounts are 89 million SDR (approximately €102 million) to be paid by the owner and an additional 203 million SDR (approximately €233 million) payable by the fund.

A second fund, ratified by a much lower number of states (27 compared to 107 for the FIPOL and 125 for the convention on civil liability), brings the overall maximum for compensation per accident to 750 million SDR (€862.5 million).

\(^{212}\) 1992 Convention on civil liability and 1992 Convention on creating international compensation funds for damages due to oil pollution.
3 - The example of Fukushima: the limits of positive law in the event of a serious accident.

In Japan, the systems of coverage for operators' liability and the damage compensation systems stem from laws or governmental decisions based on the Act on Compensation for Nuclear Damage, adopted in 1961.

The scale of the catastrophe and its dual nature (natural catastrophe/nuclear accident) quickly revealed the inadequacy of this legal framework, similar to that provided by the various international conventions. Thus, specific legislation was implemented into provide a specific legal framework stipulating the conditions for state aid in paying compensation for the damage caused by this accident.

a) The provisions of the Act of 1961

The Act on Compensation for Nuclear Damage stipulates that the operator of nuclear reactors which have caused damage shall be held liable for this damage, without limits, regardless of whether negligence was the cause of the damage. Japanese law provides that a nuclear operator can only put nuclear reactors into service if they have reserves for the compensation of nuclear damage. These "security reserves" are defined as follows: (1) civil liability insurance for nuclear damage and a contract for the compensation of nuclear damage; (2) assets deposited at the Consignment Office; (3) other provisions, in order to guarantee funds for the compensation of damages in the event of an accident.

The amount of the "security reserve" for an in-service reactor with a thermal power rating output of over 10,000 kW, as in the case of the Fukushima Daiichi power plant, is 120 billion yen (approximately €1.1 billion). The operator of the nuclear power plant assumes unlimited liability even if the accident is not due to negligence on his part. In other words, even if the amount needed to cover compensations exceeds the provisions of the security reserve (i.e. 120 billion yen), responsibility for paying compensation for damage does not fall on the state. The operator of the nuclear power plant remains solely liable, which means that in the event of a serious accident, they will undoubtedly go bankrupt, which makes the notion of "unlimited liability" entirely relative.

This is why Japanese law provides that the Government may provide the operator with "adequate aid", in order to guarantee compensation of the damages suffered. In order to define the specific content of this "adequate aid", an Act was passed on 3 August 2011
providing for the “creation of an aid organization for the compensation of nuclear damage”.

Although the Act on Compensation of Nuclear Damage is still based on the principle of unlimited liability of the operator in the event of a nuclear accident, its Article 3 introduces a proviso waiving the operator’s liability if the damage is caused by a “serious natural catastrophe of an exceptional nature or by social revolt”, i.e. in the event of force majeure. Considering that the accident at the Fukushima power plant occurred in the aftermath of the tsunami which ravaged the north-western coast of Japan, one could reasonably ask whether the waiver clause could have been applied in this case. However, in the context of public outrage and pressure for the company to assume its responsibilities, the Chairman of TEPCO announced at the general meeting of shareholders that they would not attempt to claim this waiver before the courts.

The overall cost of the nuclear accident at Fukushima can be broken down into the direct losses incurred by TEPCO and the cost of the indirect damage suffered by the population and the state. The recent nature of the accident makes it all the more risky to attempt to evaluate it, and experts agree that it will take ten years to gather the feedback from this accident. In this sense, the figures arrived at today, with a large range for the estimated costs, can only be seen as rough ideas. What makes estimation even riskier is that the Fukushima catastrophe resulted from multiple causes – earthquake, tsunami and then nuclear accident, with all of their combined effects, including very long-term consequences.

b) The Act on the Creation of an Aid Organization for the Compensation of Nuclear Damage

The Act on the Creation of an Aid Organization for the Compensation of Nuclear Damage sets out the conditions for the aid that the state has to provide for the operator of a nuclear power plant if the total compensation due exceeds 120 billion yen.

This act provides for the creation of an organization co-funded by the Japanese Government and the Japanese electric companies, the aim of which is to provide the financial aid required by the nuclear operator. Thus, this system leaves TEPCO responsible for paying compensation to the victims, but prevents the compulsory winding up which otherwise would have been unavoidable for the company, since it will be able to receive financial support from the aid organization while continuing to generate electricity.
In addition to the capital provided by its shareholders, the organization will be funded through annual and exceptional contributions paid by the various Japanese nuclear operators, i.e. all of the regional electric companies in Japan, including TEPCO. These companies are authorized to increase their rates in order to pay the annual contribution, which means that, in the end, part of the cost of creating this organization will probably be borne by the consumer.

In addition, if it proves necessary, the Government will be able to transfer state obligations to the organization in order to raise funds.

The aid offered by this organization can come in various forms, such as providing liquid assets, buying shares in the company, loans, acquisition of the company’s obligations, and loan guarantees.

In order to obtain state aid, TEPCO will have to draw up an action plan describing the measures it intends to implement in order to streamline its activities, and to undergo an audit by the organization so that its assets and management system can be precisely evaluated.

TEPCO will have to agree to pay exceptional contributions in accordance with the rules defined by the organization. These contributions could be viewed as reimbursements of the financial aid received for the compensation. A ministerial order will define the amount of these contributions according to the maximum that the operator can pay given the status of their accounts, and allowing them to be able to normally conduct their electricity generation and distribution activities.

The Act on the Creation of an Aid Organization should ensure more effective and longer-term compensation of victims, since the funds that the organization provides for TEPCO will enable it not only to pay compensation to victims quickly, but also to remain in business. The profits from its continued activities will be paid to the organization in the form of the exceptional contributions, therefore reimbursing the advanced sums.

c) The Act on Emergency Compensation for Victims of the Nuclear Accident of 2011

In 2011, an Act was also passed on emergency compensation for victims of the nuclear accident. This Act allows the state to pay provisional compensation to victims who have suffered damages caused by the nuclear accident at the Fukushima power plant, in order to ensure that they receive compensation as quickly as possible.
The state is now authorized to pay provisional compensation to victims, equivalent to the estimated amount of damage suffered, which is calculated according to calculation method and terms stipulated by decree, and multiplied by a rate of at least 50 percent, which is also stipulated by decree.

In other words, the victims of the nuclear accident can receive provisional compensation from the state in the amount of more than half the estimated damages. This provisional compensation is clearly an advance payment by the state on behalf of TEPCO, who becomes the state’s debtor.

Thus, after the accident, the civil liability and insurance system had to be adapted, since it proved inadequate and ineffective with regard to the consequences of the catastrophe.

CONCLUSION – ACCIDENT AND INSURANCE

The quality and reliability of the safety systems for nuclear facilities make the risk of accident very low. Yet failures can occur, as the accidents at Three Mile Island, Chernobyl and Fukushima have shown, and their impacts can be irreparable, both for the power generation facility itself and for the area in which they occur. Assessing the risk of accident and the ensuing financial consequences remains an imprecise exercise, and one which is still not exhaustive.

Nuclear risk cannot be assimilated to a “conventional” industrial risk, due to the intrinsic nature of its occurrence and the seriousness and nature of the damage it causes. The main concern is the civil liability of nuclear operators and transporters, which has led to implementation of a measure of derogation to common law, provided by the international Paris, Brussels and Vienna Conventions.

The principles of civil liability for nuclear damage, which are the subject of numerous international conventions, are sometimes supplemented by the provisions which translate them into national law. The latest amendments to the Paris and Brussels Conventions, signed in 2004, have still not entered into force despite the significant improvements they make to the system.

Effective application of the positive law provisions will require great rigour, particularly when it comes to approving the financial guarantee required of operators. This aspect of the current French
legislative framework is not yet fully applied, as operators’ ability to meet their obligations (in terms of funds and managing the damage claims) is not certified by the approval system provided by law.

In the current system, the state could have to pay compensation beyond the maximum liability for nuclear operators, which is currently very low. The state’s coverage of this risk is currently at no cost to operators. The cost can be estimated very approximately, but remains uncertain. Moreover, the insurance market will not be able to cover some of the extensions of liability provided by the Protocols of 2004. Thus, the state will have to take the place of the inadequate market, which raises the issue of remuneration for this coverage.

In any event, the state ultimately remains the final guarantor for the costs of compensation of nuclear damage, as is sometimes the case for damage caused by other industries or natural catastrophes.
Chapter VIII

General conclusion

The previous chapters have served “to assess the costs of the nuclear power sector” as requested by the Prime Minister in his letter dated 17 May 2011 (Annex 1), by closely analysing the different categories of past, present and future costs connected with nuclear power generation. These chapters provide answers to the two questions which are generally asked with regard to the “cost of nuclear power”: 1) have all of the costs been taken into account, and 2) have these costs been accurately assessed?

To get the “big picture” in terms of how to answer these questions, one must first examine the costs counted by the industrial operators, and then consider the other types of costs, whether expenditure funded by the public sector or externalities.

I - Costs counted by operators

The costs counted by the operators, mainly EDF and AREVA, can be broken down into two categories which include past, present and future expenses: those relating to investments and capital, and those relating to operating expenses.

As stated above, AREVA’s costs (investments and operating costs, including future expenses) are considered to be included in the fuel costs paid by EDF, for the portion of AREVA’s activities which pertain to the generation of French nuclear power. Thus, to avoid counting the same costs twice, only EDF’s accounts are examined in attempting to answer questions on the costs borne directly by operators.
A - Investment and capital

1 - Very high initial investment, with a cost per MW which increases over time

a) The amount of the initial investment in the current fleet

The first chapter assessed the investments made in research (€55 billion\textsubscript{2010}), construction of the facilities needed for nuclear power generation (€121 billion\textsubscript{2010}), and the overall cost of Superphénix (€12 billion\textsubscript{2010}).

Two avoid counting expenses twice, only the fleet construction costs will be counted as investments in the calculations below. Research costs, for example, are included in the operators’ operating expenses, for self-funded research, or in the expenditure funded by the public sector.

To measure the generation cost for the current fleet, we will count only the construction costs for the 58 existing reactors, i.e. an overnight cost of €83.2 billion\textsubscript{2010}\textsuperscript{213}. This total is calculated by adjusting to 2010 Euros the recorded or estimated costs incurred mainly between 1973 and 2002.

Interest during construction can be added to this cost, due to the fact that the construction of power plants spans several years. Not having precise information on the methods used to finance these construction costs, the Cour des Comptes estimates the interest during construction at €12.8 billion\textsubscript{2010} using a real interest rate of 4.5 percent. EDF estimates this interest at €23 billion\textsubscript{2010} based on an interest rate of 7.8 percent, which the Cour des Comptes does not consider appropriate for this calculation.

Thus, we can value the initial investment in the 58 current reactors at €96 billion\textsubscript{2010} for an installed capacity of 62,510 MW, i.e. €1,535 million\textsubscript{2010} per installed MW.

\textsuperscript{213} See Chapter I: the overnight cost is the sum of the initial construction costs (€72.9 billion\textsubscript{2010}), engineering costs (€6.9 billion\textsubscript{2010}) and pre-operating costs (€3.4 billion\textsubscript{2010}).
b) A cost of construction per MW which increases over time

If we consider the initial cost of construction alone, including the engineering costs (€79,751 million\textsubscript{2010}) with respect to reactor capacity, we see that this cost has increased over time, from €1.07 million\textsubscript{2010}/MW in 1978 (Fessenheim) to €2.06 million\textsubscript{2010} in 2000 (Chooz 1 and 2) or €1.37 million\textsubscript{2010} in 2002 (at Civaux), with an average of €1.25 million\textsubscript{2010} for the 58 reactors. This increase is notably due to changes in the safety baselines over time.

Without knowing the total final cost of the EPR we are not able to make a precise cost comparison, but we can see that the cost of construction per MW is continuing to rise with this new generation, which has to comply with very high safety requirements right from its construction. With a cost of construction estimated at €6 billion for the EPR in Flamanville (first-of-a-kind reactor) and a capacity of 1,630 MW, the cost per MW is €3.7 million; with a potential standard cost of €5 billion, the cost per MW is €3.1 million.

2 - Maintenance investments rising significantly

We were not able to calculate the total amount of investments made on current reactors since their construction, both to ensure proper operation in terms of power generation, and to gradually improve safety and security. Thus, we can only use the current data or EDF’s forecast data for the coming years.

When these investments slowed in the 2000s, it became apparent just how important they are, since the fleet’s availability and output coefficient fell considerably. Thus, in calculating the generation costs, we should probably count significantly higher maintenance investments than those seen in the past few years. EDF, for example, is working on a €50 billion investment programme for 2011 to 2025, i.e. an annual average of approximately €3.3 billion, almost double the investments made in 2010, which were already higher than in the previous years. This programme will be supplemented by the investments required under the ASN’s post-Fukushima requirements, a portion of which have already been counted in the €50 billion. Thus, maintenance investments will probably average €3.7 billion per year.
EDF’s maintenance investments

<table>
<thead>
<tr>
<th>In € billions 2010</th>
<th>Annual total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008 - 2010 average</td>
<td>€1.5 billion</td>
</tr>
<tr>
<td>In 2010</td>
<td>€1.75 billion</td>
</tr>
<tr>
<td>Forecast total for 2015 with a €50 billion programme, not counting the changes since Fukushima</td>
<td>€3.4 to 3.6 billion*</td>
</tr>
<tr>
<td>Average with the scenario of a €55 billion programme by 2025, with the new requirements since Fukushima</td>
<td>€3.7 billion</td>
</tr>
</tbody>
</table>

*information given to the financial markets by EDF in its financial report for the first two quarters 2011

3 - Dismantling costs which cannot be defined with certainty

The end-of-life expenses for power plants have to be reconciled, i.e. the cost of dismantling the facilities and the “last core” expenses, which, like the dismantling costs, are due only once, at the end of a reactor’s life.

These expenses are included in the various generation cost calculations, and are estimated at €18.4 billion\textsuperscript{2010}, in gross expenses, for the dismantling of the 58 reactors in the current fleet, and €3.8 billion\textsuperscript{2010} for the last cores.

Assessment of dismantling costs is based on a dated and simplistic method, but the results are corroborated by much more sophisticated methods with technical parameters which have to be validated by experts outside the company.

The current figures must be considered with caution, as experience in this area, for EDF (Generation I) as well as the CEA and AREVA, has shown that the estimates tend to rise when the operations are specified, and international comparisons give higher results than the EDF estimates. However, the high variability in these international comparisons is an indication of the uncertainty which reigns in this area.
### Summary of investment and related expenses

<table>
<thead>
<tr>
<th></th>
<th>In € billions 2010</th>
<th>Overall total for the entire service life</th>
<th>Annual total</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Research and Superphénix</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Total research expenses</td>
<td>55</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Superphénix</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Initial investment</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>AREVA</td>
<td>19</td>
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<td></td>
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<tr>
<td>EDF</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Generation I (excl. Superphénix)</td>
<td>6.0</td>
<td>83.2</td>
<td>12.8</td>
<td>- not including the current fleet - overnight cost - interest during construction</td>
</tr>
<tr>
<td>Generation II</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Maintenance investments</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>In 2010 or 2010-2025 plan</td>
<td>1.7 or 3.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dismantling and last core (gross expenses)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AREVA dismantling</td>
<td>3.5*</td>
<td></td>
<td></td>
<td>- included in the fuel price</td>
</tr>
<tr>
<td>EDF dismantling</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Generation I (not including Superphénix)</td>
<td>2.5</td>
<td>18.4</td>
<td></td>
<td>- not including the current fleet</td>
</tr>
<tr>
<td>Generation II</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EDF last cores</td>
<td>3.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
<td>Caution: do not add, as the time scale is different</td>
</tr>
<tr>
<td>of which is to be included in the cost of the current fleet</td>
<td>228.3</td>
<td>118.2</td>
<td>1.7 or 3.7</td>
<td></td>
</tr>
</tbody>
</table>

Source: Cour des Comptes

Figures in grey shading: amounts to be included in the generation cost for the operator of the current fleet, not including expenditure funded by the public sector

*Only half of the gross dismantling expenses are counted, since 50 percent of the investments are financed by foreign investors.*
The Cour des Comptes therefore makes two recommendations in terms of dismantling costs:

- it recommends that EDF use the 2009 Dampierre method as the basis for assessing its dismantling provision, rather than the older method which does adequately allow changes in this provision to be factored into the equation;
- it confirms the necessity and urgency of having technical audits done by external agencies and experts, as envisaged by the DGEC, in order to validate the technical parameters of the 2009 Dampierre method, and if necessary, to adjust the operators’ provision levels accordingly.

4 - Cost of capital has a strong impact, and estimates can vary depending on the question asked

As shown in the table above, of an estimated investment total of €228 billion, all expenses combined, whether funded by the public sector or by the operators, whether for current or Generation I power plants, the investments and similar expenses to be counted in calculating the cost to the operator for the generation of the electrical energy provided by the current fleet total €118.2 billion\(^{2010}\) (initial investment + future expenses related to the investment), to which one must add the annual maintenance investments totalling €1.7 billion in 2010, but liable to be doubled, on average, for the next fifteen years.

Thus, nuclear power generation relies on a long-cycle, highly capital-intensive industry, for which the cost of capital is a variable with a significant impact on the calculation of overall cost.

Today, it is difficult to accurately “reconstruct” the history of how these nuclear investments were financed, as seen in Chapter I-I-B, due both to information availability issues and because no specific and allocated financing method was used for the current fleet; indeed, the available data pertain to all of EDF’s activities. Consequently, the choice of method for calculating the cost of capital depends on the conventions.

Moreover, it is also difficult to determine the economic value of the current fleet: there is no sufficiently liquid market for second-hand power plants to allow the market value of EDF’s existing fleet to be calculated. The stock market ratios are inoperative, given that there are no strictly nuclear operators listed with fleets that are structurally different. And finally, a discounted cash flow method would be hindered by the uncertainty surrounding future electricity sales prices and the remaining operating period of the existing fleet.
Thus, various methods are used to calculate the cost of capital and its share in the overall generation cost, and multiple parameters can vary depending on what is being measured, i.e. according to the amount of capital for which the cost is being calculated, or how this cost is distributed over time (constant or decreasing annual cost)\(^{214}\). We will discuss the following approaches:

\(\textit{a) Cost accounting for generation at a given time}\)

The simplest method consists in counting the amortizations as the only component of investments and capital to be included in the cost of nuclear power generation. It determines \textit{cost accounting for nuclear power generation at a given time}. The value of the amortizations is highly dependent on the accounting methods applied in the past, and on the fleet’s service life. When the fleet has been fully amortized, this value becomes zero.

As for any input factor, this method does not take the \textit{cost of capital}, i.e. the return on capital, into account. Moreover, with the amortization total, the amount of capital invested in the fleet can be reconstituted at its initial value, without counting inflation or changes in nuclear reactor construction costs over time.

\(\textit{b) Current economic cost (CEC): calculation of average overall cost throughout the service life, which is notably useful in comparing different energy sources}\)

This approach aims to measure the annual cost of the return on capital and capital repayment, which allows the amount of the initial investment, adjusted for inflation, to be reconstituted at the end of the fleet’s life (i.e. amassing adequate funds to rebuild a new fleet identical to the existing one at the end of its service life). To calculate this, EDF uses the \textit{current economic cost} (CEC) method, which takes the cost of capital into account in calculating the average cost of nuclear power generation, combined with the capital asset pricing model (CAPM) which is commonly used in the industry sector to estimate of the rate of return expected by the market for a financial asset, depending on its systemic risk\(^{215}\).

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\(^{214}\) In this section, the Cour des Comptes does not aim to provide an exhaustive presentation of all of the existing approaches and methods, but rather to explain the differences which exist between the most commonly used approaches and results.

\(^{215}\) The CAPM is used to calculate the WACC (weighted average cost of capital).
In this method, the cost of the return on capital and capital repayment is measured through an *economic rent* in constant annual instalments throughout the fleet’s service life. This rent is calculated so as to allow an investor to be reimbursed and paid for his investment at a value re-adjusted at the end of the service life. In other words, the economic rent, which is constant in constant Euros, reflects the price that a supplier would be liable to pay if he had to rent the nuclear fleet rather than build it.

This approach does not take into account the former financing conditions for construction of the fleet, and attempts to give an idea of what it would cost to build the fleet now *with the same technology*. It calculates the average overall generation cost, to the operator, for the nuclear fleet over its entire service life.

EDF’s calculation method has been verified by the Cour des Comptes, which has drawn up a revised version of this method (see Annex 15).

The results of this method are sensitive to the applied rate of return on capital, and inversely, are also slightly sensitive to the service life of the power plants. Thus, the method cannot be used to calculate the financial impact of extending the fleet’s service life.
c) The Champsaur commission approach: calculation of generation cost in France for the next 15 years\textsuperscript{216}, considering that the fleet has already been largely amortized, used to calculate a tariff

While taking the cost of capital into account, if the goal is to calculate the current generation cost of the existing fleet, the fleet’s history must also be considered, notably the conditions of its financing and its past amortizations. Thus, one must first determine the share of the capital invested during construction of the fleet which has not yet been reimbursed and remains to be paid or reimbursed. Then, one must calculate the cost of this share of the capital, with a method such as that used in the previous approach.

The Champsaur commission approach\textsuperscript{217}, cited in large part in a CRE opinion on defining the ARENH tariff, aims 1) to fulfil the NOME Law objective of incorporating the competitiveness of the existing nuclear fleet into the ARENH price, considering that the fleet has been largely amortized, and 2) to comply with the need to "converge" with the tariff system which preceded it. Its objective is to reimburse the remaining capital by 2025 (based on the assumption of a 40-year operating period for power plants), considering that the capital was initially reimbursed in step with the accounting amortization (thus at a faster pace than in the CEC calculation), which justified lower tariffs at the end of the fleet’s life.

In terms of return on capital and capital amortization, the approach consists in calculating them based on an unadjusted net accounting value\textsuperscript{218}, and only for the remaining service life of the fleet. This approach accounts for the fact that when the fleet was built, the tariffs were higher than today in real value, because of the amortizations which were initially degressive and applied for a period of only 30 years (see Chapter I I-B)\textsuperscript{219}.

\textsuperscript{216} That is, with an average operating life of 40 years. The average age of the fleet was 25 years in 2010.
\textsuperscript{217} The task entrusted to the Champsaur commission was “to make methodological proposals on determining a fair ARENH price for the regulation period (2011 – 2025), to give orders of magnitude for this price, and to measure the impact in terms of tariff changes”. - Source DGEC
\textsuperscript{218} To be more specific, the asset base is the sum of two components: the net accounting value of the fleet and a portion (15/40\textsuperscript{th}) of the assets earmarked for long-term nuclear costs.
\textsuperscript{219} Chapter I I-B shows that the initial investment expenses for the nuclear fleet have been 75 percent amortized, and that the fleet’s construction was subject to financing
As with the CEC, since the calculation of the average cost for the remaining years of operation uses the same methods, the results are sensitive to the applied rate of return on capital; the duration of the fleet’s service life has relatively little effect on the amount calculated. Moreover, the value of the capital reconstituted during the calculation period (15 years in the framework of the ARENH calculation) is the original value in current Euros, and not its value in constant Euros – meaning that it is adjusted for inflation since construction of the fleet, as in the CEC calculation.

\[ d) \text{ Full cost accounting: calculation of a cost which decreases over time, as its aim renewing the fleet in the current construction conditions (FCA)} \]

One can also attempt to calculate the annual expense of the cost of capital, using an adjusted value for the nuclear fleet to offset the documented effect of the rising costs of investments in reactors over time, particularly due to tighter safety requirements (in addition to the effect of inflation which is factored into the equation in €2010). Based on this simulation, which EDF refers to as full cost accounting (FCA), for all power generation from any source (nuclear, hydraulic, thermal), the Cour des Comptes did a similar simulation, by way of comparison, limited solely to nuclear power generation.

This approach consists in an accounting method which factors in part of the cost of renewal through over-amortization intended to compensate for the fact that rebuilding the fleet will cost more than construction of the current fleet\(^{220}\), even if calculated in Euros 2010. Thus, this diverges from the tariff-based aim of the ARENH, since the NOME Law explicitly excludes renewal of the park from the calculation of this tariff\(^{221}\); in addition, it does not allow an economic cost to be calculated because, in order to reassess the value, it counts the accounting value of the fleet and its amortizations at the calculation date. Unlike in the two conditions facilitated by the State’s implicit guarantee of its debt and the low payments required by the state shareholder.

\(^{220}\) Thus, determining the amount of this “over-amortization” is particularly sensitive and still under discussion, which is why this approach is not discussed further in this report.

\(^{221}\) The NOME law provides that the question of renewal will be examined in 2015, when the authorities will have more information on extending operation of the current fleet, and that this will be funded separately from the ARENH price, in the tariffs for the final consumers.
previous methods, this translates into a cost of capital which decreases over time.

Whichever approach is used\(^\text{222}\), with the exception of cost accounting, the cost of capital is given significant weight in the equation with regard to the other expenses, which is consistent with the highly capital-intensive nature of nuclear power generation.

However, these different approaches do not by any means attempt to answer the same question, which is why one must take care to ensure that the same methods of calculation are used when comparing the generation cost of different energy sources.

**B - Operating expenses**

1 - Present and future operating expenses

Only EDF’s operating expenses were analysed, as the portion of AREVA’s expenses which relate to the generation of French nuclear power are incorporated into the price of the fuel sold to EDF. These operating expenses represented €8.9 billion\(_{2010}\) for the generation of 407.9 TWh in 2010. These expenses have been clearly identified and quantifying them was fairly straightforward.

EDF’s future expenses for spent fuel management (€14.4 billion\(_{2010}\)) and long-term waste management (€23 billion\(_{2010}\)) must be reconciled to these operating expenses, since they result from the annual consumption of fuel required for power generation. Each year, the gross amount of these expenses is increased by the future cost of managing the fuel consumed during the year.

These gross expenses are updated and entered into EDF’s accounts in the form of a provision (€8.8 billion\(_{2010}\) for the spent fuel and €6.5 billion\(_{2010}\) for waste). Each year, there are two types of changes which affect this provision:

- an increase corresponding to the future cost of managing the fuel consumed during the year. In 2010, due to the fuel consumption during this fiscal period, the provision for spent fuel and waste management increased by €336 million;
- and, each year closer to the time these expenses will have to be paid, the book reserves must be increased by the amount of the accretion

\(^{222}\) See Annex 15 which explains the calculations for the different methods.
expense for this provision. In 2010, this accretion expense totalled €740 million\textsuperscript{2010}. The Cour des Comptes counts this amount because it wants to calculate the gross cost of nuclear power generation, which means not taking into account how its is financed, by the sale price, the tariff or investing\textsuperscript{223}. EDF and the DGEC, on the other hand, do not count this amount in their calculations, as they consider that the annual accretion expense is financed by managing and investing the annual provision allocation. This way, they calculate the net cost of the revenue earned on the supposed investment of this provision.

- It can be considered that during the 2010 fiscal period, the future cost of spent fuel and waste management represented a total cost of €1.1 billion\textsuperscript{2010}, which breaks down into €336 million due to the increased volume of fuel to be processed and waste to be stored, and €740 million due to the fact that we are nearing the year in which the fuel and waste produced thus far will have to be managed and stored.

  In total, the operating expenses supplemented by the provision for spent fuel management and long-term waste management add up to €10 billion\textsuperscript{2010}.

\textsuperscript{223} The Cour des Comptes applies the IAS/IFRS accounting standards, notably standard IAS 37 on "provisions, potential liabilities and potential assets". According to these standards, the provision to cover expenses for the back end of the cycle (spent fuel management and long-term waste management) has to be in the amount of the current value (when there is a significant change in value over time) of the expected expenses required to fulfil the long-term legal obligation. The accretion expense resulting from advancing the expected disbursement dates is an integral part of the obligation cost assessment and must be counted as a financial expense. The Cour des Comptes considers, moreover, that by virtue of the basic accounting principles included in the conceptual framework of applicable standards, the conservatism principle (i.e. not underestimating liabilities and expenses and not overestimating assets and revenue) and the rule against offsetting revenue and expenses, must prevail in calculating provisions for long-term expenses when uncertainty is involved.
The operating expenses and related provisions

<table>
<thead>
<tr>
<th>Operating expenses</th>
<th>In € million 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear fuel (including financial charges for inventory)</td>
<td>2,135</td>
</tr>
<tr>
<td>Staff costs</td>
<td>2,676</td>
</tr>
<tr>
<td>External charges</td>
<td>2,095</td>
</tr>
<tr>
<td>Taxes and duties</td>
<td>1,176</td>
</tr>
<tr>
<td>Central functions</td>
<td>872</td>
</tr>
<tr>
<td><strong>Total operating expenses</strong></td>
<td><strong>8,954</strong></td>
</tr>
<tr>
<td>Provision for spent fuel and waste</td>
<td><strong>1,076</strong></td>
</tr>
<tr>
<td><em>including the increase in gross expenses</em></td>
<td>336</td>
</tr>
<tr>
<td><em>including the accretion expense</em></td>
<td>740</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10,030</strong></td>
</tr>
</tbody>
</table>

Source: Cour des Comptes

2 - Major uncertainty surrounding the cost of long-term waste management

The provision for the future cost of spent fuel management (see Chapter III-II) can be calculated with no major uncertainties, based on AREVA’s costs and tariffs.

However, the provision for the long-term management of high-level and medium-level long-lived waste, has not been clearly defined. This provision is currently calculated using an estimate drawn up in 2003, which has since been thoroughly revised by ANDRA, resulting in an estimate nearly double the initial one, in current Euros. Thus, EDF, AREVA and the CEA will have to readjust the amount of their provisions once the estimate has been finalized.

Furthermore, since there is currently no industry capable of recycling the quantities of spent MOX and enriched uranium produced by power plants, EDF calculates the provision for long-term management of

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224 Furthermore, a number of materials which are now considered worth recovering could one day be considered waste, in whole or in part. The costs associated with this potential requalification have thus far not been taken into account by operators, in accordance with the current legal and accounting framework.
these materials in the same way as for deep disposal waste, to be managed under the same conditions as HLW and ILW-LL. This provision is acceptable if, based on this assumption, it is properly “calibrated”, which is not currently the case. Beyond simply determining figures, it would be more reassuring if this assumption were actually analysed and eventually developed, should any difficulties arise with the Generation IV programme.

Thus, the Cour des Comptes has two recommendations with regard to long-term waste management:

− 1) that the new estimate of the cost of deep disposal be promptly defined and calculated as realistically as possible, i.e. taking into account the results of the research conducted on this subject, but without anticipating these results, and in compliance with the decisions of the ASN, the only authority competent to declare this disposal repository’s level of security;

− 2) that this new estimate include a figure for the cost of potential direct disposal of the MOX and enriched uranium produced each year, and that this assumption be taken into consideration in future dimensioning and design tasks for the deep disposal repository.

C - Generation cost calculations and their sensitivity to changes in different parameters

1 - Costs which vary considerably depending on the calculation method

As seen in A-4, the different methods of calculating the cost of nuclear power generation all incorporate the various types of identified operator costs (past, present and future), as developed above, but investments and cost of capital are given different weight in the different calculations. By way of illustration, the Cour des Comptes has chosen four approaches (cost accounting, current economic cost, cost aimed at calculating the tariff, and full cost accounting):

- each of which, according to the users concerned, has multiple variants with limited impact;

- which treat the operating costs in fairly similar ways, but fundamentally diverge when it comes to the return on capital and reconstitution of the invested capital.

The following table contains the amounts for the main categories of costs, as given by the four types of cost assessment.
Comparison of the results of the four types of cost assessment for nuclear power generation in 2010

<table>
<thead>
<tr>
<th>In € millions 2010</th>
<th>Cost accounting</th>
<th>According to the Champsaur approach</th>
<th>FCA for nuclear power generation</th>
<th>CEC calculated by EDF</th>
<th>CEC calculated by the Cour des Comptes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating expenses*</td>
<td>10,084</td>
<td>9,295</td>
<td>9,549</td>
<td>9,295</td>
<td>10,084</td>
</tr>
<tr>
<td>Maintenance investments</td>
<td>1,747</td>
<td>1,747</td>
<td>1,747</td>
<td>1,747</td>
<td>1,747</td>
</tr>
<tr>
<td>Cost of using nuclear assets (cost of capital)</td>
<td>1,813</td>
<td>2,447</td>
<td>6,689</td>
<td>9,104</td>
<td>8,341</td>
</tr>
<tr>
<td>Total generation cost</td>
<td>13,644</td>
<td>13,489</td>
<td>16,238</td>
<td>20,146</td>
<td>20,172</td>
</tr>
</tbody>
</table>

Source: Cour des Comptes

*The minor differences with the operating expense calculations in Chapter II and part B of this chapter are explained in Annex 15.

The calculation results and analysis of the points of “convergence” and “divergence” are presented in Annex 15, which describes the CEC, FCA and Champsaur calculation methods, i.e. the three methods applied to 2010:

- cost accounting gives the sum of the operating expenses validated by the Cour des Comptes in the CEC calculation, the maintenance investments and €1,831 million representing the total amortizations in 2010 (€1,352 million) plus the annual dismantling cost calculated by the Cour des Comptes (€461 million);

- with regard to the CEC, the annex explains the differences in the methods applied by the Cour des Comptes and EDF. For the operating expenses, this difference mainly concerns the accretion expenses for the provisions for spent fuel management and waste management; for the cost of capital, the Cour des Comptes does not include future dismantling costs in the calculation of the “economic rent”, but it counts them as a gross value. These two inverse corrections are nearly equivalent;

- with regard to the Champsaur commission approach, the Cour des Comptes has applied it to the year 2010, whereas the higher figures which are usually used and discussed are those calculated on average for the period from 2011 to 2025, which include maintenance investments consistent with EDF’s
€50 million programme by 2025, i.e. almost double the maintenance investment made in 2010\(^{225}\).

The following table sets out the results of the previous table, expressed in terms of cost per MWh produced. These calculations are based on a 40-year service life of the 58 reactors in the current fleet and the amount of maintenance investments made in 2010, which is considerably lower than in coming years.

**Results of the various changes in the cost per MWh in 2010 depending on the question asked**

<table>
<thead>
<tr>
<th>Description</th>
<th>In €2010/MWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost accounting which counts amortization of the fleet but not return on capital</td>
<td>€33.4</td>
</tr>
<tr>
<td>Cost with the Champsaur commission approach, which counts amortization of the fleet and return on unamortized capital (aim: to calculate a tariff)</td>
<td>€33.1</td>
</tr>
<tr>
<td>Full cost accounting of generation (FCA) which counts amortization, return on unamortized capital, and the higher cost of replacing the fleet</td>
<td>€39.8</td>
</tr>
<tr>
<td>Current economic cost (CEC) which does not count amortization of the fleet, and with inflation-adjusted return on capital (aims at defining an average without consideration of the past).</td>
<td>€49.5*</td>
</tr>
</tbody>
</table>

*Source: Cour des Comptes  
**Cour des Comptes estimate  

*Note: Generation in 2010: 407.9 TWh*

This is not the generation cost currently calculated in certain international comparisons, such as those by the AEN, nor in comparisons with other energy sources, such as the DGEC’s reference costs. In both of these cases, except for the cost of capital which may be calculated using yet other methods, the cost is calculated for an investor entering the market today with new power plants, i.e. EPRs for France. This type of cost assessment is highly theoretical: whereas one can ask an operator to state the effective cost of an actual industrial tool, simulating the fictive...

\(^{225}\) The small difference between the cost accounting calculated by the Cour des Comptes and that calculated with the Champsaur approach is due to the fact the latter does not count the accretion expenses; indeed, the Cour des Comptes method is intended to calculate the *gross cost*, while the aim of the Champsaur method is to calculate a tariff.
cost of a fictive fleet remains fairly arbitrary. The result will only be meaningful in the context of an actual nuclear programme with observed effects of optimization and standard plants. Thus, it is much too early for the Cour de Comptes to be able to assert and validate a calculation of the generation cost for an EPR fleet.

2 - The results have relatively low sensitivity to changes in future expenses covered by provisions

As indicated above, certain cost components are calculated using assumptions, and sometimes involve a fair amount of uncertainty. Thus, it is important to assess the sensitivity of overall cost of nuclear power generation, using different values for the cost components which seem the least certain.

To give an idea of generation cost’s sensitivity to the three most uncertain parameters – the discount rate, spent fuel and radioactive waste management, and the dismantling cost – using simplified assumptions (such as a constant inflation rate of 2 percent), it is interesting to calculate the effect that changing these variables has on the annual generation cost.

Based on the available accounting data, simulations have been done using the 2010 parameters and the CEC calculation as revised by the Cour des Comptes, i.e. a total annual cost of €20 billion: these simulations only measure the effect on generation cost and do not assess possible consequences on the amount of allocated assets to be amassed in order to cover certain provisions.226

Discount rate

Provisions are currently calculated with a discount rate of 5 percent, which includes an inflation rate of 2 percent. This rate is roughly equivalent to that used abroad, and as shown above (in Chapter IV), reducing this rate by 1 percent would result in a 21 percent increase in EDF’s provision (i.e. up €6 billion from the current €28.3 billion).

Based on a simplified simulation, limited to the recurrent effect of this type of variation, and without considering adjustment of the accretion expense in the year in which the discount rate would be changed:

- if the discount rate were lowered to 4 percent (instead of 5 percent): the annual cost of nuclear power generation would rise by €162 million/year, i.e. a 0.8 percent increase;

226 See Annex 16 for more detailed information on the calculations.
− if the discount rate were lowered to 6 percent (instead of 5 percent): the annual cost would decrease to €131 million/year, i.e. a 0.6 percent decrease.

**End of cycle expenses**

In terms of end of cycle expenses, while the provisions for spent fuel management seem relatively reliable, those for waste management urgently need to be reassessed. The new ANDRA estimate was slightly more than double that which serves as the current basis for calculating provisions. Thus, it is useful to assess the impact of doubling this provision, which should also be increased once the effects of storing spent MOX and enriched uranium have been calculated more precisely.

Based on a simplified simulation, and using the latest ANDRA estimate, the annual cost of nuclear power generation would increase by €200 million (i.e. a 1 percent increase in €/MWh)

**Dismantling costs**

EDF’s dismantling costs, like those of AREVA and the CEA, are subject to calculations and regular monitoring which show: 1) that as a general rule, the estimates tend to increase over time despite progress in the methods used to calculate them, due to the fact these are new subjects and there is not yet feedback from experience in this domain, and 2) dismantling costs are regularly increased in the operators’ accounts, which reduces the risk of major slippage.

By way of illustration, with a simplified calculation at an unchanged discount rate (5 percent):

− if the estimate for dismantling increased by 50 percent: the annual cost of nuclear power generation would increase by €505 million, i.e. a 2.5 percent increase in the total generation cost;

− if the estimate for dismantling doubled (a 100 percent increase): the annual cost of nuclear power generation would increase by €1 billion. However, this still only represents a 5 percent increase in the generation cost.

As shown by these tests on sensitivity to variation in certain parameters relating to future expenses, based on the 40-year service life for the current fleet used to calculate these expenses, their impact on the annual cost of nuclear power generation is not negligible, but is fairly limited.
3 - Changes in maintenance investments have a significant impact

While changes in future expenses for dismantling and waste management have a limited effect on generation cost, changes in maintenance investments have a considerably greater impact.

The previous calculations used the 2010 maintenance investment values (€1.7 billion). Based on the €55 billion investment programme envisaged by EDF, which it began to implement in 2010, and which appears to count investment levels pursuant to the ASN’s work on complementary safety assessments, the average annual investments would be much higher, totalling €3.7 billion.

The following table sets out the result of the different cost assessments based on this amount, and shows that this change in the cost of investments results in a 10 to 15 percent increase in the generation cost per MWh, depending on which cost assessment method is used. In any event, the impact is significant.

**Impact of the €55 billion investment programme on cost per MWh**

<table>
<thead>
<tr>
<th>Maintenance investments</th>
<th>2010 value €1.7 billion</th>
<th>Average value (2011 – 2025) €3.7 billion</th>
<th>Variation in%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost accounting</td>
<td>€33.4</td>
<td>€38.2</td>
<td>+ 14.5%</td>
</tr>
<tr>
<td>Champaur approach</td>
<td>€33.1</td>
<td>€37.9</td>
<td>+ 14.5%</td>
</tr>
<tr>
<td>CEC</td>
<td>€49.5</td>
<td>€54.2</td>
<td>+ 9.5%</td>
</tr>
</tbody>
</table>

*Source: Cour des Comptes*
4 - Extending the service life of power plants has an impact on profitability

Of the approaches set out above, only cost accounting can be used to measure the effect of extending the service life of power plants, by calculating cost sensitivity. The two other methods in the table above do not take service life into account in their calculations, but look only at the value of the initial investment.

However, assuming that revenue (prices, tariffs, etc.) covers the calculated costs, it is obvious that with each additional year of service life, the greater the revenue produced by the initial investment will be, and the more profitable the initial investment will be for its operator.

In addition, extending the fleet’s service life would also push back the disbursement date for future dismantling costs, which would reduce the provision amounts and delay the investments required to renew the fleet, especially considering that the construction costs for the new generations are higher than for the previous generations.

II - Expenditure funded by the public sector

In addition to the cost to the operator, expenditure funded by the public sector, which by definition is not included in the operators’ accounts, must also be taken into account if we want to calculate the “cost to society” of nuclear power generation. Considering the various information on safety and security presented in the previous chapters of this report, five observations can be made in this regard.

1 - In 2010, recurring expenditure funded by the public sector were limited, and close in value to the tax on basic nuclear installations (INB)

In 2010, expenditure funded by the public sector was estimated at €644 million (€414 million in public research and €230 million for safety/security/transparency). Limiting its analysis to the determination of these costs, the Cour des Comptes makes no judgment as to whether or not these funds are sufficient and/or used effectively.

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227 See Chapter VI-III-B: “variant: operating life of 50 years”.
228 See Chapter II.
Thus, these expenses represent only 6.4 percent of the €10 billion in operating expenses calculated above.

Moreover, it is noted that the amount of these expenses is roughly equivalent in value to the tax on basic nuclear installations (INB) – specific taxation for nuclear operators (€580 million in 2010) which can be considered as intended to offset the related public expenditure.\footnote{Note: the tax on basic nuclear installations and the fees which preceded it were originally intended solely to finance safety and security expenses.}

\begin{center}
\begin{tabular}{|c|c|c|}
\hline
Expenses paid by operators & Expenditure funded by the public sector \\
\hline
Operating expenses & Research & Safety/security \\
€10,030 million & €414 million & €230 million \\
\hline
\end{tabular}
\end{center}

\textit{Source: Cour des Comptes}

2 - The development of nuclear energy depends on major investments in research, which was mainly funded by the public sector

The study on changes in research from the mid-1950s to today, presented in the first chapter, shows that the total expenditure on research in nuclear power can be estimated at €55 billion\footnote{Note: the tax on basic nuclear installations and the fees which preceded it were originally intended solely to finance safety and security expenses.}, i.e. approximately €1 billion\footnote{Note: the tax on basic nuclear installations and the fees which preceded it were originally intended solely to finance safety and security expenses.} per year.

The public sector has funded €38 billion\footnote{Note: the tax on basic nuclear installations and the fees which preceded it were originally intended solely to finance safety and security expenses.} of this expenditure (an average of €690 million\footnote{Note: the tax on basic nuclear installations and the fees which preceded it were originally intended solely to finance safety and security expenses.} per year), which represents a considerably higher percentage (70\%) than that registered in 2010, and during the past ten years in general (i.e. approximately 40\%).

Quantifying the expenditure in safety/security/transparency was not possible, but it is likely that, contrary to publicly funded research expenses, this expenditure tends to increase slightly over time, with the creation and expansion over time of the organizations which account for the bulk of these costs: the ASN and the IRSN.

As shown in Annex 9 on the changes in the INB tax rates over the past ten years, a new situation appeared in 2010, in that the revenue from this tax was almost equivalent to the amount of expenditure funded by the
public sector. This new situation is the result of two opposing developments: a gradual reduction in publicly funded research and a substantial increase in revenue from the tax, which has been multiplied by 4.6 from 2000 to 2010 (in current Euros).

Comparing (in current Euros) the actual revenue from the tax over the last decade (2000 to 2010), i.e. €3.3 billion, and the amount spent on publicly funded research for the same period, i.e. €5.5 billion, illustrates that the situation before 2010 was much more unbalanced.

3 - The State will have to fund the CEA’s provision

The CEA’s future expenses totalled €6.8 billion at the end of 2010, i.e. €4.4 billion in discounted provisions, which breaks down into €2.9 billion for dismantling, €1.2 billion for long-term waste management and €0.3 billion for spent fuel management.

Of these provisions, €3.1 billion are deemed to be covered by allocated assets mainly consisting in receivables from the State or AREVA shares which the CEA can sell to the State as needed.

In short, the State directly or indirectly funds these future expenses, and while diligently calculated, their value remains uncertain – as illustrated by the often drastic revisions of the related estimates during the last ten years.

4 - The Generation IV programme significantly increases publicly funded future research expenses

The “nucléaire du futur” (“nuclear power of the future”) programme for future investment is to provide €650 million in funding (between 2011 and 2017) for the final design package (APD) for ASTRID, a demonstrator aimed at developing Generation IV sodium-cooled fast reactors (SFRs). Based on the outcome of the final design package, if France continues this development, other forms of funding will be needed, as the demonstrator will still be far from industrial maturity.
5 - The State covers part of the “civil liability” in the event of a nuclear accident, at no cost to operators

In terms of insurance, the nuclear power sector is in a unique situation: the probability of the risk occurring is very low, but in the event of a major accident, the consequences could be catastrophic. Both the probability of occurrence and the gravity of the consequences are difficult to assess and highly debated. Nevertheless, it is clear that in the event of a serious accident, the damages would quickly reach and probably surpass the current upper limits for the operator civil liability guarantees which are stipulated in international conventions.

Thus, in the (granted, highly unlikely) event of nuclear accident, with the current system of civil liability for nuclear damage, the State would potentially have to pay the compensation for damages exceeding the upper limits for liability provided by the provisions currently in force, and to bear the cost of any economic consequences not covered by the compensation system. This guarantee is currently provided at no cost to operators. The Cour des Comptes has shown that the cost of this coverage is very low, compared with the overall cost of nuclear power generation. But in the event of a serious accident, the costs could be massive and draw heavily on State funds, given that the State is the ultimate guarantor of compensation for nuclear damage and the overall impact of a nuclear accident.

The Cour des Comptes makes the following two recommendations in this regard:

- it recommends that France make every effort to quickly promulgate the Paris and Brussels Conventions, signed in 2004, as they significantly raise the upper limit on operator liability, although it remains limited;

- it also emphasizes the need for rigorous application of the provisions of positive French law, particularly with regard to approval of the imposed financial guarantee for operators, which means that the regulatory system must be strictly applied.
III - Unresolved issues

Beyond the uncertainties discussed above, for which the Cour des Comptes has tried to assess the sensitivity of nuclear power generation costs, four questions with potentially far-reaching consequences merit particular consideration.

1 - Cost assessment for different forms of energy must not overlook externalities, both positive and negative

The positive and negative externalities of different methods of power generation are numerous and often have opposing effects on the various areas involved: economy, health and the environment. Thus there is a need for more in-depth studies on the scope of these impacts.

Consequently, the Cour des Comptes recommends promoting and supporting research and studies in these areas, both for nuclear power and other sources of energy, since many impacts cannot be monetized but can be compared between different forms of energy.

2 - The figures from the complementary additional safety assessments following the Fukushima accident

After the Fukushima accident, at the Government’s request, the ASN launched an initiative to thoroughly reassess the safety of the reactors in the current fleet. Its report and opinion on the “priority facilities” was made public on 3 January 2012. While these publications do not allow precise overall figures to be determined for all of the consequences which will be drawn from this accident, they do provide specific information on certain aspects, although the available information differs considerably for EDF, AREVA and the CEA.

• **EDF**

  The information pertaining to EDF is probably the most comprehensive. Limiting the scope to the financial consequences alone, there are two major categories of costs:

  - provisions for “increasing the facilities’ robustness with respect to extreme situations, notably with the creation of a ‘hard core’” of material and organizational measures for managing the essential safety functions in exceptional situations, in order to reduce the risk of dewatering of the fuel
in the pools, and the creation of a Force d’Action Rapide Nucléaire (FARN, Nuclear Rapid Response Force) which can intervene at any location to relieve the teams at the accident site. The financial consequences of these measures, in terms of investments, are currently estimated at approximately €10 billion over the next several years; as discussed in Chapter VI, these investments, in part, have already been included in the provision investment programmes, and will therefore have a limited effect on the cost of nuclear power generation. However, the staff costs of these measures also have to be taken into account, notably with the creation of the FARN, which, according to EDF’s estimate, will represent a considerable cost, i.e. €300 million a year;

- social, organizational and human factors, the costs of which are currently still difficult to quantify; as discussed in Chapter II, they will, however, have an impact on the ensuing staff and wage costs and the organization of sub-contracting.

- **AREVA**

   Generally speaking, for AREVA, the ASN has acknowledged that the requested task was difficult due to the diversity of its facilities and the need to adapt the specifications, initially drawn up for power reactors, to their specific parameters. It considers that AREVA has not completed the required process and must continue its efforts in order to complete the safety improvements. By mid-May 2012, AREVA still has to produce the definition of concrete measures through cross-functional studies relating to crisis management.

   As for EDF, the emphasis is placed on the creation of a hard core for each AREVA “platform” and complementary measures ensuring more robust pool filling systems. However, the creation of a rapid response force seems less relevant in this case, as there are fewer sites and a much wider range of different activities, and it would perhaps make more sense to strengthen the crisis management systems for each individual “platform”.

   AREVA’s investments are planned within a strategic five-year plan, for a total of €2 billion. At present, the company appears to estimate that the investments relating to the complementary safety assessments will total an additional several hundred million Euros over this five-year period. However, the Cour des Comptes has no means of validating these figures, especially since the ASN’s requirements are still somewhat vague.
• **The CEA**

The CEA’s situation is quite similar to AREVA’s in terms of the diversity of its facilities, but it is unique in that 1) the majority of its facilities will be examined in 2012, and 2) three of the five facilities examined during the first series of assessments are in the process of being dismantled (Phénix, the Plutonium workshop and Osiris). Thus, in each of these cases, the relevant investments have to be quantified, accounting for the progressively lower risk as the dismantling operations advance.

The CEA currently gives quite a broad estimate for the potential cost of implementing the complementary safety assessment measures, i.e. €50 to 500 million over the next three to four years.

Thus, generally speaking, it is still too soon to quantify and verify the levels of the investments and human costs resulting from these first complementary safety assessments. The ASN is going to request that operators conduct complementary studies in order to clarify its initial findings. Thus, the consequences will have to be defined as clearly as possible, with respect to the assumptions and figures put forward by the Cour des Comptes in this report. However, as the ASN stated in its own report: “...it could take about ten years to draw the lessons learned from the Fukushima accident. But it seemed important, without delay, to evaluate the facilities' robustness with respect to extreme situations”. Yet this is only the first step in a process of analysis and reflection which will be long.

3 - **The effects of the financial crisis on management of allocated assets need to be closely watched**

The listed financial assets covering provisions, excluding the fuel cycle, represented some **€18.2 billion at the end of 2010**, i.e. approximately 65% of the €27.8 billion total required by 2016, a value which is very sensitive to the applied discount rate.

Thus, these assets are supplemented by €7 billion from other forms of coverage, since recent developments have brought the need to diverge from the original objectives. Notably, this involves increasing the proportions of the least disposable assets and “inter-operator receivables”, while also pushing back the date at which these assets must fully cover the provision.
At the same time, the current financial crisis adds to the uncertainty surrounding the medium- and long-term profitability of the assets making up the portfolio, reducing the probability that the assets will total the required amounts by the time the disbursements have to be paid.

Regrettably, the changes in the system occurred without the commission which was supposed to structure its governance being in place. The CNEF is now up and running, and is able to give an opinion on the system’s current status, and if necessary, its adaptation to the current financial situation.

Moreover, the Cour des Comptes recommends that this system be re-examined, and possibly modified, because it is not sound practice for its initial structure and logic to be drastically changed through successive waivers each time a new difficulty arises.

4 - The service life of power plants is a strategic variable

A power plant’s service life is analysed, case by case, every decade by the ASN, which is tasked with taking decisions in this regard. At present, only two units (Tricastin 1 and Fessenheim 1) have received the authorization to continue operating for ten additional years after their third ten-year inspection, on the condition that significant investments were made.

Since 2003, EDF’s accounts have been based on a service life of 40 years, since this is the operating period considered “most probable” according to the IFRS standards.

The Cour des Comptes has observed that by the end of 2020, 12 reactors representing 10,900 MW will have completed their 40-year service life, and that 22 of the 58 reactors, i.e. approximately 30% of the fleet’s net capacity (18,210 MW), will have reached their 40th year in service by 2022. Thus, in the scenario of a service life limited to 40 years, and assuming that we wanted to maintain nuclear power generation at its current level, six or seven EPRs would have to be built by the end of 2020, and eleven by the end of 2022.
This observation leads the Cour des Comptes to make the following recommendations:

− beyond the fact that the “multi-year investment plan” (PPI) for power generation from 2009 to 2012 provides for “focusing on a central scenario which extends the nuclear fleet beyond 40 years”, the strategic consequences of this situation have to be analysed in order to help guide energy policy in the medium term, with publicly known guidelines which can be used by all players in the sector. Indeed, in energy policy, there is a time lapse between the taking of a decision and its actual effects. This is especially long in the nuclear sector, but also an issue in the other energy sectors, including energy saving. Thus, not taking a decision amounts to making the choice to continue operating the current fleet for more than 40 years;

− the financial consequences of this situation also have to be clearly identified, according to the strategic choices. In this case, the level of investments needed to keep the power plants in service, at a “good” level of power generation, has to be quantified, taking into account the consequences of the ASN’s decisions after the Fukushima accident. For EDF, this represents a maintenance investment programme of more than €50 billion by 2025, i.e. twice the current maintenance investments. And this is with no guarantee of being able to extend the reactors’ service life, since this depends on the opinion issued by the ASN, which will undoubtedly make a careful inspection of the tanks and enclosures, which a priori are not replaceable;

− if the choice is made to replace part of the fleet of reactors, and even more so if the entire fleet is replaced, it is important to anticipate these renewals, particularly to allow for organization of the industrial sector. Furthermore, unless extraordinary efforts are made or power consumption decreases dramatically, which is highly unlikely, it seems that it would be difficult to make the energy investments needed to replace or phase out the current fleet, regardless of which system was chosen (energy saving, other sources of energy, new nuclear reactor) soon enough to avoid having to keep part or all of the current fleet in service beyond 40 years;

− regardless of future responses to these questions which may emerge, the Cour des Comptes emphasizes that in the short- and medium-term, major expenses are foreseeable for investments in both

230 It is also important to note that “unbalanced demography” in the fleet of reactors is an aggravating factor in terms of risk (e.g. if a systemic defect appeared which was related to the ageing of the fleet).
maintenance and the construction of replacement power generation means, as well as investments in the distribution grids or research, if the choice is made to continue developing the Generation IV reactors.

5 - The need to ensure transparency regarding the figures and to regularly update the data in this report

Due to the complexity of the subject, the uncertainty of the data, and the large number of assumptions used to calculate the figures in this report, it is essential that the information herein be regularly reviewed and further developed, through governance adapted to the strategic aspect of energy, and the highly sensitive nature of this subject for the public.

Thus, the Cour des Comptes recommends that this study be regularly updated, in total transparency and objectivity, in order to allow the following:

- gradually defining the assessment methods for situations of uncertainty, which are needed to economically evaluate the decisions to be taken; notably, studies on costs and accident probabilities should be further developed and clarified;
- based on the feedback from experience, keeping track of future changes in the various cost components which have been analysed, especially figures on the impact of the complementary safety assessments following the Fukushima accident;
- capitalizing on the efforts made by the various players and specialists in the sector.

Furthermore, the importance of the externalities which cannot be quantified (except perhaps by comparison with other solutions), notably the impact on the environment, health, jobs and the trade balance, make it clear that costs are certainly not the only variables to consider in taking decisions regarding nuclear power generation.
ANNEXES
Dear Mr First President,

When France decided back in 1973 after the first oil crisis in 1973, to become self-sufficient in electricity, it began developing a nuclear fleet which has made it one of the major players in the international nuclear industry.

Over the years, in light of the lessons learned from each incident or accident that occurs in the world, France has developed an increasingly sophisticated dismantling strategy. That is the meaning of the Act No. 91-1381 of 30 December 1991 on the search for the sustainable management of radioactive wastes. The choice of nuclear power implies responsibilities which the State must handle with the highest discipline.

In the same vein, I wanted us to fully learn from the disaster that struck Japan last March and accordingly improve the safety of our facilities. I have entrusted the Autorité de Sûreté Nucléaire, (ASN, French Nuclear Safety Authority) with the task of conducting an audit of all our nuclear facilities. The first findings will be published before the end of the year.

I think it is also important for us to take into account, at their right level, the costs linked to the dismantling of nuclear facilities, the recycling of spent fuel, waste disposal and research and development or control of nuclear safety and radiation protection.

In 2005, the Cour des Comptes already examined these issues, with the findings compiled in a public report on the dismantling of nuclear facilities and radioactive waste management. A few weeks to the fifth anniversary of the Act of 28 June 2006, and as the President of the Republic recently expressed the need, I would like these findings to be thoroughly updated.

Mr. Didier MIGAUD  
First President of the Cour des Comptes  
13 rue Cambon  
75100 Paris

Hôtel de Matignon – 57 rue de Varenne – 75007 PARIS – Tel.: 01 42 75 80 00
So pursuant to Article 47-2 of the French Constitution, I'm requesting your cooperation for you to assist the French Government to appraise the costs of the nuclear industry, including those linked to the dismantling of facilities and the insurance of sites.

Your services will primarily concern the implementation of provisions of the Act of 28 June 2006 which requires operators of nuclear facilities to evaluate the costs linked to dismantling and waste management. We will expect your opinion on the proper processing of long-term costs.

You can rely on the review of all the financial statements of all operators such as EDF, CEA and Areva as well as the Agence Nationale pour la Gestion des Déchets Radioactifs (ANDRA, French National Radioactive Waste Management Agency), the ASN and the Institut de Radioprotection et de Sûreté Nucléaire (IRSN, French Institute for Radiological Protection and Nuclear Safety) and all the reports produced by nuclear operators pursuant to the Act of 28 June 2006.

Your task will include appraising the data given to you by the civil nuclear sector operators and collecting pertinent questions, from economists as well as environmental protection associations.

Your report will reflect the general goals with respect to the commissioning of new reactors and the continued operation of nuclear power plants after 40 years, as expressed in the investments multiyear programming.

To complete this task, you may also refer to the works carried out by the OPECST and especially the January 2011 report on the evaluation of the three-year national plan for the management of radioactive materials and wastes.

I particularly insist on the need for an open and transparent approach: the HCTISN can make a useful contribution depending on the terms that you consider the most relevant.

I would like to have your report before 31 January 2012.

Yours sincerely,

François FILLON
Mr Prime Minister,

You asked the Cour des Comptes, through your letter of 17 May 2011, to conduct an investigation on the costs of the nuclear sector, in application of Article 47-2 of the French Constitution.

Considering the huge importance of this subject, I decided to place it on our agenda and I have made the necessary internal organization arrangements to make sure that the investigation is conducted with the utmost efficiency in line with the usual procedures of the Cour des Comptes. I have formed a task force comprising the representatives of all the relevant chambers of the Cour des Comptes. It will be assisted by a committee of independent experts. There will be extensive hearings. The works will be completed on 31 January 2012, and the findings will be published in a report, just like the report on the comparison between French and German tax systems.

Therefore, the Cour des Comptes will examine for fiscal 2010 five main topics:

- the structure and measurement of electricity generation costs of nuclear origin in France analysed in light of the 2010 economic conditions,
- the evaluation of the future costs linked to the dismantling of power plants currently in activity,
- evaluation of the future costs of the sustainable management of nuclear waste.
- estimating the total cost for extending the operation period of reactors beyond forty years,
- costs of the research and development carried out by public operators.
In addition to direct production costs, expenses attributable to the inspection of the secure and safe operation of the electricity and nuclear fleet will also be taken into consideration.

All these costs will be analysed in the current "closed cycle" context namely, according to the principle of the recycling of spent fuel, as well as in the context of the current safety guidelines of the competent Authority, notwithstanding the future findings of the ongoing audit of power plants.

This survey will reflect the general goals "emphasized in the last multiyear planning of electricity generation investments, linked to the commissioning of the two EPR type nuclear reactors (Flamanville and Penly).

The Cour des Comptes will examine, in accordance with the Planning Act No. 2006-736 of 28 June 2006 on the sustainable management of radioactive wastes, the correct match between the accrual of provisions for the future long-term costs and the evaluation of the original costs, as well as where applicable, their hedging by dedicated assets.

I remain,

Yours respectively,

Didier MIGAUD
### Annex 3: Membership of the Group of Experts

<table>
<thead>
<tr>
<th>Name</th>
<th>Position and Additional Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jean-Michel Charpin</td>
<td>member of the Academy of technologies, former Plan commissioner, chairman of the French association of economic science; inspector general of finance;</td>
</tr>
<tr>
<td>Roland Desbordes</td>
<td>chairman of the Commission de Recherche et d'Information Indépendantes sur la Radioactivité (CRIIRAD, French commission for independent research and information on radioactivity)</td>
</tr>
<tr>
<td>Christian Gollier</td>
<td>economist and director of the Jean-Jacques Laffont – Toulouse Sciences Economiques Foundation, member of the Laboratoire d'Economie des Ressources Naturelles (LERNA, French laboratory for the economy of natural resources) and director of research at the Toulouse Institut d'Economie Industrielle (IDEI, the industrial economy institute).</td>
</tr>
<tr>
<td>François Jacq</td>
<td>formerly at the DGEMP (General Directorate for Energy and Raw Materials); former CEO of ANDRA; Chairman and CEO of Météo France</td>
</tr>
<tr>
<td>Jean-Pierre Lamoure</td>
<td>president of Solétanche Freyssinet (subsidiary of Vinci); member of the Commission Nationale d'Evaluation du Financement des charges de démantèlement des installations nucléaires de base et de gestion des combustibles usés et des déchets radioactifs (CNEF, French National Committee for the Evaluation of Funding for the costs of dismantling basic nuclear facilities and managing used fuel and radioactive waste)</td>
</tr>
<tr>
<td>Claude Mandil</td>
<td>former CEO of the Direction Générale de l'Energie et des Matières Premières (DGEMP, French General Directorate for Energy and Raw Materials); former CEO of the Agence Internationale de l'Energie (IEA, French International Energy Agency)</td>
</tr>
<tr>
<td>Jean-Paul Minon</td>
<td>CEO of the Organisme national des déchets radioactifs et des matières fissiles enrichies (ONDRAF, Belgian equivalent of the French ANDRA)</td>
</tr>
<tr>
<td>Jacques Percebois</td>
<td>professor in economics and energy law (CREDEN) in Montpellier</td>
</tr>
<tr>
<td>Pierre Radanne</td>
<td>former CEO of ADEME; chairman of 4D; energy consultant</td>
</tr>
<tr>
<td>William Ramsay</td>
<td>formerly of the IEA, director of the IFRI energy programme</td>
</tr>
<tr>
<td>Michel Spiro</td>
<td>physicist, former head of the IN2P3, chairman of the CERN; member of the Scientific committee of the ASN.</td>
</tr>
<tr>
<td>Virginie Schwarz</td>
<td>executive director in charge of ADEME programmes, especially in charge of energy</td>
</tr>
</tbody>
</table>
### Annex 4: List of hearings

<table>
<thead>
<tr>
<th>Hearings</th>
<th>Date</th>
</tr>
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<tbody>
<tr>
<td>NGO: Fondation pour la nature et l’homme (FNH)</td>
<td>1 July 2011</td>
</tr>
<tr>
<td>WWF</td>
<td></td>
</tr>
<tr>
<td>Ecologie sans frontière</td>
<td></td>
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<tr>
<td>NGO: France Nature Environnement (FNE)</td>
<td>7 July 2011</td>
</tr>
<tr>
<td>Greenpeace</td>
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<tr>
<td>Réseau Sortir du nucléaire</td>
<td></td>
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<tr>
<td>the CRIIRAD</td>
<td></td>
</tr>
<tr>
<td>DGEC (Messrs. Chevet and Abadie)</td>
<td>7 July 2011</td>
</tr>
<tr>
<td></td>
<td>10 January 2012</td>
</tr>
<tr>
<td>ASN (Mr. Lacoste)</td>
<td>7 July 2011</td>
</tr>
<tr>
<td></td>
<td>10 January 2012</td>
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<tr>
<td>IRSN (Mr. Répussard)</td>
<td>7 July 2011</td>
</tr>
<tr>
<td>CEA (Mr. Bigot)</td>
<td>21 July 2011</td>
</tr>
<tr>
<td></td>
<td>11 January 2012</td>
</tr>
<tr>
<td>EDF (Mr. Proglio)</td>
<td>21 July 2011</td>
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<tr>
<td></td>
<td>11 January 2012</td>
</tr>
<tr>
<td>OPECST (Mr. Birraux)</td>
<td>27 July 2011</td>
</tr>
<tr>
<td>CRE (Mr. de Ladoucette)</td>
<td>8 September 2011</td>
</tr>
<tr>
<td>Union organizations:</td>
<td>16 September 2011</td>
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<td>CGT</td>
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<tr>
<td>ANDRA (Mr. Gonnot and Ms. Dupuis)</td>
<td>23 September 2011</td>
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<tr>
<td>AREVA (Mr. Oursel)</td>
<td>26 September 2011</td>
</tr>
<tr>
<td></td>
<td>13 January 2012</td>
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</table>
Annex 5: Gross domestic product price index

To express certain amounts according to 2010 economic conditions, the Cour used the GDP price index (INSEE index 1.103p), to calculate the following multiplication factors.

<table>
<thead>
<tr>
<th>Year</th>
<th>Index 1979</th>
<th>Year</th>
<th>Index 1979</th>
<th>Year</th>
<th>Index 1979</th>
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<tbody>
<tr>
<td>1953</td>
<td>13.756</td>
<td>1973</td>
<td>5.177</td>
<td>1993</td>
<td>1.292</td>
</tr>
<tr>
<td>1959</td>
<td>9.970</td>
<td>1979</td>
<td>2.816</td>
<td>1999</td>
<td>1.218</td>
</tr>
<tr>
<td>1962</td>
<td>8.969</td>
<td>1982</td>
<td>2.018</td>
<td>2002</td>
<td>1.150</td>
</tr>
<tr>
<td>1963</td>
<td>8.497</td>
<td>1983</td>
<td>1.839</td>
<td>2003</td>
<td>1.128</td>
</tr>
<tr>
<td>1965</td>
<td>7.916</td>
<td>1985</td>
<td>1.629</td>
<td>2005</td>
<td>1.088</td>
</tr>
<tr>
<td>1966</td>
<td>7.685</td>
<td>1986</td>
<td>1.548</td>
<td>2006</td>
<td>1.065</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1990</td>
<td></td>
<td>2010</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: National accounts - Base 2005, Insee

Interpretation: one euro spent in 1979 (or FRF 6.56 in 1979) is equivalent to €2.816 in 2010.
Annex 6: Production of the current nuclear fleet.

Units: TWh

<table>
<thead>
<tr>
<th>Year</th>
<th>TWh</th>
<th>Year</th>
<th>TWh</th>
<th>Year</th>
<th>TWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>1977</td>
<td>1.0</td>
<td>1991</td>
<td>309.9</td>
<td>2005</td>
<td>429.2</td>
</tr>
<tr>
<td>1978</td>
<td>12.8</td>
<td>1992</td>
<td>319.3</td>
<td>2006</td>
<td>428.1</td>
</tr>
<tr>
<td>1979</td>
<td>21.7</td>
<td>1993</td>
<td>348.5</td>
<td>2007</td>
<td>418.0</td>
</tr>
<tr>
<td>1980</td>
<td>33.2</td>
<td>1994</td>
<td>340.2</td>
<td>2008</td>
<td>417.6</td>
</tr>
<tr>
<td>1981</td>
<td>57.4</td>
<td>1995</td>
<td>358.3</td>
<td>2009</td>
<td>389.8</td>
</tr>
<tr>
<td>1982</td>
<td>89.5</td>
<td>1996</td>
<td>374.8</td>
<td>2010</td>
<td>407.9</td>
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<tr>
<td>1983</td>
<td>120.3</td>
<td>1997</td>
<td>376.0</td>
<td></td>
<td></td>
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<tr>
<td>1984</td>
<td>160.7</td>
<td>1998</td>
<td>368.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>197.3</td>
<td>1999</td>
<td>375.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td>221.4</td>
<td>2000</td>
<td>395.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td>239.6</td>
<td>2001</td>
<td>401.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1988</td>
<td>246.0</td>
<td>2002</td>
<td>416.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1989</td>
<td>278.9</td>
<td>2003</td>
<td>420.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>289.9</td>
<td>2004</td>
<td>427.1</td>
<td></td>
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</tr>
</tbody>
</table>

*Source: EDF*

Annual average on production observed from 1977 to 2010: 388 TWh.

<table>
<thead>
<tr>
<th>Unit of electrical power</th>
<th>Unit of electrical power</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 TW = 1 000 GW</td>
<td>1 TWh = 1 000 GWh</td>
</tr>
<tr>
<td>1 GW = 1 000 MW</td>
<td>1 GWh = 1 000 MWh</td>
</tr>
<tr>
<td>1 MW = 1 000 kW</td>
<td>1 MWh = 1 000 kWh</td>
</tr>
<tr>
<td>1 kW = 1 000 W</td>
<td>1 kWh = 1 000 Wh</td>
</tr>
</tbody>
</table>

Equivalence: €1 / MWh = €0.1 / kWh
Annex 7: key legislative and regulatory provisions

Relevant provisions of the French Act No. 2006-686 of 13 June 2006 on nuclear transparency and safety (so-called TSN Act)

Article 1 (definitions)

I. – Nuclear security includes nuclear safety, radiation protection, the prevention of malicious acts and measures to protect the public in the event of an accident.

Nuclear safety consists of all the technical provisions and organizational measures relating to the design, construction, operation, shutdown and dismantling of installations and to the transport of radioactive materials, adopted with a view to preventing accidents and mitigating their effects.

Radiation protection is the protection against ionizing radiation, i.e., all the rules, procedures and means of prevention and surveillance aimed at preventing or reducing the direct or indirect adverse effects on people of ionizing radiation, including damage to the environment.

Transparency in the nuclear sector consists of all the provisions taken to guarantee the public's right to reliable and accessible information about nuclear safety.

Article 2 (principle of participation and polluter-pays principle)

II.-According to the principle of participation and the polluter-pays principle, people involved in nuclear operations must especially follow the following rules:

1° Every person shall be entitled, on the conditions laid down by the present act and its implementing decrees, to be informed about the risks related to nuclear activities and their impact on the health and safety of people and on the environment, and on the release of effluents from installations;

2° Those responsible for these activities shall bear the cost of the preventive measures, especially the analyses, as well as the measures for reducing risks and effluent releases prescribed by the administrative authority in application of the present law.
Article 4 (missions of the ASN)

The Nuclear Safety Authority, independent administrative authority, participates in the inspection of nuclear safety and radiation protection and provides information to the public in these areas. Thus:

1° The Nuclear Safety Authority is consulted on drafts of ministerial decrees and orders of a regulatory nature relating to nuclear safety. It can take regulatory decisions of a technical nature to supplement the procedures for implementing decrees and orders relating to nuclear safety and radiation protection, with the exception of those related to occupational medicine. [...]

2° The Nuclear Safety Authority controls compliance with the general rules and special provisions in nuclear safety and radiation protection binding on basic nuclear installations [...], transport of radioactive substances as well as the activities mentioned in Article L. 1333-1 of the public health code and the people mentioned in Article L. 1333-10 of the same code.

The authority organizes constant monitoring of radiation protection on the national territory. [...]

3° The Nuclear Safety Authority helps to inform the public in the areas of its competence;

4° The Nuclear Safety Authority participates in the management of emergency radiological situations resulting from events likely to impact human health and the environment through exposure to ionizing radiations and occurring in France or likely to affect the French territory. [...]

5° In the event of an incident or accident concerning a nuclear activity, the Nuclear Safety Authority can proceed to a technical investigation [...]

Article 18 (right to information – role of the State)

The State shall be responsible for informing the public about monitoring procedures and results with regard to nuclear safety and radioprotection. It shall inform the public about the consequences, on the national territory, of nuclear activities performed outside such territory, notably in the event of an incident or accident.
Article 19 (right to information – role of operators)

I.-Every person shall be entitled to obtain, from the operator of a basic nuclear installation, or where the quantities are above the thresholds provided by decree, from the person in charge of transporting radioactive substances or the holder of such substances, the information held, whether received or established by them, on the risks linked to exposure to ionizing radiation that may result from this activity and on the safety and radiation protection measures adopted to prevent or mitigate these risks or exposures, under the conditions defined in Articles L. 124-1 to L. 124-6 of the Environment Code.

Article 22 Local information commissions (CLIs)

I.-Local information commissions shall be set up on any site comprising one or several basic nuclear installations as defined in Article 28. They shall have the general duty of monitoring, informing and consulting on nuclear safety, radiation protection and the impact of nuclear activities on people and the environment with respect to the site's facilities. The local information commission shall widely circulate the results of its works in an accessible form to a wide public. […]

Article 24 High Committee for Nuclear Safety Transparency

The Haut Comité pour la transparence et l'information sur la sécurité nucléaire (HCTISN – French High Committee for Nuclear Safety Transparency) is a body for information, consultation and debate about the risks related to nuclear activities and the impact of these activities on the health of people, the environment and on nuclear safety. Its task is to give opinions on any question within its field of competence and any monitoring and information relating thereto. […]

Article 29 (rules applicable to Basic Nuclear Installations)

I. - Creating a basic nuclear installation requires a license. This license cannot be issued unless, in light of current scientific and technical knowledge, the operator demonstrates that the technical or organizational provisions adopted or planned at the design, construction and operation stages as well as the general principles proposed for the dismantling, for the disposal of radioactive waste, for their maintenance and their monitoring after their final shutdown using the procedures defined in VI, are capable of preventing or sufficiently mitigating the risks or inconveniences that the facility presents for the interests mentioned in I of Article 28. The licence takes account of the operator's technical and financial capacities which must allow it to implement its project in compliance with these interests, especially for hedging the facility's dismantling and restoration expenses, monitoring
and maintenance of its location or for radioactive waste disposal installations, to hedge the costs of final shutdown, maintenance and monitoring.

The license is issued by decree made after consulting the Nuclear Safety Authority and after public investigation performed in accordance with chapter III of title II of Book 1 of the Environment Code. This decree determines the characteristics and scope of the installation and sets the period during which it must be commissioned.

For the application of the licensing decree, the Nuclear Safety Authority defines, in compliance with the general rules in Article 30, the prescriptions concerning the design, construction and operation of the installation which it considers necessary for protecting the interests mentioned in Article 28. […]

The Nuclear Safety Authority shall allow the commissioning of the installation under the conditions defined by the decree set out in Article 36 and shall pronounce the individual decisions set out by the regulation for pressurized equipment mentioned in 2 of Article 4.

During the review of an application for a license, the Nuclear Safety Authority can take temporary measures to protect the interests mentioned in Article 28. […]

III. - The operator of a basic nuclear installation shall periodically review the safety of its installation by taking account of best international practices. This review must allow the operator to assess the situation of the installation with respect to the applicable rules and update the evaluation of risks or inconveniences of the installation for the interests mentioned in I of Article 28, while taking account in particular of the state of the installation, the experience acquired from operating it, the progress in knowledge and the rules applicable to similar installations. […] Safety reviews are performed every ten years. However, the licensing decree may set a different frequency if required by the specific nature of the installation.

IV. - If it appears that a basic nuclear installation shows serious risks for the interests mentioned in I of Article 28, the ministers in charge of nuclear safety may, by decree, declare the suspension of its operation during the time required to implement the measures required to remove those serious risks. […]
In the event of serious and imminent risks, the Nuclear Safety Authority shall suspend, if necessary, temporarily and as a precaution, the operation of the installation. It will immediately inform the ministers in charge of nuclear safety.

V. – Final shutdown and dismantling of a basic nuclear installation are subject to prior license. The license application includes the provisions relating to the shutdown conditions, the procedures for dismantling and waste management as well as monitoring and subsequent maintenance of the installation's location allowing, in light of current scientific and technical knowledge and projections about the site's ulterior use, to sufficiently prevent or mitigate the risks or inconveniences for the interests mentioned in I of Article 28.

The license is issued by decree made after consulting the Nuclear Safety Authority and after public investigation performed in accordance with the provisions of chapter III of title II of Book 1 of the Environment Code. The decree sets out the characteristics for dismantling, the time frame for completing the dismantling and the types of operations to be borne by the operator after the dismantling.

For the application of this licensing decree, the Nuclear Safety Authority defines in compliance with the general rules set out in Article 30, the prescriptions relating to the dismantling required for the protection of the interests mentioned in I of Article 28. […]

VI. - The final shutdown and the transition to a monitoring phase of a radioactive waste disposal facility require a license. The license application includes the provisions concerning the final shutdown as well as the maintenance and monitoring of the site allowing, in light of the current scientific and technical knowledge, to prevent or sufficiently mitigate the risks or inconveniences for the interests mentioned in I of Article 28. […]

VIII - When a basic nuclear installation has been dismantled in accordance with the provisions defined in V, or moves to monitoring phase pursuant to the provisions defined in VI, and the facility no longer requires the implementation of the provisions set out hereunder, the Nuclear Safety Authority shall submit for approval to the ministers in charge of nuclear safety, a decision concerning the decommissioning of the installation.

IX. - In the event of threat for the interests mentioned in Article 28, the Nuclear Safety Authority can prescribe at any time the evaluations and the implementation of measures made necessary. Barring an emergency, the operator is required to submit its observations. […]

Art. L. 542-1 (principles: health and safety, responsibility, intergenerational equity)
The sustainable management of radioactive materials and wastes stemming notably from the operation or dismantling of facilities using radioactive sources or materials, entails ensuring protection for human health, safety and environment.

The search for and the implementation of the resources required for the definitive securing of radioactive wastes are undertaken to prevent or mitigate the costs that will be borne by future generations.

Generators of spent fuels and radioactive wastes are responsible for these substances, notwithstanding the liability of their possessors as the entities responsible for nuclear activities.

Art. L. 542-1-1 (definitions)

A radioactive substance is a natural or artificial substance that contains radionuclides, whose activity or concentration justifies radiation protection monitoring.

A radioactive material is a radioactive substance that can be potentially used, if necessary, after treatment. […]

Radioactive wastes are radioactive substances for which no subsequent use is planned or envisaged.

Final radioactive waste is radioactive waste that cannot be processed in light of our present technical and economic conditions, especially by extracting their recyclable part or by reducing their polluting or hazardous nature. […]

Disposal of radioactive waste is the operation consisting of placing these substances in an installation especially designed to hold them in a potentially permanent way in compliance with the principles set out in Article L. 542-1. […]

Art. L. 542-2 (prohibition on foreign waste disposal)
This Article prohibits the disposal in France of radioactive waste from abroad as well as that of radioactive waste stemming from the processing of spent fuels and radioactive wastes from abroad.

Art. L. 542-10-1 (deep geological repository, authorization, public debate, reversibility)
A deep geological repository for radioactive waste is a basic nuclear installation.

- the French government presents [...] a bill setting the reversibility conditions. After promulgating this law, the construction permit for the facility can be issued by decree from the Conseil d'Etat, taken after a public survey;

- no construction permit shall be issued for a deep geological repository for radioactive waste which does not guarantee the facility's reversibility in the conditions provided by this law. [...] 

*L. 542-12 (ANDRA's role)*

[The Agence Nationale pour la Gestion des Déchets Radioactifs, (ANDRA, French National Radioactive Waste Management Agency), a public industrial and commercial institution, is in charge of the long-term management of radioactive wastes:] [...] 

1° establish and update every three years and publish the inventory of radioactive materials and waste present in France as well as their location on the national territory, the waste referred to in Article L. 542-2-1 is listed by country;

2° conduct or steer, in accordance with the national plan set out in Article L. 542-1-2, research and studies on deep geological disposal and ensure their coordination;

3° contribute under the conditions defined in the penultimate section of this article, to the assessment of the costs linked to the implementation of long-term management for high and medium level long-lived radioactive waste, depending on their nature;

4° plan in accordance with nuclear safety rules, specifications for radioactive waste disposal and give the competent administrative authorities an opinion on the specifications for waste conditioning;

5° design, set up, develop and manage radioactive storage or disposal facilities taking account of long-term prospects for the production and management of these wastes and conducting any necessary studies; [...] 

ANDRA shall propose to the minister in charge of evaluating the costs linked to the implementation of long-term management solutions for high and medium level long-lived radioactive waste, depending on their nature. After collecting the observations of those liable to the payment of additional taxes [to the INB tax] and the opinion of the Nuclear Safety Authority, the minister in charge of energy shall decide on the final evaluation for these costs and disclose them to the public. [...] 

Cour des comptes
The costs of the nuclear power sector – January 2012
13 rue Cambon 75100 PARIS CEDEX 01 - tel : 01 42 98 95 00 - www.ccomptes.fr
Pertinent provisions of the French planning Act No. 2006-739 of June 28, 2006 on the sustainable management of radioactive materials and wastes

Article 20 (evaluation of costs, provisions, update, report, dedicated assets, CNEF)

I. – Operators of basic nuclear installations shall make a conservative evaluation of the dismantling costs of their facilities or, for their radioactive waste disposal facilities, their costs for final shutdown, maintenance and monitoring. They shall use the same procedure to evaluate, notably by taking account of the evaluation set in application of Article L. 542-12 of the Environment Code, the management costs of their spent fuel and radioactive wastes.

II. - Operators of basic nuclear installations shall accrue provisions for the costs mentioned in I and earmark the necessary assets exclusively for hedging these provisions.

They shall keep separate accounts of these assets which must present a sufficient level of security and liquidity to meet their goal. The realizable value shall at least be equal to the amount of the provisions mentioned in the first section of Article II hereunder, barring those linked to the operating cycle.

With the exception of the State, entitled to exercise its inherent powers to ensure that operators comply with their obligations to dismantle their facilities and manage their spent fuel and radioactive waste, none can claim a right to the assets mentioned in the first section of Article II hereunder, including on the grounds of Book VI of the French Commercial Code.

III. - The operators shall transmit every three years to the administrative authority a report describing the evaluation of the costs mentioned in I, the methods applied to calculate the provisions for these costs and the choices adopted with respect to the composition and management of the assets assigned to hedge the provisions. They shall transmit every year to the administrative authority an update note to this report and shall immediately inform it of any event likely to amend the content thereof. They shall communicate upon request, to the administrative authority, copies of all accounting documents or supporting documents.

[...]

The operators shall implement the asset building plan no later than within a period of five years reckoned from the publication of this law.

Exceptionally, a nuclear operator may be granted a five-year postponement for implementing the asset building plan defined in II if the two conditions below are met:
1° The costs mentioned in I, barring those linked to the operating cycle, assessed in current euros for the period from the publication date of this law in 2030 are less than 10 percent of all the costs mentioned under the same article, barring those linked to the operating cycle, evaluated in current euros;

2° At least 75 percent of the provisions mentioned in the first paragraph of II, barring those linked to the operating cycle, shall be hedged by 29 June 2011 by the assets mentioned in that same II.

IV. - A national committee for the evaluation of funding for the costs of dismantling basic nuclear installations and spent fuel and radioactive waste management shall be created.

The committee shall evaluate the inspection of the adequacy of the provisions set out in II with the costs mentioned in I and the management of the assets set out in II as well as the management of the funds mentioned in Articles L. 542-12-1 et L. 542-12-2 of the Environment Code.

It can, at any time, send to Parliament and to the Government opinions on issues that fall within its purview. The committee's opinions can be rendered public. It shall submit […], every three years, a report presenting the evaluation mentioned in the previous paragraph. This report is rendered public.

The commission shall comprise:

1° Presidents of Assemblée Nationale and Senate committees, with competences in energy or in charge of finance, or their representative;

2° Four qualified key people equally appointed by the Assemblée Nationale and by the Senate;

3° Four qualified people appointed by the Government.

The qualified people shall be appointed for six years […]

---

**French decree No. 2007-243 of 23 February 2007 on securing funding for nuclear costs (consolidated version)**

*Article 2 (category of costs and evaluation methods, definition of operating cycle)*

I. – Operators shall evaluate the costs mentioned in I of Article 20 of the foregoing Act of 28 June 2006 according to the five categories below:

1° the **dismantling** costs of the basic nuclear installations, excluding long-term management of radioactive waste packages;

2° the costs for managing their spent fuel, excluding the long-term management of radioactive waste packages;
3° the costs of recovering and conditioning their old waste, excluding long-term management of radioactive waste packages;
4° the costs of long-term management of radioactive waste packages;
5° monitoring costs after shutting down disposal facilities.

These costs are broken down in operations defined in accordance with the nomenclature set by decree of the ministers in charge of the economy and energy.

II. - These costs are evaluated through a method based on:
1° an analysis of the various options that can be reasonably envisaged for implementing the operation;
2° on this basis, the conservative choice of a reference strategy;
3° taking account of the residual technical uncertainties within the adopted reference strategy;
4° taking account of construction hazards;
5° taking account of operating feedback, especially for ongoing operations.

III. - the operating cycle mentioned in the second paragraph of point II of Article 20 of the aforementioned Act of 28 June 2006 refers to industrial facilities built or under construction. The nomenclature mentioned in the last paragraph of point I determines the costs linked to the provisions connected to the above operating cycle.

Article 3 (discount rate)
The discount rate used to calculate the amount of the provisions mentioned in paragraph 1 of point II of Article 20 of the Act of 28 June 2006 above shall be determined by the operator in compliance with applicable accounting standards.

This discount rate may not exceed the rate of return, as anticipated with a high confidence level, of hedging assets managed with a sufficient degree of security and liquidity to meet their goal.

Furthermore, the discount rate may not exceed a ceiling defined by the ministers in charge of the economy and energy, compatible with the applicable accounting standards.

To determine the discount rate mentioned in the first paragraph and for the evaluation of the rate of return mentioned in the second paragraph, the operator shall adopt a specific and long-term method.
**Article 4 (hedging assets)**

III. - Are however, excluded from hedging assets, notwithstanding the provisions of point 3 of section II, securities issued by the operator or by a corporation belonging to the same group as the operator, as well as those issued by a company in which the operator or a corporation belonging to the operator holds an equity interest as defined by Article 20 of decree No. 83-1020 of 29 November 1983 in application of Act No. 83-353 of 30 April 1983 and concerning the accounting obligations of merchants, except for the units and shares of undertakings for collective investment in transferrable securities.

Notwithstanding the foregoing paragraph:

a) when the operator has assigned, as of 31 December 2005 such securities to hedge the provisions mentioned in Article 3, the administrative authority can decide, at the operator's request, on the admissibility of this type of securities, in a proportion that it shall determine. This authorization can lead to a waiver of the provisions set out in II of Article 5, provided that the operator ensures that all the hedging assets are adequate to fully hedge the operator's cash outflow requirements;

b) The administrative authority can decide, at the operator's request, on the admissibility of the assets that fall under point 5 of II of this article, in a proportion that it determines, notwithstanding the provisions of Article 5 of this decree.

Real estate assets assigned to the use of the operator or a corporation belonging to the same group as the operator shall also be excluded.

**French decree of 21 March 2007 relating to the securing of funding for nuclear costs.**

**Article 1 (notion of recyclable spent fuel)**

Under this decree, we mean by:

[...]

2° “Spent fuel recyclable in built industrial facilities and under construction”: spent fuel that can be processed in an industrial facility built or under construction and authorized for this purpose and for which it is planned that the plutonium from these processing operations shall be recycled in the industrial facilities built or under construction, with the required authorizations. For these different facilities, the operator takes account in its forecasts of their planned residual operating term; [...]

**Article 3 (supervision of the discount rate)**

The nominal value of the ceiling mentioned in the third paragraph of Article 3 of the aforementioned decree of 23 February 2007 is equal to the arithmetic mean on the last forty-eight months of the French treasury 30-year constant maturity rate (TEC 30), observed on the financial year reporting date, increased by 1 point.

### Annex (simplified)

| 1. Dismantling costs of INB, excluding long-term management of packages of radioactive wastes. | 1.1. Cross functions (the operator's dedicated structures to organize the dismantling of its facilities, cost of studies, physical and inventories ...). |
| 1.2. Cost of specific investment and developments. | 1.3. Operating costs: |
| 1.4. Other costs. | A) Operations aimed at decommissioning the facility: final shutdown, dismantling and cleanup, including waste management (on-site commissioning of wastes and their storage, if necessary); |
| 1.5. Share of dismantling costs payable by the concerned operator and relating to facilities operated by a third party. | B) monitoring of the site if this time is individualized. |

This category does not include costs "linked to the operating cycle" as defined under ii of article 20 of Act No. 2006-739 of 28 June 2006. For categories 1.1 to 1.4, the percentage of costs to be implemented by the operator and payable by a third party. The costs mentioned in 1.5 do not require the earmarking of assets by the operator.

| 2. Spent fuel management costs excluding long-term management of radioactive wastes packages. | 2.1. Management costs of spent fuels recyclable in built industrial facilities or under construction: |
| 2.2. Costs relating to other spent fuels. | A) storage in the operator's facility; |
| | B) transport to the treatment facility; |
| | C) storage on site before processing; |
| | D) processing; |
| | E) storage of final waste packages on site after processing. |

The costs mentioned in 2.1 are "linked to the operating cycle".

| 3. Costs of recovering and conditioning their old waste, excluding long-term management of radioactive waste packages. | 3.1. Recovery and conditioning operations for wastes stored in one of the operator's facilities concern: |
| 3.2. Other. | A) recovery and conditioning; |
| 3.3. Percentage of the operator's waste recovery and conditioning operations listed in the reported inventory under facilities operated by third parties. | B) storage. |

This category does not include costs "linked to the operating cycle". 3.1 only includes a list of waste management costs that require accrual of provisions. The costs mentioned in 3.3 do not require the earmarking of assets by the operator.
### 4. The costs of long-term management of radioactive waste packages

**4.1. Cost of long-term management of conditioned waste packages listed in the inventory and corresponding to:**
- *A)* waste package to produce, resulting from end of operation, final shutdown and dismantling described in 1, while stating the costs:
  - (i) if necessary, studies and research;
  - (ii) if necessary, construction of the disposal facility;
  - (iii) evacuation to the disposal facility;
  - (iv) operation of the disposal facility;
  - (v) shutdown of the disposal facility;
- *B)* waste packages to produce, from existing spent fuels not currently described in 2, by specifying the costs: (i) …
- *C)* waste packages to produce, from old waste recovery and conditioning operations described in 3, by specifying the costs: (i) …
- *D)* waste packages already produced, by specifying the costs: …

**4.2. Others, by specifying the costs:** …

This category does not include costs "linked to the operating cycle".

The costs of handing short-lived wastes resulting from the operation of facilities in service does not require the accrual of provisions are not listed in 4.

### 5. Monitoring costs after shutdown

Disposal facility monitoring costs.

This category does not include costs "linked to the operating cycle".
Annex 8: EDF cost accounting

The EDF group reports its financial statements in compliance with the International Financial Reporting Standards in the ERP system (under SAP architecture), interfaced with the EDEN cost accounting system that allows itemization of the costs of the Production and Engineering Division (hereafter DPI) of EDF SA.

The scope of the nuclear production activity was defined along the boundaries of the DPI, which encompass the business divisions below:

- the nuclear fuel division (DCN),
- the nuclear engineering division (DIN),
- the nuclear production division (DPN),
- the industrial support for production division (DAIP),
- the head DPI (TDPI),
- the thermal engineering production division (DPIT)
- the hydraulic engineering production division (DPIT)

The data communicated by EDF indicate that 84% of the costs charged to nuclear activities in the cost accounting are charged directly, as they concern divisions working exclusively in the nuclear field or costs charged specifically to nuclear activities (through a time sheet system for staff). The remaining 16% are indirectly charged using distribution formulae.

The practical procedures for calculating the full cost have been noted on "45 decision sheets", leading to the set up of nearly "130 calculation rules". The rules are validated by the finance management department (DGF) and by the production economics and industrial strategy department.
Procedures for charging costs to nuclear activities

<table>
<thead>
<tr>
<th>Description</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct charge to nuclear units</td>
<td>38%</td>
</tr>
<tr>
<td>Direct charge to nuclear concerning common units</td>
<td>1%</td>
</tr>
<tr>
<td>Direct charge to the power plants</td>
<td>27%</td>
</tr>
<tr>
<td>Direct charge to the nuclear sector at national level</td>
<td>18%</td>
</tr>
<tr>
<td><strong>Direct charge without using distribution formulae</strong></td>
<td><strong>84%</strong></td>
</tr>
<tr>
<td>Indirect charge by using distribution formulae</td>
<td>16%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

*Source: EDF*

In the context of the investigation, there was no audit of EDF's information systems, but the Cour considers that the data from EDF's cost accounting is sufficiently reliable to be used for this report, for the reasons below:

- EDF has tasked Ernst & Young with reviewing the 2009 calculation of the current economic cost, in order to specifically check the traceability of the data used with the accounting systems: this engagement concluded that data traceability was satisfactory and especially observed the absence of significant variance between general accounting and cost accounting;
- the EDF group risks and audit department conducted in spring 2011 an audit engagement on the construction chain of the nuclear sector operating costs which specifically concluded that the data construction chain was sturdy overall and that the controls on cost data fed into the cost accounting are documented;
- EDF supplied the Cour with a reconciliation between general accounting and cost accounting for 2008 to 2010.
### Annex 9: Annual income from fees then taxes on basic nuclear facilities (INB) since 1998

<table>
<thead>
<tr>
<th>Year</th>
<th>Annual amount in €M</th>
</tr>
</thead>
<tbody>
<tr>
<td>1998</td>
<td>87,18</td>
</tr>
<tr>
<td>1999</td>
<td>89,04</td>
</tr>
<tr>
<td>2000</td>
<td>128,10</td>
</tr>
<tr>
<td>2001</td>
<td>128,72</td>
</tr>
<tr>
<td>2002</td>
<td>128,72</td>
</tr>
<tr>
<td>2003</td>
<td>213,10</td>
</tr>
<tr>
<td>2004</td>
<td>345,87</td>
</tr>
<tr>
<td>2005</td>
<td>347,07</td>
</tr>
<tr>
<td>2006</td>
<td>358,68</td>
</tr>
<tr>
<td>2007</td>
<td>365,00</td>
</tr>
<tr>
<td>2008</td>
<td>365,10</td>
</tr>
<tr>
<td>2009</td>
<td>365,30</td>
</tr>
<tr>
<td>2010</td>
<td>584,42</td>
</tr>
<tr>
<td>2011</td>
<td>580,76</td>
</tr>
</tbody>
</table>

*Source: ASN*

(1) Taking account of the amendment to Article 43 of the 2000 Budget Act enacted in application of article 3.8 of the 2010 Initial Budget Act No. 2009-1673 of 30 December 2009 which raised the flat value of production nuclear reactors from the previous €2,118,914.54 to €3,583,390.

(2) Taking account of the revised Budget Act for 2003 (No. 2003-1312 of 30 December 2003) comprising two measures:
- replacement of the "energy production nuclear reactors (by unit)" category by the energy production nuclear reactors other than those devoted primarily to research (by unit)" category for which the flat tax rate is set at €2,088,000;
- creation of a "energy production nuclear reactors devoted primarily to research" category for which the flat tax amount is set at €180,000 and the multiplying factor 1 and 4.

(3) Taking account of the amendment to Article 43 of the Budget Act for 2000 in application of Article 36 III of the Initial Budget Act for 2003 (No. 2002-1575 of 30 December 2002). The amount of the flat tax concerning production nuclear reactors is set at €1,180,000.

(4) Publication of Article 43 of the Budget Act introducing INB taxes.
Annex 10: Dismantling:
final state adopted by the operators

Extract from the ASN 2010 Annual Report – Chapter 15.1.2

"Following decommissioning, a nuclear installation can be delicensed. It is then deleted from the list of INBs and is no longer attached to the INB system. To support its delicensing application, the licensee must provide a file demonstrating that the envisaged final status has indeed been reached and describing the state of the site after decommissioning (analysis of the state of the soil and remaining buildings or equipment, etc.). Public protection restrictions may be implemented, depending on the final status reached. These may set a certain number of restrictions on the use of the site and buildings (use limited to industrial applications for example) or precautionary measures (radiological measurements to be taken in the event of excavation, etc.). ASN may make delicensing of a INB dependent on the implementation of such restrictions."

The final destination of the sites adopted by licensees is specified in the three-year report drafted in application of Article 20 of the planning Act No. 2006-739 of 28 June 2006 regarding the sustainable management of radioactive materials and wastes.

For EDF, "a comprehensive health study leads to the delicensing associated with potential servitude. After demolishing the superstructures, the remaining cavities under the ground level are filled with the appropriate backfill. As much as possible, the non nuclear gravel from the demolition shall be used as backfill after crushing. The baseline assumption taken for the 2009 study is that of the demolition of buildings including the containment of the nuclear island and the machine room. There are plans to reuse the site for industrial purposes."

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231Evaluation study of the dismantling costs of reactor fleets in operation.
AREVA seeks:

"– the recycling / reuse of materials stemming from the dismantling of the conventional waste areas of facilities; for materials derived from nuclear waste areas, this recycling/reuse can only be envisaged in the nuclear area in accordance with the regulation in force;

- reusing all or part of the buildings for a long-term industrial activity, nuclear related or not, or the reconversion of buildings and sites for other purposes."

For the CEA, "the full decommissioning of inoperative INBs allow their potential reuse without restrictions or supervision, or their demolition into conventional waste. Therefore, the cleaned up facility no longer includes nuclear waste areas. When this goal presents difficulties that are considered too high by the CEA, or where the future use of the facility requires mandatory specific nuclear constraints, interim situations can be envisaged, servitudes linked to specific hot points maintained under restrictive access, for example.

The full decommissioning criteria, with a view to the long-term future of the free site, is the annual dose likely to be integrated by the future users of the site. Residual radioactivity left on the site must ultimately be for the future users at a maximum annual dose lower than the exposure accepted for the public of 1 mSv/year, excluding natural radioactivity.

With respect to radiological state, the target is the radiological decontamination of the premises and buildings. The latter become standardized buildings characterized by a change in the radiological zoning and a change in the zoning of the buildings' reference waste, with changeover of the premises into a conventional waste area, inasmuch as the area is decontaminated without any residual risk points."

Source: Cour des Comptes, operators
Annex 12: Compliance of operators with the list of costs and nuclear provisions

In their reports "Article 20", operators do not always comply with the categories and sub-categories of the nomenclature attached to the order of 21 March 2007 pertaining to the securing of financing for nuclear costs (see below). Non compliance with this nomenclature is a breach of the financial transparency policy, insofar as the sum of the costs of this category does not truly reflect the actual level of costs corresponding to the headings of this category. However, non-compliance with the nomenclature does not lead to underhedging in dedicated assets.

Category 1: Dismantling costs of INBs, excluding long-term management of radioactive waste packages.

CEA includes in dismantling costs, the costs of the long-term management of radioactive wastes resulting from dismantling (€341 million); they should normally be recognized in category 4.

Category 2: "spent fuel management costs excluding long-term management of radioactive wastes packages."

EDF does not report the long-term storage costs of spent fuels, mostly MOX and EUR in this category (€1,148 million); they should however find a place in the subcategory 2.2 (expenses relating to other spent fuel) which, by analogy with subcategory 2.1, should contain storage expenses.

CEA separates these spent fuels into categories of recyclable (subcategory 2.1) or non recyclable (subcategory 2.2) in current facilities but does not seem to pay attention to the lack of dedicated assets to hedge the costs of subcategory 2.1 (though linked to the operating cycle).

The costs of subcategory 2.1 are the only ones which, because they are "linked to the operating cycle" are not hedged by dedicated assets once discounted to present value. No operator inappropriately reports costs in subcategory 2.1; therefore reporting mistakes have no material impact on the hedging level of provisions by dedicated assets.
Category 3: "old wastes recovery and conditioning costs, excluding long-term management of radioactive waste packages."

CEA includes in this category, the long-term handing costs of radioactive wastes from recovery and conditioning operations (€79 million); they should normally be recognized in category 4;

Category 4: "long-term management costs of radioactive waste packages" (this category only concerns disposal and transport costs)

EDF includes in this category, the costs of long-term storage of spent fuels, mostly MOX and REU (€1,148 million) which should be recognized in category 2. EDF also reports in this category costs after shutting down storage facilities which should be in category 5 (€1,056 million).

CEA reports in this category a certain number of storage or packaging expenditure (€190 million) that should be in the other categories (1, 2 or 3 depending on the origin of the waste).

AREVA reports a certain number of interim storage expenditures in this category (€19 million).

Category 5: "post shutdown monitoring costs"

This category includes all costs after shutting down the disposal facilities: supervision, maintenance of the facility's blanket, tax regime. EDF does not include the post shutdown costs of disposal facilities (€1.56 million), considering that they correspond to incidental expenses to the long-term management costs of radioactive waste packages.

Miscellaneous

EDF recognized in its provision for last core (excluding nomenclature) management costs for spent fuel and long-term management of radioactive waste packages; these amounts are however in the categories of the corresponding nomenclature (two and four) under the title "regulatory effect – committed fuel". This dual accounting is not conducive to transparency.
Annex 13: Liability arrangements through cash payments

Since 2004, several protocols have been signed between the three leading nuclear operators, sometimes following several years of negotiations, in order to simplify the breakdown of financial costs relating to the dismantling of sites and the recovery and conditioning of old waste.

Without cash payment agreement, the use of an operator's facilities by other operators creates for them debts corresponding to the sharing of future dismantling and waste management costs. The exchange of cash payments helps to identify with more certainty a single debtor for the future costs but does not exempt the waste producers of all legal responsibility. In fact, this responsibility is the application of the polluter-pays principle, in accordance with directive 2011/70/EURATOM of 19 July 2011\textsuperscript{232}, stated in Article L. 542-1, al. 3, of the French Environment Code: "Producers of spent fuels and radioactive wastes are responsible for these substances, notwithstanding the responsibility of their possessors as responsible for nuclear activities."

It must be noted that the amounts of cash payments made correspond to the discounted amounts of the outstanding future costs to be paid. The cash payments are just the results of the liability arrangements and must therefore not be added to dismantling costs or waste management costs as they appear in the accounts of operators.

Even if the amounts of cash payments may stem from broader negotiations which reduce the theoretical value, with respect to the financial amounts involved, the execution of exchange protocols between operators striving to defend their own interests is a way of validating the evaluations for future costs financed in this way.

\textsuperscript{232}This directive is yet to be transposed into French law and is not contrary to the principle of transfer of liability: "the national framework shall give primary responsibility for the spent fuel and radioactive waste to their generators or, under specific circumstances, to a licence holder to whom this responsibility has been entrusted by competent bodies;" (art. 5 f).
# Liability arrangements through cash payments

<table>
<thead>
<tr>
<th>Date of agreements</th>
<th>Facilities</th>
<th>Transfer of liability versus cash payment</th>
<th>Amount of cash payment in current € million</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>UPI Marcoule&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>EDF CEA</td>
<td>2004</td>
</tr>
<tr>
<td></td>
<td>Cadarache MOX production workshop</td>
<td>CEA AREVA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>La Hague Elan IIB workshop&lt;sup&gt;(2)&lt;/sup&gt;</td>
<td>CEA AREVA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>UP2-400 of La Hague&lt;sup&gt;(3)&lt;/sup&gt;</td>
<td>CEA AREVA</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>Phenix reactor&lt;sup&gt;(4)&lt;/sup&gt;</td>
<td>EDF CEA</td>
<td>2008</td>
</tr>
<tr>
<td></td>
<td>Brennlis reactor&lt;sup&gt;(4)&lt;/sup&gt;</td>
<td>CEA EDF</td>
<td></td>
</tr>
<tr>
<td>2008-2010</td>
<td>La Hague&lt;sup&gt;(5)&lt;/sup&gt;</td>
<td>EDF AREVA</td>
<td>2008-2010</td>
</tr>
<tr>
<td></td>
<td>St-Laurent silos</td>
<td>AREVA EDF</td>
<td></td>
</tr>
</tbody>
</table>

Source: Cour des Comptes-

<sup>(1)</sup>“Defense” installations not included in the scope of this report- The transfer does not cover wastes intended for deep disposal.

<sup>(2)</sup>Cleaning up – CEA remains the owner of its long-lived HA and MA wastes to be conditioned.

<sup>(3)</sup>Under the recovery and conditioning services for wastes resulting from CEA’s treatment in the La Hague plant prior to the incorporation of Cogema (AREVA NC)

<sup>(4)</sup>Of which the future of fuel. However, there is no liability transfer for wastes, excluding fuel, from dismantling, which do not have a disposal sector. They remain the responsibility of the generators in proportion to their liabilities in 2008.

<sup>(5)</sup>Final shutdown – dismantling-recovery and condition of wastes - EDF and the CEA remain the owners of these long-lived HA and MA wastes to be conditioned under the waste recovery and conditioning policy.
Annex 14: Aging of facilities and irreplaceable components

1 - Aging reactor vessels and primary circuit components

In so-called PWR (pressurized water reactor) power plants, heat is generated by the fission of the uranium nuclei of the fuel placed in the reactor core (all the fuel assemblies). These fuel assemblies are contained in the reactor core which comprises a vessel body and head. It is made up of welded and machined steel parts weighing a total of 330 tonnes. On the central portion of the vessel, the steel is 20 cm thick.

The vessel contains the primary fluid which flows through the fuel assemblies. It forms a barrier that ensures the containment of radioactive components. The control rods and measuring devices (neutronic, temperature) required for running the reactor are inserted from the top of the vessel through the head.

It plays a key role for the three safety functions of the facility: the confinement of radioactive materials, control of nuclear reaction and cooling of fuels. Its integrity must therefore be guaranteed in all operating circumstances: in a normal operating situation but also in case of an accident and for the entire duration of the operation.

Contrary to other reactor components (primary or secondary circuit components, such as steam generators), EDF is not planning on replacing the vessel. And yet, the reference operation term of 40 years was initially defined on the basis of the vessel and the physical properties of its steel. The aging of the vessel also depends on the specific operating mode of each vessel, especially its load factor. Furthermore, temperature or pressure variations ("transient situations") are also events that change the properties of steels. Thus, the more the equipment is subject to strong temperature and pressure changes, or to an intense (full power) neutron bombardment, the more its properties change and the vessel metal

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233: Aging is characterized by irradiation effects and strong pressures and temperature on the vessel material and the primary circuit: “fragilization” of the steel characterized by reduced tensile strength (capacity to withstand mechanical stress in the presence of a fault).
becomes fragile. It could specifically become less resistant to an accidental situation, such as a cold shock (safety injection in the event of a breach in the primary circuit).

This clarification is important in the case of the French fleet, since contrary to other foreign reactors, French reactors have the specific characteristics of operating in "load following" mode: in other terms, the reactor's power is modulated during the day to follow the peaks and troughs of electricity consumption and the number of transients (power and temperature variation) is in fact higher than for a reactor operated in base load. These transients are monitored and a detailed record is kept for each reactor.

In accordance with the regulation, the vessels are examined after they are designed, when in operation and during the ten-year inspections:

- faults are monitored: like any welded object, vessels may present faults or cracks right from the beginning and new faults may be detected; the primary circuit is tested (hydraulic test) by raising the pressure, beyond the operating pressure and checking the leak tightness of the circuit;
- the change over time of the transition temperature between the ductile (flexible) state of the metal and its fragile state is known and monitored, etc.

Significant progress has been made in crack measuring and detection instruments.

The physical observations are compared to the results obtained by modelling the expected behaviour of faults. The ability to accurately project the potential residual operating life of vessels depends on the quality of this modelling. These modelling programs run on very complex fundamental and experimental research resources. In France, research resources are primarily located in CEA and EDF.

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This reactor operation mode also wears out fuel assemblies.
2 - The aging of reactor containment housings

The housing around vessels play a containment role: they must prevent the scattering of radioactive particles in the environment in the event of a rupture of the primary circuit and help to mitigate radioactive releases in the event of serious accident (core meltdown).

a) Two categories of housing

- The single-wall containments of the 900 MW series are composed of a cylindrical-shaped prestressed concrete building (37 m in diameter 60 m high), with a dome roof. The inner surface is covered with a 6-mm "metallic liner" designed to guarantee leak tightness in case of an accident. The design and sizing of structures therefore ensure passive containment, based on significant physical barriers and on the internal metallic skin. However these enclosures are neither completely leakproof, nor definitively protected from the risk of deterioration of the concrete's properties. The leakage rate in case of an accident is limited by regulation to 0.3% a day of the mass of fluids (air and water vapour) contained in the housing.

- Double-wall housings of the 1300 MW and 1450 MW series (N4): For these reactors, the internal wall is built with prestressed concrete but is not covered by a leak proof liner. Its role is to withstand the internal pressure and temperature conditions while providing "relative" leak tightness: The leakage rate in an accident situation is limited by regulation to 1.5% a day by fluid mass (air and water vapour) contained in the housing. The 1300 MW and 1450 MW series are based on the principle of "dynamic containment" provided by the pressure difference, the vacuum between the two housings, and the fact that these components are built in prestressed concrete.

In other words, the design, and subsequently the construction of these reactors, do not include the goal of totally blocking radioactive releases into the atmosphere in the event of a serious accident with core meltdown.

A different approach was used, right from the design stage, for the EPR reactor under construction in Flamanville. Serious accidents with complete meltdown of the core and formation of corium, explosion of hydrogen in the enclosure, generation of projectiles inside the housing, piercing of the vessel by the corium, etc. were studied and designed into the size of the housing.
b) Effects of aging on the containment housing

Reactor buildings in reinforced and prestressed concrete suffer from various phenomena of aging and characteristics of the concrete: they include distortion, or "shrinking", corrosion of the steel cables used for the reinforcement, or again slack in the cables used in the prestressed concrete.

EDF should, during safety inspections (ten-year inspections) prove the capacity of the housing to contain radiological releases in the event of an accident. In any event, in case of a serious accident with core meltdown, the radioelements cannot be totally confined. The limits indicated above (leak rate in case of an accident is limited by regulation to 1.5 percent by day of fluid mass (air and water vapour) contained in the housing for the 1,300 MW and 1,450 MW) are to be compared to the new limits proposed by the EPR reactor.

In France, the housings are tested under air pressure equivalent to what could appear in the housing in case of accidents such as a steam line break (RTV), in order to check their strength and their leak tightness. The corresponding trials, known as containment tests, are carried out before the building is commissioned, then periodically (normally every 10 years, sometimes every five years).

The test places substantial stress on the housing and allows the operator to check the robustness of the structure's general construction. However, the test is just partially representative of the actual conditions in case of an accident in the housing, since in addition to the higher pressure, there would be a brutal increase in temperature, which is not reproduced during the test.

For some housings of the 1,300 MW series, EDF has applied composite coatings on the bends of inner housings to improve its leak tightness and is currently considering coatings for the outside bends of the inner housing. However, none of these solutions provides total leak tightness. EDF is planning to request an increase in the release rate criteria of housings on the grounds of improving the containment of peripheral buildings which, according to EDF would make up for the slackness of the first criteria, in terms of radiological consequences.
Calculating the comprehensive cost of nuclear power production involves more than simply identifying and estimating the different cost items analysed in the report. The cost of capital (equity and debt) which is massively invested for a very long time must also be taken into account. As the nuclear industry is extremely capital intensive, evaluating this part of the cost plays a key role in the methods used to calculate production cost.

Notwithstanding the effective method used to set rates, which involve the interpretation of the specific provisions of the French electricity market reform law, the so-called NOME law, we present below the different methods for determining the cost of nuclear production which currently coexist. The Cour has mainly retained three which are used in various contexts: the Champsaur report method, the so-called FCA (full cost accounting) method, and lastly, the CEC ("current economic cost") method.

These three methods have the common goal of proposing a baseline for power production cost per annum. Two of them (Champsaur report and CEC) are specifically designed to calculate the cost of nuclear power generation, the third (FCA) was originally designed to cover the full spectrum of power generation, regardless of the source.

\[ a) \text{ A similar starting point} \]

All three methods start from the same premise, namely that the cost of power generation is the sum of two types of items:
\[ \text{a-1: the operations costs of the fleet} \] (including the share linked to the foreseeable future costs for maintenance, dismantling, and back end fuel management, etc.).

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235 We have included a brief presentation on how to calculate accounting cost, for information, in the calculation of different methods.  
236 The French Government used this report to set, in the context of the NOME law, the initial ARENH price, as provided by the NOME law "consistent with the rate described in Article 30-1 law No. 2004-803 of 9 August 2004", in other words with the “Tarif Réglementé Transitoire d’Ajustement de Marché”, (TaRTAM- French transitional regulated tariff for balancing markets).
With respect to these costs, we note a few variants in approach between the three methods, depending on whether certain costs incurred for the future are included or excluded from the costs mentioned below.

However, there are no differences between the various methods on the amounts in question, but only on the breakdown between operating costs and the asset building expenditure below.

\( a - 2 \): the expenditures incurred by EDF to build the fleet assets, as shown by the corporation’s general and cost accounting or, which amounts to the same, from the remuneration and reimbursement, at the end of lifecycle, of the capital (equity and debt) invested in the fleet.

On this second point, the three methods are not fundamentally different on neither the nature nor the historic amount of the first investment assets.

However, and that is a major difference between the three methods, the Champsaur report and the calculation of the CEC both define an economic rent for the fleet. This replaces the amortization annuities and the financial costs borne by the operator. This means that the operator is considered as a holder of a finance lease agreement for the fleet, and that it will have to bear the financial cost (remuneration and reimbursement of the various fundings incurred in the initial constitution of the fleet through the finance lease rent): they determine on this basis a fixed rental payment in constant currency. But the Champsaur report calculates this rent on the basis of the current net carrying amount and on the planned residual operating term of the incumbent fleet, without taking account of interim interests \(^{237}\), while the CEC calculates this rent on the revalued initial value (including interim interests) of the fleet and over the entire operating term currently under consideration.

The calculation of the FCA adopts a different approach, a purely accounting basis, by revaluing in light of inflation and the reintegration of interim interests, the net carrying amount of the fleet: on this basis, the cost of capital (remuneration and reimbursement) is equal to the addition of depreciations (the latter including, with respect to the depreciations reported in the EDF financial statements, over-depreciation linked to taking account of the extra-accounting revaluation of the fleet) and of the remuneration of equity and loans, which results, unlike the other two methods in a decreasing cost of capital over time in constant currency. Another characteristic differentiates the FCA method from the two other methods: the asset base taken into account is not limited to "first

\(^{237}\) We recall that interim interests represent the porting cost of power plants prior to their actual commissioning, which marks the beginning of their book depreciation.
investment assets”, but to all investments made under the incumbent fleet, since the origin, while the other two methods take account of the subsequent investments mentioned above.

For an observer watching from the initial date of constitution of the fleet, and who would reason in constant currency (excluding inflation), the three methods would in principle result, with respect to the mobilized capital, in an average discounted cost of the same order for a given operating period of the fleet, since on that date, they would have to deal with the same amount of invested capital to be remunerated and fully depreciated over the same period and at the same rates, without the distortions inherent in the choices made with respect to the zero, partial or total allowance for inflation. However, even if we use the departure date, the annual breakdown of this cost would present, at the same time, significantly different profiles according to the method adopted (constant annuity for the Champsaur report method and the CEC, or straight line depreciation of the capital invested for the FCA method).

b) The differences

Considering these characteristics, the three approaches diverge with respect to the apprehension over time of the first two inputs above (operating costs and first investment assets), as well as in the inclusion of inflation:

- the method of the Champsaur report "crystallizes", over a specific period (2011-2025), the annual utilization cost of the nuclear production asset on the basis of the net carrying amount of the historic nuclear fleet, used to evaluate, for the term of the planned residual operation of the historic fleet on that same date, the "economic rent" enabling the remuneration and amortization of the residual equity and debt necessary for building the first investment assets of the fleet; the calculation of the FCA, an accounting-type calculation, defines a capital cost calculated on the basis of the revalued net carrying amount of inflation (and therefore with depreciation recalculated on the basis of the revalued cost of assets building) leading to the externalization of decreasing production cost over time, over the planned residual operating term of the fleet;

- lastly, the calculation of the CEC "crystallizes", just like the method of the Champsaur report, a utilization cost of the production asset that is constant in time (barring inflation), but
on the basis of the revalued value of first investment assets and for the fleet’s envisaged total operating term.

The first two methods therefore offer, by construction, a "dated" vision of the cost of capital, which is not the same, even in constant terms, depending on the year used for the evaluation, while the third, barring inflation, proposes in principle a constant annual amount solely linked to the consistence and technical characteristics of the fleet, regardless of the phase of its existence taken into account. In short, the first two methods take account of the past and the third method does not.

As previously indicated, the Champsaur report method ignores inflation in the value of the fleet, as the latter is considered as equal to its net carrying amount (therefore not revalued), but it partially includes it through the future indexing of the rent. The FCA and CEC methods take the value of the fleet in constant terms into consideration and therefore neutralize inflation. Lastly, the three methods use the remuneration rates of invested funds that take inflation into account, and we notice in passing that they have the same order of magnitude.

c) Comparing the results of the three methods

The Cour could thoroughly review just the CEC method during its investigation since it had limited time. Although the Cour could not certify the validity of the hypotheses used to calculate the remuneration rate of invested capital, it made a number of restatements, which are taken into account in the comparative table below. Similarly, EDF was asked to supply data that would allow the Cour to calculate the FCA of the nuclear fleet for 2010. Furthermore, the Cour made an estimate consistent with the elements of the Champsaur report on production cost for 2010 on the basis of available data.

These different restatements help to highlight, on the basis of 2010 taken as a reference by the Cour (last year for which the Cour had EDF’s certified accounts at the time of the investigation), the differences between the three approaches:
Comparing the results of methods for evaluating the production cost of nuclear power (in €million for 2010)

<table>
<thead>
<tr>
<th>Operating costs and maintenance investments (a + b)</th>
<th>Accounting cost (1)</th>
<th>Champsauro method</th>
<th>FCA nuclear</th>
<th>CEC EDF</th>
<th>CEC reviewed by the Cour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel and energy purchases</td>
<td>2 579 (1)</td>
<td>1 839</td>
<td>2 579 (1)</td>
<td>1 839</td>
<td>2 579 (2)</td>
</tr>
<tr>
<td>External consumptions</td>
<td>2 095</td>
<td>2 095</td>
<td>2 095</td>
<td>2 095</td>
<td>2 095</td>
</tr>
<tr>
<td>Personnel costs</td>
<td>2 042</td>
<td>2 042</td>
<td>2 042</td>
<td>2 042</td>
<td>2 042</td>
</tr>
<tr>
<td>Income tax and other taxes</td>
<td>1 176</td>
<td>1 176</td>
<td>1 176</td>
<td>1 176</td>
<td>1 176</td>
</tr>
<tr>
<td>Other revenues and costs</td>
<td>60 (3)</td>
<td>47</td>
<td>60</td>
<td>47</td>
<td>60 (3)</td>
</tr>
<tr>
<td>Overheads and administrative costs</td>
<td>872</td>
<td>872</td>
<td>872</td>
<td>872</td>
<td>872</td>
</tr>
<tr>
<td><strong>Total operating costs according to cost accounting (a)</strong></td>
<td><strong>8 824</strong></td>
<td><strong>8 071</strong></td>
<td><strong>8 824</strong></td>
<td><strong>8 071</strong></td>
<td><strong>8 824</strong></td>
</tr>
<tr>
<td>Agent rate</td>
<td>116</td>
<td>116</td>
<td>116</td>
<td>116</td>
<td>116</td>
</tr>
<tr>
<td>Pension reform and LT employee benefits</td>
<td>518</td>
<td>518</td>
<td>518</td>
<td>518</td>
<td>518</td>
</tr>
<tr>
<td>Investment maintenance of the capitalized fleet</td>
<td>1 747</td>
<td>1 747</td>
<td>N/A</td>
<td>1 747</td>
<td>1 747</td>
</tr>
<tr>
<td>Financial charges of the inventory</td>
<td>535 (4)</td>
<td>632</td>
<td>N/A</td>
<td>632</td>
<td>535 (4)</td>
</tr>
<tr>
<td>Cost of last core</td>
<td>91 (5)</td>
<td>0</td>
<td>91</td>
<td>0</td>
<td>91 (5)</td>
</tr>
<tr>
<td>Cost of relations with RTE</td>
<td>0 (6)</td>
<td>-42</td>
<td>0</td>
<td>-42</td>
<td>0 (6)</td>
</tr>
<tr>
<td><strong>Total other cost components (b)</strong></td>
<td><strong>3 007</strong></td>
<td><strong>2 971</strong></td>
<td><strong>725</strong></td>
<td><strong>2 971</strong></td>
<td><strong>3 007</strong></td>
</tr>
<tr>
<td>Utilization cost of nuclear assets (rent)</td>
<td>1 813</td>
<td>2 447</td>
<td>6 689</td>
<td>9 104</td>
<td>8 341</td>
</tr>
<tr>
<td>Gross nuclear asset revalued at the end of 2010</td>
<td>N/A</td>
<td>88 556</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Net nuclear asset revalued at the end of 2010</td>
<td>N/A</td>
<td>38 149</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Book depreciation</td>
<td>1 352</td>
<td>N/A</td>
<td>1 352</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Over-depreciation</td>
<td>N/A</td>
<td>1 300</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Subtotal depreciation on revalued net asset</td>
<td>N/A</td>
<td>2 652</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Basis of net nuclear asset to be remunerated</td>
<td>N/A</td>
<td>39 473</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Nuclear WCR</td>
<td>N/A</td>
<td>6 374</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Subtotal invested capital</td>
<td>N/A</td>
<td>45 847</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Capital remuneration rate</td>
<td>8.4%</td>
<td>7.8%</td>
<td>7.8%</td>
<td>7.8%</td>
<td>7.8%</td>
</tr>
<tr>
<td>Remuneration of invested capital, including WCR</td>
<td>3 576</td>
<td>N/A</td>
<td>3 576</td>
<td>N/A</td>
<td>3 576</td>
</tr>
<tr>
<td>Economic rent excluding dismantling</td>
<td>N/A</td>
<td>8 720</td>
<td>7 880 (7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of dismantling</td>
<td>461 (8)</td>
<td>461 (8)</td>
<td>384</td>
<td>461 (8)</td>
<td></td>
</tr>
<tr>
<td><strong>Total production cost (€ million)</strong></td>
<td><strong>13 644</strong></td>
<td><strong>13 489</strong></td>
<td><strong>16 238</strong></td>
<td><strong>20 146</strong></td>
<td><strong>20 172</strong></td>
</tr>
</tbody>
</table>

Source: Cour des Comptes
(1) No capital remuneration is factored into the calculation of accounting cost

(2) The Cour considers that a total of €740 million must be included for the financial accretion cost of provisions for spent fuel and waste management.

(3) The Cour considers that other revenues must not be taken into account (for €13 million) when measuring a cost.

(4) The Cour takes account of the financial charge of nuclear working capital requirement instead of the financial charge of inventories only.

(5) The Cour considers that the cost of last cores should be taken into account.

(6) The Cour considers that when measuring a production cost, it is not appropriate to include distribution revenues and costs, which are not related to production.

(7) The economic rent is modified to reflect the adjusted amount of interim interests (€12.78 billion instead of €23 billion).

(8) The Cour retained accounting costs recognized in 2010 as dismantling costs.

The Champsaur report method, drafted for the purpose and under the specific constraints of the NOME law, mechanically lowers the economic rent of the nuclear fleet as we move forward in time (since the net carrying amount of the fleet, ignoring inflation, is by construction lower from year to year). Furthermore, we note that very logically, the Champsaur report does not propose such a calculation every year: the base established early 2011 leads to a cost which, once and for all (in other words until the end of the NOME law, in 2025), provides an indication for setting the ARENH initial tariff, the subsequent adjustments being based on inflation only.

The FCA method proposes the breakdown of the cost of capital (depreciation and compensation on the basis of revalued assets) in such a way as to mechanically record a decline over time. The closer we get to the end of lifecycle of a fleet, the lesser the apparent cost of nuclear power would be, which compared to an objective economic reasoning, introduces an accounting illusion that is hardly compatible with the magnitude of the amount and the life span of the relevant investment. In fact, regarding the evaluation of annual costs, that would lead to a continuity solution when the time comes to renew the investment (we would then suddenly start basing the calculation in constant terms, on a high apparent cost, that would fall gradually, over several decades). From this viewpoint, and especially in line with the pricing logic, the two other
methods propose a more satisfactory solution with the payment of constant amounts of "economic rent".

The CEC has none of these disadvantages, since the goal is to evaluate a comprehensive annual production cost for the historic nuclear fleet. It must however be used with precaution, independently of the fact that it does not meet, according to the Commission de Régulation de l'Énergie (CRE, French energy regulatory commission) the legal requirements for setting electricity prices. Apart from the fact that the Cour takes a "theoretical" standpoint, meaning that it does not factor in the fact that the fleet is already 25 years old on average and that it has already been the subject of various funding, especially through power rates, it presents two weaknesses resulting from:

- strong sensitivity to the remuneration/depreciation rate of equity and debt used to build the first investment assets. The sensitivity to this rate is actually stronger because unlike the other two methods, it concerns a gross investment amount on the entirety of the operating period of power plants (40 years, according to the common hypothesis adopted by the three methods): the rate currently adopted by the CEC is 7.8 percent,

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238 The CRE in the context of its exchanges with the Cour, stresses the fact that the interest of the CEC method "is limited to allowing the calculation [...] of the comprehensive production cost of the nuclear fleet over a year in the context of a method applicable over its entire life span. Furthermore, the choice of the current economic costs method includes de facto, a portion of renewal of the historic fleet [...] It should be stressed that this evaluation cannot and must not be compared to the setting of the regulated sale price for electricity, which meets the principle of hedging the real costs as borne each year by the operator". The Cour confirms that it is obviously not conducting its review from a pricing viewpoint. With respect to the inclusion of the cost of "renewing the historic fleet" raised by the CRE, and in the logic of the evaluation of the full economic cost, the CEC actually incorporates (insofar as the "economic rent" aims to ensure the full recomposition, in value of the capital invested in the first investment assets of the historic fleet), a cost equal to the reconstitution of the capital required to carry out the theoretical renewal of the historic fleet "identically" and without taking account of technological changes. From this viewpoint, the CEC does not specifically include, by construction, the surplus capital needs linked to the possible renewal by next generation power plants. The Cour observes that there is a debate about whether the NOME law, in the context of setting the AREHN tariff, generally excludes, as the CRE seems to indicate, consideration for the renewal of the historic fleet, or if it only excludes, as EDF believes, consideration for the additional cost that would be caused by the renewal of the historic fleet by next generation power plants (i.e. EPRs) : as the Cour des Comptes is not interested in the pricing debate, it does not have to give an opinion on this controversy, since it is unrelated to the objective evaluation of the economic cost of nuclear power production using the existing historic cost, which obviously includes, like for any other economic activity, the reconstitution cost of initially invested capital.
and the table below illustrates the strong sensitivity of economic rent to this variable:

<table>
<thead>
<tr>
<th>Capital remuneration rate</th>
<th>6%</th>
<th>8%</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rent annuity (€ billion)</td>
<td>6.65</td>
<td>8.39</td>
<td>10.23</td>
</tr>
</tbody>
</table>

*Source: CRE*

The Cour des Comptes cannot validate the 7.8 percent level adopted in the context of the CEC and FCA methods, no more than the 8.4 percent used in the Champsaur report;

- a paradoxical result when used to measure the effect of an extension or shortening of the life cycle of the latter, due to the fact that this method concerns the entire life cycle of power plants: thus, for an extension from 40 to 50 years, the economic rent would be, according to EDF’s CEC approach, €8.9 billion for a period of 50 years, while it amounts to €9.1 billion for 40 years, i.e., the scale of the difference is so low that it is clearly not realistic. To measure in 2010 the sensitivity of nuclear power production cost to a change in the life cycle of power plants in relation to the current accounting assumption of 40 years, we must calculate the economic rent in relation to the net asset.

239 The solution suggested by EDF, which entails "crystallizing" the net value of the fleet on the amount of non amortized capital as of 2010 in terms of economic rent, to calculate the effect of a change of term on the basis of a net asset value, is not satisfactory either, since the calculation shows, for example, that for a power plant such as that of Civaux, this would mean that after bearing the cost of twelve annuities of €481 million, only €447 million of capital would have been reimbursed.
Annex 16: Sensitivity test of production cost to changes in three inputs

To give an idea of the sensitivity of nuclear power production cost to three inputs – dismantling cost, spent fuel and waste management, discount rate (by adopting simplified hypotheses and especially a constant inflation rate of 2 percent), it is interesting to calculate the effect of their change on annual production costs.

On the basis of EDF’s available accounting data, the simulations below were made with 2010 conditions, and established according to the CEC method as revised by the Cour des Comptes (i.e. especially by reintegrating the discount charge into production cost). The data below concern the "recurring" effect of such a variation, in other words, by disregarding the instant readjustment of the discount charge the year in which the rate and/or the amount of the provision is changed, as follows:

Impact of a change in the dismantling quotation

For a 50 percent increase

<table>
<thead>
<tr>
<th>Deconstruction costs</th>
<th>Provision as of 31.12.2010</th>
<th>Impact provision</th>
<th>Recurring annual impact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>€9.2 billion</td>
<td>+€4.5 billion</td>
<td>+€290 million</td>
</tr>
<tr>
<td></td>
<td>+€215 million</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total impact</td>
<td></td>
<td></td>
<td>+€505 million</td>
</tr>
</tbody>
</table>

For a 100% percent increase

<table>
<thead>
<tr>
<th>Deconstruction costs</th>
<th>Provision as of 31.12.2010</th>
<th>Impact provision</th>
<th>Recurring annual impact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>€9.2 billion</td>
<td>+€9 billion</td>
<td>+€575 million</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>+€430 million</td>
</tr>
<tr>
<td>Total impact</td>
<td></td>
<td></td>
<td>+€1005 million</td>
</tr>
</tbody>
</table>
This table shows that if, at the same discount rate (5 percent):

- the dismantling quotation increases by 50 percent: The annual production cost of nuclear power would increase by €505 million;
- the dismantling quotation increases by 50 percent: the annual production cost would increase by €1005 million (it is, among the sensitivity tests presented here, the most disruptive hypothesis, and its effect would be limited to an increase of +5 percent with respect to the cost of MWh).

**Impact of a change in the spent fuel and waste management quotation**

This simulation is based on the assumption of a quotation estimated by ANDRA:

<table>
<thead>
<tr>
<th></th>
<th>Provision as of 31.12.2010</th>
<th>Impact provision</th>
<th>Recurring annual impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel costs</td>
<td>€5 billion (M-LLHLW)</td>
<td>€4 billion</td>
<td>+€200 million</td>
</tr>
</tbody>
</table>

Since there is no counterparty asset for waste management, the impact would solely relate to the financial accretion cost of the provision for recycling wastes, excluding deconstruction waste

On this basis, the annual production cost would be €200 million (or only +1 percent in terms of €/MWh)

**Impact of a change in discount rate**

The two tables below show that:

- if we lower the discount rate to 4 percent (instead of 5): the annual production cost of nuclear power would increase by +€162 million/year (increase mainly due to the increase of the counterparty asset for the deconstruction linked to the decline of the discount rate: +€157 million in recurring annual effect);
- if we raise the discount rate to 6 percent (instead of 5): the annual cost would fall by -€131 million/year (same observation – the change of the counterparty asset for the deconstruction has the highest impact: -€120 million in recurring annual effect)
### 4 percent discount rate

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>Description</th>
<th>Provision as of 31.12.2010</th>
<th>Impact provision</th>
<th>Recurring annual impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating costs</td>
<td>Fuel and energy purchases</td>
<td>€15.3 billion</td>
<td>€3.2 billion</td>
<td>-€23 million</td>
</tr>
<tr>
<td></td>
<td>Accretion cost (waste)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Last core cost</td>
<td>€1.9 billion</td>
<td>€0.4 billion</td>
<td>+€26 million</td>
</tr>
<tr>
<td></td>
<td>Depreciation counterparty asset + Accretion cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deconstruction costs</td>
<td>Dismantling</td>
<td>€9.2 billion</td>
<td>+€2.3 billion</td>
<td>+€157 million</td>
</tr>
<tr>
<td></td>
<td>Depreciation counterparty asset + Accretion cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Amortization counterparty asset + Accretion cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total impact</td>
<td></td>
<td></td>
<td></td>
<td>+€162 million</td>
</tr>
</tbody>
</table>

### 6 percent discount rate

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>Description</th>
<th>Provision as of 31.12.2010</th>
<th>Impact provision</th>
<th>Recurring annual impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating costs</td>
<td>Fuel and energy purchases</td>
<td>€15.3 billion</td>
<td>-€2 billion</td>
<td>+€29 million</td>
</tr>
<tr>
<td></td>
<td>Accretion cost (waste)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Last core cost</td>
<td>€1.9 billion</td>
<td>-€0.3 billion</td>
<td>-€20 million</td>
</tr>
<tr>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>Amortization counterparty asset + Accretion cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deconstruction costs</td>
<td>Dismantling</td>
<td>€9.2 billion</td>
<td>-€1.8 billion</td>
<td>-€120 million</td>
</tr>
<tr>
<td></td>
<td>Depreciation counterparty asset + Accretion cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Amortization counterparty asset + Accretion cost</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Total impact</td>
<td></td>
<td></td>
<td></td>
<td>-€131 million</td>
</tr>
</tbody>
</table>
I – Nuclear power production in the United States.

The United States is the first country in the world through the number of its reactors in operation: 104 reactors are currently in operation in 70 power plants unevenly distributed on the US territory. 31 States are equipped with nuclear reactors, primarily in the eastern part of the country.

20 percent of the country's power is generated from nuclear energy, behind coal (46 percent), natural gas (23 percent) and before renewable energy (9 percent, of which 7 percent from hydroelectric sources). But it is a major resource for several States. It represents more than half of the power production in Vermont (72.3 percent), New Jersey (55.1 percent), Connecticut (53.4 percent) and South Carolina (52 percent).

Out of the 104 reactors in service, 35 are boiling water reactors (BWR), and 69 pressurized water reactors (PWR).

One of the specific features of the American nuclear fleet is that it is almost exclusively managed by private operators and uses a large variety of reactor models. 26 electricity corporations generate nuclear energy, by using the different technologies of Westinghouse, Toshiba or General Electric.

These players include a federal company, the Tennessee Valley Authority (TVA), created at the time of the New Deal to generate hydraulic power. TVA invested after the war in the construction of nuclear power plants. It remains an instrument of the State (example: its active participation in the NP 2010 programme intended to test the new procedures for safety licensing) but at the same time it conducts its own policy as operator on a competitive market.

A movement is underway to restructure the capital of power generation companies, which might lead to harmonization, or to a standardization of equipment.

The US energy policy has been characterized in the last decades by hesitations and directional changes, that have been confusing for
investors. They did not however question the key role of nuclear energy in the national economy.

The Three Mile Island accident (1979) had led to a first pause in the construction of new power plants, the suspension of debate on recycling and the postponement of a decision concerning the choice of a national waste disposal site.

The Chernobyl accident reinforced the reluctance of US authorities to encourage a recovery of nuclear investments in the United States, just as in other countries. Washington has since the 90s, strove to reinforce through the AIEA, sanctions, inspections and guarantees in the safety of nuclear power plants and fuel management worldwide.

In the early 2000, tensions on the hydrocarbon market and climatic concerns rekindled interest in nuclear energy. The US authorities took a number of measures designed to facilitate and encourage power generation by the existing power plants (whose activity had been, for a large number of them, extended) at the same time as investments in new power plants, sometimes from foreign investors. The plan to build a national disposal facility returned to the agenda.

However, after its installation, the Obama administration has decided not to continue on the selected path. The priority given to promoting renewable energies such as the mining of shale gas, the temporary abandonment of the Yucca Mountain project, the appointment of think tanks such as the "Blue Ribbon" commission, have encouraged private economic players, who in the US are the prime energy policy drivers, to adopt a cautious or wait and see attitude.

Several construction projects for new reactors, for which licensing applications had been filed with the Nuclear Regulatory Commission (NRC) in 2008 and 2009, are nevertheless under review. They specifically concern AREVA and EDF, candidates for the construction of EPR reactors for several American power generation companies.
II – Nuclear power generation in the United Kingdom

1 - Place of nuclear in the UK energy policy

The United Kingdom has 18 nuclear reactors in operation. In 2010, nuclear power accounted for 16 percent of power generation: the other sources are natural gas (46.3 percent), coal (28.5 percent), wind power (2.7 percent), hydroelectricity (0.95 percent) and other renewable energies, especially biomass (3.4 percent).

Nuclear represented 26 percent of power generation in 1997. The percentage then fell, due to the ageing of the fleet of reactors, and the loss of interest of investors, who turned as a priority in the 70s and 80s to hydrocarbon resources in the North Sea.

The depletion of hydrocarbon resources, the priority given to climate concerns, led to a change of policy from 2005 onwards. Two White Books (2007 and 2008) and several parliamentary reports recommended a return to nuclear, considered inevitable and urgent.

In 2008, the British government announced its intention to launch the construction of a new generation of reactors. The declared goal was to raise the percentage of nuclear energy in the UK’s power generation to 40 percent by 2050.

Achieving this goal requires the full renewal of existing nuclear facilities. The British fleet comprises reactors based on low performing and outdated technology (AGR, Magnox), a recycling plant (Sellafield) of uncertain reliability, while the problem of waste disposal remains unsolved.

Upgrading or developing the facilities for a genuine relaunch of the nuclear industry requires substantial investments. This has led to the need for industrial reconstruction, including resorting to foreign partners. It’s against this background that EDF, RWE and E.ON applied in 2008 for the acquisition of British power generation companies.

EDF completed the acquisition of British Energy in January 2009 for £12 billion to create a new company (EDF Energy) in which the British company CENTRICA (subsidiary of British Gas) acquired a stake of £2.5 billion. EDF-Energy (80 percent owned by EDF and 20 percent by CENTRICA), applied for the construction of four EPRs in the UK (two on the Hinkley site, and two on the Sizewell site).
At the same time, the Horizon group (RWE/E.ON) also applied for the construction of five to seven third generation reactors (EPR or AP.1000) on the sites of Oldbury and Wilfa.

The NuGeneration consortium (Iberdrola and GDF SUEZ) also applied for the construction of the Cumbria EPR.

After the May 2010 elections, the new British government confirmed its decision to promote the construction in the UK (excluding Scotland) of eight nuclear power plants comprising each at least two third generation reactors. The final sites have been chosen and the procedures for construction permits continue.

The Fukushima accident has not affected this decision.

2 – Condition of the nuclear fleet

The British fleet comprises several reactors:

- three Magnox-type reactors (Oldbury1, Wilfa 1 and 2) with a capacity of 217 MW (Oldbury) and two times 490 (Wilfa) commissioned respectively in 1967 and 1971, are scheduled for decommissioning in 2012.
- 14 AGR-type reactors (two on each of the Dungeness, Hartlepool, Hinkley Point, Hunterston, Torness sites, four on the Heysham site), commissioned between 1976 and 1989, are scheduled for decommissioning between 2016 and 2023.
- 1 PWR-type reactor (Sizewell), commissioned in 1995, scheduled to stay in operation until 2035.

The EDF Energy consortium, acquirer of British Energy facilities, runs the 14 AGR-type reactors and the Sizewell PWR reactor.

The Nuclear Decommissioning Authority (NDA), created in 2005 by the British government to manage the decommissioning of first generation power plants, and ensure the recycling of fuel and waste management, runs the Magnox reactors still in activity.

The upcoming shutdown of these facilities is driving the rapid launch of the construction of the planned new reactors.
The first project proposed by EDF Energy concerns the construction of two EPR reactors (1630 MW x 2) at Hinkley Point in Somerset. The construction was slated to begin in October 2011 and the power plant to be connected to the mains by late 2017. This calendar will probably change considering the slowness of the General Design Assessment (GDA) procedure. The first EPR reactor at Hinkley Point could start working in 2019. The two EPRs of Sizewell will probably be connected to the power mains between 2020 and 2022.

The Horizon consortium intends to file in 2012 construction permit applications for five EPRs or seven AP1000 on the sites of Oldbury and Wilfa. These reactors are expected to be commissioned between 2022 and 2025.

III – Generation of nuclear origin power in Germany

1 – Germany’s nuclear power policy and the share of nuclear in power generation

Previously, Germany’s energy policy gave a huge place to nuclear power, but in 2001, it (Schroder government) decided to slowly phase out nuclear energy. Mrs. Merkel’s government, which had started to overturn this decision, finally confirmed it in 2011 and even decided to speed up its implementation after the Fukushima disaster.

In early 2011, Germany had 17 nuclear reactors, providing 23 percent of national electricity. The other sources of power generation include coal (55 percent), wind (7 percent), hydroelectricity (4 percent) and solar (2 percent).

On 6 June 2011, the federal government decided to immediately decommission eight of the reactors (those in service since 1980 or before). The remaining nine reactors are scheduled for outage by 2022. This decision was approved by the Bundestag on 8 July 2011.

The decision immediately led to an energy shortage (6.4 percent reduction in installed capacity) offset by purchases from France and the Czech Republic but the goal of the federal government is to ensure in the long term, the replacement of nuclear by improved energy efficiency and an increase in the use of renewable energies. The percentage of renewable energy in power generation should increase in ten years from 17 percent (2010) to 35 percent (2020), to reach 80 percent in 2050. The federal government asserted its determination to maintain the goals previously set in CO2 emission reduction (40 percent less in 2020 over 1990, 80 percent less in 2050). To achieve this goal, the country is mostly focusing on
wind power (North Sea), encouraged by investment incentives (€5 billion support fund), and an energy consumption reduction policy.

At the same time, the federal government has decided to launch the construction of new gas power plants. There is also renewed debate about the possibility of relaunching energy generation based on "clean" coal.

The new energy policy is expected to impact power transmission and distribution, which will require the construction of more than 4,000 km of high tension lines.

2 – Condition of the nuclear fleet

In 2010, Germany generated 133 TWh of nuclear power over a total power generation of 590TWh.

The reactors in service at the beginning of 2011, with capacities ranging from 771 to 1360 MW were of several types: six boiling water reactors (BWR), 11 pressurized water reactors (PWR), all built by KWU, a subsidiary of Siemens (now part of AREVA).

Eastern Germany had built six WER technology reactors. After the reunification in 1990, those reactors were decommissioned and dismantled.

The current fleet of 17 reactors (as of 1 September 2011, the fuel had not been removed from the eight decommissioned reactors, and dismantling has not begun) is held by four private operators:

E.ON (merger of Veba and Viag) totally or partially owns nine reactors: Grafenheidfeld, Isar1, Isar2, Unterweser, Grohnde, Brokdorf, Kruemmel, Brunsbuettel, Gundremmingen, and Emsland;

RWE operates alone or in partnership the three reactors of Gundremmingen, Biblis, and Emsland

VATTENFALL, Swedish power utility (which owns in Sweden Ringhals and Forsmark) is the full or part owner of Brunsbuttel, Krummel and Brokdorf

EnBW operates the reactors of Neckarwestheim and Phillipsburg.
The operators have initiated judiciary proceedings and are involved in consultations with the government after the decision to decommission reactors belonging to them. They are fighting the levying of a compensatory tax on nuclear production by the federal government in September 2010, which had been previously introduced to compensate the extension of the lifecycle of power plants. They argue the additional cost represented by the accelerated dismantling of reactors and the lack of sufficient provisions to meet these costs.

IV – Nuclear power generation in Sweden

1 – Role of nuclear in power generation

Sweden has ten nuclear reactors in service. Nuclear provides 40 percent of the country’s power generation (the other sources are hydroelectricity (48 percent), fossil energies (10 percent) and wind power (2 percent).

Following the referendum held in 1980, the Swedish government had decided to interrupt the operation of all the nuclear reactors before 2010. In March 2002, the government renounced the date of 2010 for the abandonment of nuclear as planned in the referendum. Only two nuclear units of the Barseback power plant have been decommissioned (one in 1999, the other in 2005), partly because they are very close to Denmark and Copenhagen.

The lingering uncertainty about the future of nuclear power during the 2002-2009 period led to limited investments in this sector and a decline in the percentage of nuclear (which was 52 percent in 2004) in national power generation. In June 2010, the Swedish Parliament adopted a law that overturned the ban on building new power plants. The operating term of several power plants, planned for 25 years, was extended to 40. The power of several reactors was raised.

On 8 December 2010, the Vattenfall group indicated that they had launched a study of two new reactors, which could be coupled to the mains by 2020. The E.ON group would examine a comparable project.

2 - Situation of the electricity market

Despite the works undertaken since 2005 to raise the capacity of existing power plants, Sweden has been facing strong tensions on the electricity market for some years now. The capping of nuclear production and uncertainties about hydroelectric production have caused huge
shortages on the Swedish market, organized into pools between the Nordic countries.

In winter 2009/2010, the price of the MWh in the Nordpool market reached €1,400/MWh (35 times the "normal" price) with strong consequences on the paper industry. These tensions, which were solved by increasing imports from Finland, created or accentuated a favourable climate for raising investments in nuclear production, considered inevitable.

3 – Condition and productivity of the nuclear fleet

The ten reactors in service, on the sites of Ringhals, Forsmark, and Oskarshamn, are BWR types (seven boiling water reactors) and PWR (three pressurized water reactors).

Three operators manage the fleet: Vattenfall, E.ON and FORTUM (Finnish group). The Swedish nuclear fleet suffers from low availability, one of the lowest in Europe (63 percent), a result of poor maintenance investments over the last decade.

Today, the political context allows the construction of new reactors, but the Swedish government has stated in principle before the three operators that no public aid would be given to fund the construction of new power plants.

The funding is expected to be provided in the context of an agreement with major clients from power-hungry industries. Negotiations were made in 2011, for this purpose with the Industrikkraft consortium.

IV – Nuclear power generation in Belgium

1 – Role of nuclear in power generation and condition of the fleet

Belgium has seven nuclear reactors, which supply 54 percent of the national electricity production (46 billion kWh), versus 28 percent for natural gas (24 billion for kWh) and 9 percent for coal (7 billion kWh), with the rest provided by renewable energies.

Belgium's nuclear fleet comprises four PWR reactors with a total power of 2839 MW at DOEL, and three PWR reactors with total power of 2985 MW, at Tihange.

The Belgian government's policy towards nuclear power has been through radical changes recently. In 1999, an AMPERE commission was created with the goal of studying the country's energy future and the alternatives to nuclear power. The commission's report, submitted in 2000
concluded on the need to maintain the nuclear effort, while developing other sources of energy.

However, after a long political debate, the Belgian Parliament adopted on 31 January 2003, a Federal law which bans the construction of new power plants and limits the operation of existing power plants to 40 years, such that the last power plant would stop operating in 2025.

An energy commission, created in 2007, proposed a partial overturn of these orientations, by stressing that nuclear power was vital for allowing Belgium to comply with European goals with respect to limiting greenhouse gas emissions. The government announced that it would submit amendments to allow the extension of the life of several power plants. Due to the political crisis which followed the April 2010 elections, the process could not be continued; the legal position remains the scheduled outage of all power plants, staggered between 2015 and 2025; the new Belgian government recently indicated that this schedule would be re-examined.

The Fukushima accident rekindled debate in Belgium about the future of nuclear power. A decision will be taken after a new government is formed.

2 - Organization of production

Nuclear origin power is generated by two main license holders:

- Electrabel, subsidiary of GDF SUEZ, owns 50 percent of the Tihange 1 reactor, 89.8 percent of Tihange 2 and 3, 100 percent of Doel 1 and 2, and 89.8 percent of Doel 3 and 4;

- EDF owns the outstanding 50 percent of Tihange 1.

Through SPE (in which it holds a 51 percent stake since 2009), EDF also owns 10.2 percent of Tihange 2 and 3 and Doel 3 and 4.

The Commission de Régulation de l’Electricité et du Gaz (CREG – Belgian Commission for Regulation of Electricity and Gas) is the central body for regulating the operation of the Belgian electricity market. It specifically audits the accounts of utilities and ensure their transparency. Recently, the CREG imposed a fine of €100,000/day on Electrabel for non disclosure of data on nuclear production cost, information considered vital for calculating the "nuclear revenue" obtained by the operator. Electrabel has filed an appeal to overturn this sanction.
II – Nuclear power generation in Japan

1 - Place of nuclear in the Japanese energy policy: condition of the fleet

Japan launched an ambitious policy to develop civilian nuclear power in the 1950s as a solution to the country's shortage of energy resources.

The programme was launched in 1954, after the adoption of a law imposing the limitation of research and investments to a peaceful use of the atom.

Japan invested in the construction of British (GEC) then American (Westinghouse, General Electric) technology power plants. This policy continued despite the misgivings of a portion of public opinion, strengthened by a number of accidents, especially seismic, which led to the outage of several reactors in the 1970s and 1980s. Japanese authorities, and the power generating companies, invested massively in anti-seismic technologies, while continuing an ambitious programme of building power plants, a recycling plant, based on the reasoning that the country had no other choice since 80 percent of its energy (and which without nuclear, would be 96 percent) was imported.

In the beginning of 2011, on the eve of the Fukushima disaster, Japan had 55 nuclear reactors. Nuclear energy represented 11.4 percent of its energy mix and 30 percent of electricity production (versus 60 percent for gas/oil and 10 percent for hydroelectricity).

The new national strategy for energy, defined in 2006 by the METI, planned on the construction of 11 new power plants (two of which were under construction early 2011). The goal was to raise the portion of nuclear energy in power generation to 50 percent by 2030.

This programme relied on powerful groups (Toshiba, MHI and Hitachi) which, using imported technologies, then purely Japanese ones, had developed during the last two decades, an industrial and technological potential which made Japan a first-class nuclear power.
Nine operators share the country's nuclear power generation, using a fleet that is not very homogenous, composed of:

- Hokkaido Electric Power Co (HEPCO) Six PWRs
- Tohoku Electric Power Co (Tohoku Electric) Seven BWRs
- Tokyo Electric Power Co (TEPCO) 15 BWRs Two ABWRs
- Chubu Electric Power Co (CHUDEN) Four BWRs One ABWR
- Hokuriku Electric Power Co (Rikuden) One BWR One ABWR
- Kansai Electric Power Co (KEPCO) 11 PWRs
- Chugoku Electric Power Co (Energia) Two BWRs
- Shikoku Electric Power Co (Yonden) Three PWRs
- Kyushu Electric Power Co (Kyushu Electric) Six PWRs

plus

- Japon Atomic Power Company which manages Two BWs
  One GCR
  One PWR

After the 11 March 2011 accident in Fukushima, the Japanese Government decided to dismantle six reactors from the Fukushima 1 power plant, where one had already been stopped. It decreed for the 1st time "a nuclear state of emergency". 140,000 residents were evacuated within a radius of 20 kilometres. The Hamaoka nuclear power plant was closed in May, considering the high seismic risk existing on the site. Other power plants were stopped for servicing or safety tests. In October 2011, only 11 nuclear power plants were in operation. A White Book, approved by the Japanese Government on 28 October, observed that the "public's confidence in nuclear energy had been shaken". The Japanese government announced its intention to "reduce Japan's dependency on nuclear power".

2 - Organization of power generation and distribution

A reform introduced from 1995 deregulated the Japanese electricity market in stages. Power generating companies, which organize their activity on the basis of territorial sharing, operate on a more competitive mode. The regulation for tariffs became more flexible. 60 percent of the electricity market had been deregulated at the end of 2010.
3 – The situation after the Fukushima accident

It is too early to know the consequences in terms of cost of the
Fukushima accident on other Japanese power plants. We must distinguish
between several levels:

− the measures immediately requested by the Safety Agency from
  operators, end March, are inexpensive (purchase of additional
  generator trucks and pump trucks, additional protections against
  tsunamis);

− long-term measures concerning a number of power plants vulnerable
  to tsunamis, to be implemented within two or three years, will be
  more costly in works and civil engineering structures;

− the stress test decided since then will probably lead to expenditures to
  bolster protections, the cost of which has not yet been assessed.
Annex 18: the dismantling of nuclear power plants
International comparisons

A – Report by La Guardia – 2009

As part of the Dampierre 09 exercise, EDF ordered an audit from the La Guardia auditing firm, which in the United States is specialized in the evaluation of dismantling costs. EDF requested a quotation for the theoretical dismantling of a site with two PWR 1 150 MW units and by comparing it to that of DA09. The study was made on a like-for-like basis by restating the results of the DA 09 study to go from four units to two then one. EDF did not take the power difference into account as it considers that it is immaterial with respect to the level of precision required. The calculations of La Guardia give a very narrow difference with the Dampierre 2009 evaluation.

Results of the La Guardia study ordered by EDF

<table>
<thead>
<tr>
<th></th>
<th>Two PWR units</th>
<th>One PWR unit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With</td>
<td>Without</td>
</tr>
<tr>
<td></td>
<td>contingencies</td>
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</tr>
<tr>
<td>DA 09</td>
<td>855.7</td>
<td>777.9</td>
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<tr>
<td>Theoretical US</td>
<td>844.5</td>
<td>692.5</td>
</tr>
</tbody>
</table>

Source: Cour des Comptes- EDF Data

(1) : 10 percent for EDF - 18 percent for the US power plant

B – Available international comparisons

The calculations made by the Cour des Comptes consisted, as far as possible, in comparing the foreign gross dismantling costs to a cost in €2010 per installed MW, then considering the latter as the reference cost to be used as a baseline in accordance with the method used by EDF. The reference value amounts to €2010291/MW for the 58 PWRs in service, i.e., €201018.1 billion.

The huge discrepancies in scope have been corrected as far as possible with available information, and where there was not such information, the Cour des Comptes made the arbitrary choice of using available data, namely those of EDF to adjust the scopes.

The Cour des Comptes analysed the reactor dismantling costs of six countries, namely Germany, Belgium, Japan, United Kingdom, Sweden and USA with sometimes several evaluations available by country and applied to the EDF's PWR fleet in service.
1 - Comparison with Germany

There are three possible evaluations in the German case. Available amounts were brought down to a reference cost by MW. The baseline retained for power is that of 17 reactors of the German nuclear fleet still in operation, but which were stopped after Fukushima (eight reactors including five PWRs) or should be around 2022 according to the nuclear phase-out law of 2011 (nine reactors of which seven PWRs), i.e., an aggregate power of 20,464 MW, and on average, 1,203 MW.

Generally, and until recently, the dismantling cost of a PWR, was evaluated in Germany, by operators EnBW, E.ON, RWE and Vattenfall, at €500 million, excluding waste and spent fuel management, especially excluding temporary storage buildings on site, and without a specific dismantling schedule. The reference cost would amount to €415/kW.

Since the decision taken after Fukushima to phase out nuclear energy, E.ON has significantly adjusted its quotations upwards and announces, regardless of the technology of reactors, an amount of €1.1 billion, including the cost of spent fuel management, contrary to the previous evaluation. To correct this difference, a rough calculation consisting in comparing EDF’s spent fuel management cost (€201014.38 billion) to a PWR, i.e., €248 million would allow the comparison. The German cost to be compared to EDF’s evaluation would then be €2010 852 million. The reference cost would then amount to €707/kW.

Furthermore, the total dismantling cost for 17 reactors was estimated by the Arthur D.Little consulting firm in September 2011 at €18 billion and for a reactor between €670 million and €1.2 million, depending on the installation and without taking account of the permanent disposal of wastes. The reference cost would then be in a range of €556/kW to €996/kW. Compared to EDF’s fleet, gross dismantling costs would then be as follows.

**Application of the results of the German studies to EDF’s fleet**

<table>
<thead>
<tr>
<th>In 2010 € billion</th>
<th>Application of results to EDF’s 58 reactors</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDF evaluation</td>
<td>The 1st evaluation of German operators</td>
</tr>
<tr>
<td>at reference cost</td>
<td>2nd evaluation of E.ON</td>
</tr>
<tr>
<td>€18.1 billion</td>
<td>€25.8 billion</td>
</tr>
</tbody>
</table>

*Source: Cour des Comptes*
2 - Comparison with Japan

Japan has 54 reactors of which 24 BWRs and 30 BWRs (boiling water reactors) for an aggregate power of 27,537 MW, or average power of 510 W.

The estimated cost for dismantling a BWR reactor, at end 2009 was, according to the operators, 42.2 billion yen, excluding spent fuel and waste management, i.e. €2010\[240\]319.6 million or €626/kW.

On the basis of Japanese costs, the dismantling cost for the 58 reactors of the EDF fleet would therefore amount to €2010\[38.9\] billion, to be compared to the €2010\[18.1\] billion retained by EDF.

However, the cost of dismantling the four damaged BWR technology reactors of Fukushima, estimated late September 2011 by the "administrative and financial investigation commission", created especially to deal with the case of TEPCO, the operator, would amount to 1,150 billion yen for one reactor, i.e., €2.7 billion\[241\]. But this estimate is not comparable to the estimate for a non damaged reactor, because the Fukushima reactors will have to be dismantled in particularly harsh contamination conditions.

3 – Comparison with the United States

The range of dismantling costs for the BWR reactor of Maine Yankee, with a power of 830 MW is quite accurately estimated thanks to three available evaluations. Compared to the situation observed in France, four elements specific to the United States limits the scope of the comparison:

– the existence of a release threshold in the United States helps to limit the volume of waste generated and the safety procedures to be implemented to deal with the volumes concerned;

– the use of explosives to destroy the upper sections of buildings, limiting the use of specialized equipment, which is more expensive;

\[240\]At the 31 December 2009 rate, or €0.0075 for 1 JPY. At the economic conditions of 2009, in other words with a reference cost of €286/kW (EDF source), the average non-discounted cost of dismantling a BWR reactor in service from EDF's fleet would be €2009\[306.7\] million.

\[241\]At the rate of 29 September 2011, or €0.0095 for 1 JPY and inflated from 2009 to 2010.
the duration of dismantling could be limited to eight years, from 1997 to 2005, while in France, the duration for dismantling a unit is estimated at fifteen years;

- on the contrary, during dismantling, the company in charge of operations defaulted due to funding problems and the operator had to continue alone, which meant it had to bear higher costs.

The three American evaluations of dismantling costs for Maine Yankee are as follows:

- that of TLG Services, project owner assistant, in charge of evaluating and checking the dismantling costs of the three power reactors between 1995 and 2005: USD$_{1997}$ 343.6 million for dismantling only or again USD$_{2004}$446 million$^{242}$;

- the evaluation of the Federal Energy Regulatory Commission (FERC): USD$_{2003}$ 752.2 million of which USD$_{2003}$525.7 million of actual expenditures for the 1997 to 2003 period;

- the evaluation of the Electric Power Research Institute (EPRI), an independent energy and environmental research body: USD 558 million at the end of 2004.

**Evaluations of dismantling costs for the Maine Yankee reactor (economic conditions 2004$^{243}$)**

<table>
<thead>
<tr>
<th>Origin of studies</th>
<th>TLG Services</th>
<th>FERC</th>
<th>EPRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{2004}_{\text{million}}$</td>
<td>446.1</td>
<td>545.6</td>
<td>558</td>
</tr>
<tr>
<td>€$^{2004}_{\text{million}}$</td>
<td>329.1</td>
<td>402.5</td>
<td>411.6</td>
</tr>
<tr>
<td>€$^{2010}_{\text{million}}$</td>
<td>365</td>
<td>446.4</td>
<td>456.5</td>
</tr>
</tbody>
</table>

*Source: Cour des Comptes*

The corresponding reference costs would therefore amount respectively to €439.7/kW, €537.8/kW and €550/kW. Compared to EDF’s fleet, the gross dismantling costs would be:

---

$^{242}$Basis: coefficient of inflation retained by NRC of 3.8 percent per annum

$^{243}$Bases: coefficient of inflation retained by the NRC of 3.8 percent per annum and exchange rate €1.3555/$ at 31 December 2004
Application of the results of the US studies to EDF’s fleet

<table>
<thead>
<tr>
<th>In 2010 € billion</th>
<th>Application of results to EDF’s 58 reactors</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDF evaluation at reference cost</td>
<td>TLG Services</td>
</tr>
<tr>
<td>€18.1 billion</td>
<td>€27.3 billion</td>
</tr>
</tbody>
</table>

Source: Cour des Comptes

4 – Comparison with Belgium

The fleet of Belgian reactors in service comprises seven PWR technology nuclear units distributed on the sites of Tihange and Doel, operated by Electrabel from the GDF SUEZ group for aggregate power of 5,926 MW.

The dismantling costs for the three PWR reactors of the Tihange power plant are evaluated by the operator at €2006 1,069 million, or €2010 1,139 million and those of the four reactors of the Doel reactor amount to, according to ONDRAF (excluding waste management facilities) to €2009 1,182 million, or €2010 1,191.6 million.

The reference cost should therefore amount to €393.2/kW and compared to EDF’s fleet, the gross dismantling costs would amount to €2010 24.4 billion.

5 – Comparison with Sweden

The costs of dismantling three PWRs of the Ringhals power plant with an aggregate power of 2,799 MW and 933 MW on average, operated by RAB, are evaluated by a private company used by all operators, SKB.

The following table presents the discounted dismantling costs of the three reactors, calculated at the economic conditions of January 2010 by SKB which performs this operation by extrapolating the estimated costs for the Barseback 1 and 2 reactors powered by BWR technology. The adopted price is that of 31 December 2009.
Evaluation of the discounted dismantling costs of Ringhals reactors by SKB

<table>
<thead>
<tr>
<th></th>
<th>Ringhals 2</th>
<th>Ringhals 3</th>
<th>Ringhals 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>In SEK 2009 million</td>
<td>1 513</td>
<td>1 459</td>
<td>1 520</td>
</tr>
<tr>
<td>In € 2009 (1) million</td>
<td>147.5</td>
<td>142.2</td>
<td>148.2</td>
</tr>
<tr>
<td>In € 2010 million</td>
<td>148.7</td>
<td>143.3</td>
<td>149.4</td>
</tr>
</tbody>
</table>

Source: Cour des Comptes

(1) : €1 = SEK 10,2561

Thus, the estimated cost for dismantling three reactors with a total power of 2,799 MW is €2009 441.4 million, i.e., € 157.6 /kW. This amount cannot be taken as a reference cost because it has been discounted to present value, it must therefore be compared to the aggregate installed power for the 58 French reactors, 63,130 MW, or €2010 9.9 million corresponding to roughly €20 billion of gross costs.

6 - Comparison with the United Kingdom

Several inputs call for caution when comparing French and British estimates, with respect to the dismantling of power plants:

- the British fleet is primarily composed of GCR type (gas cooled, graphite moderated reactor) reactors which have a structurally higher dismantling costs; their design requires more materials and highly complex structures, therefore leading to a significant increase in the volumes to be disposed off and the operations to implement, and subsequently the costs;

- the average power of decommissioned reactors, for which the dismantling costs was estimated by the Nuclear Decommissioning Authority (NDA), totals 182 MW by reactor; it corresponds to 582 MW by reactor for the British Energy (BE) power plants while the average net power for the 58 French reactors is 1,072 MW;

- in Great Britain, there are plans to build on-side disposal facilities for irradiated fuels for a hundred or more years;

- the dismantling schedules and the number of power plants between the two countries are different. The large number of French reactors
(58) reduces their unit dismantling costs compared to the 15 British reactors in service;

- we must distinguish between British power plants: those that have been decommissioned and are managed by the Nuclear Decommissioning Authority created in 2005, in charge of cleaning up and dismantling all existing British nuclear facilities at the time of its creation or depending on whether they are operated by British Energy. We must therefore take British Energy power plants into consideration as well.

If, despite all the reservations linked to technical distortions, discounting, organizations and scopes, we still want to compare French and British evaluations of discounted dismantling costs per MW, we must first distinguish between the decommissioned facilities managed by the NDA and secondly, the power plants in service managed by British Energy, whose dismantling is funded by the NLF (Nuclear Liabilities Fund).

6.1 : Decommissioned power plants (or in the process in 2012) and the Nuclear Decommissioning Fund of the Nuclear Decommissioning Authority

When we analyse the cost breakdown presented by the NDA, it appears that the highest costs are not related to the power plants but to other nuclear facilities. For example, Sellafield represents 52 percent of identified costs. To compare to EDF, we should therefore consider power plants only, or £10 billion in discounted value.

Furthermore, the publications of the NDA (e.g.: 2006 and 2011 strategic reports) increase decommissioning costs, operations costs but include as well commercial revenues which significantly reduce the amount of costs.
Decommissioned facilities in the NDA's scope

<table>
<thead>
<tr>
<th>Name</th>
<th>Type of activity</th>
<th>Number of reactors</th>
<th>Type of reactor</th>
<th>In service</th>
<th>Overall power MW</th>
<th>Power by reactor MW</th>
<th>Demanding costs – discounted value 2009-2010 annual report – £ million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sellafield Windscale</td>
<td>Power plant</td>
<td>1</td>
<td>GCR</td>
<td>No</td>
<td>24</td>
<td>987.00</td>
<td>987.00</td>
</tr>
<tr>
<td>Berkeley</td>
<td>Power plant</td>
<td>1</td>
<td>GCR</td>
<td>No</td>
<td>138</td>
<td>608.00</td>
<td>608.00</td>
</tr>
<tr>
<td>Bradwell</td>
<td>Power plant</td>
<td>2</td>
<td>GCR</td>
<td>No</td>
<td>123</td>
<td>724.00</td>
<td>724.00</td>
</tr>
<tr>
<td>Chapelcross</td>
<td>Power plant</td>
<td>4</td>
<td>GCR</td>
<td>No</td>
<td>48</td>
<td>804.00</td>
<td>804.00</td>
</tr>
<tr>
<td>Dungeness A</td>
<td>Power plant</td>
<td>2</td>
<td>GCR</td>
<td>No</td>
<td>225</td>
<td>879.00</td>
<td>879.00</td>
</tr>
<tr>
<td>Berkeley Dounreay</td>
<td>Power plant</td>
<td>7</td>
<td>GCR</td>
<td>No</td>
<td>130</td>
<td>886.00</td>
<td>886.00</td>
</tr>
<tr>
<td>Sellafield Calder hall</td>
<td>Power plant</td>
<td>4</td>
<td>GCR</td>
<td>No</td>
<td>49</td>
<td>671.00</td>
<td>671.00</td>
</tr>
<tr>
<td>Berkeley Dounreay</td>
<td>Power plant</td>
<td>1</td>
<td>GCR</td>
<td>No</td>
<td>117</td>
<td>348.00</td>
<td>348.00</td>
</tr>
<tr>
<td>Berkeley Dounreay</td>
<td>Power plant</td>
<td>2</td>
<td>GCR</td>
<td>No</td>
<td>220</td>
<td>516.00</td>
<td>516.00</td>
</tr>
<tr>
<td>Berkeley Dounreay</td>
<td>Power plant</td>
<td>3</td>
<td>GCR</td>
<td>No</td>
<td>220</td>
<td>516.00</td>
<td>516.00</td>
</tr>
<tr>
<td>Berkeley Dounreay</td>
<td>Power plant</td>
<td>4</td>
<td>GCR</td>
<td>No</td>
<td>220</td>
<td>516.00</td>
<td>516.00</td>
</tr>
<tr>
<td>Wylfa</td>
<td>Power plant</td>
<td>2</td>
<td>GCR</td>
<td>Yes</td>
<td>240</td>
<td>916.00</td>
<td>916.00</td>
</tr>
<tr>
<td>Central costs North &amp; South</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>23</td>
<td>4 182.00</td>
<td>4 182.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>859.00</td>
<td>859.00</td>
</tr>
<tr>
<td>Sellafield Windscale</td>
<td>Manufacture and recycling of fuel, disposal of radioactive waste and used materials</td>
<td></td>
<td></td>
<td>No</td>
<td>225</td>
<td>2 357.00</td>
<td>2 357.00</td>
</tr>
<tr>
<td>Sellafield Calder hall</td>
<td>Power plant</td>
<td>1</td>
<td>GCR</td>
<td>No</td>
<td>330</td>
<td>1 357.00</td>
<td>1 357.00</td>
</tr>
<tr>
<td>Sellafield Capenhurst</td>
<td>Separation and mixed activities</td>
<td>4</td>
<td>GCR</td>
<td>No</td>
<td>420</td>
<td>1 645.00</td>
<td>1 645.00</td>
</tr>
<tr>
<td>Harwell</td>
<td>Research</td>
<td>5</td>
<td>GCR</td>
<td>No</td>
<td>220</td>
<td>2 388.00</td>
<td>2 388.00</td>
</tr>
<tr>
<td>Winfrith</td>
<td>Research</td>
<td>6</td>
<td>GCR</td>
<td>No</td>
<td>220</td>
<td>2 388.00</td>
<td>2 388.00</td>
</tr>
<tr>
<td>LLWR</td>
<td>Disposal of low-level waste</td>
<td>1</td>
<td>GCR</td>
<td>No</td>
<td>92</td>
<td>796.00</td>
<td>796.00</td>
</tr>
<tr>
<td>Springfield</td>
<td>Manufacturing of fuel</td>
<td>2</td>
<td>GCR</td>
<td>No</td>
<td>187</td>
<td>290.00</td>
<td>290.00</td>
</tr>
<tr>
<td>Decontamination</td>
<td>Treatment and disposal</td>
<td>1</td>
<td>GCR</td>
<td>No</td>
<td>92</td>
<td>187.00</td>
<td>187.00</td>
</tr>
<tr>
<td>HEALTH &amp; SAFETY</td>
<td>Safety of nuclear installations</td>
<td>2</td>
<td>GCR</td>
<td>No</td>
<td>2</td>
<td>2 785.00</td>
<td>2 785.00</td>
</tr>
<tr>
<td>total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>28</td>
<td>2 873.00</td>
<td>2 873.00</td>
</tr>
<tr>
<td>total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15</td>
<td>6 213.00</td>
<td>6 213.00</td>
</tr>
<tr>
<td>total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>23</td>
<td>11 086.00</td>
<td>11 086.00</td>
</tr>
<tr>
<td>total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>45</td>
<td>45 023.00</td>
<td>45 023.00</td>
</tr>
</tbody>
</table>


To reach the figure advanced by the French press\(^\text{244}\) of €2006 100 billion (£70 billion), the following costs, dating from 2006, were compiled:

- £62.7 billion (gross value)\(^\text{245}\) which correspond to the sum of £48.5 billion of decommissioning and clean-up costs + £14.2 billion (gross value) of operations costs. These are gross amounts.
- The NDA then converts the costs to present value at a rate of 2.2 percent but are, net of commercial revenues which nearly make up for the amount of current costs and capex (operations costs). In

\(^{244}\) Internet articles: Nouvel Observateur – 1\(\text{st}\) June 2011 - Les Echos – 8 September 2011
\(^{245}\) Rapport stratégique NDA 2006 p115
2006, the final amount totalled £35.6 billion and not £62.7 billion; £7.5 billion of R&D funded by the NDA, LLW (low-level waste) disposal costs and contingency costs for the long-term management of contaminated land.\(^{246}\)

The table below, extracted from the NDA’s strategic document of April 2011, details the updates of these discounted costs:

<table>
<thead>
<tr>
<th>Sites</th>
<th>Decom &amp; Clean-up Costs</th>
<th>Commercial Revenue</th>
<th>Net Running Cost</th>
<th>Government Funding</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SLCs</strong></td>
<td><strong>A</strong></td>
<td><strong>B</strong></td>
<td><strong>C</strong></td>
<td><strong>D = (B-C)</strong></td>
</tr>
<tr>
<td>Magnon Limited</td>
<td>Magnox Support</td>
<td>£154</td>
<td>£23</td>
<td>£151</td>
</tr>
<tr>
<td></td>
<td>Bradwell</td>
<td>£605</td>
<td>-</td>
<td>605</td>
</tr>
<tr>
<td></td>
<td>Bradwell</td>
<td>-</td>
<td>-</td>
<td>724</td>
</tr>
<tr>
<td></td>
<td>Sizewell</td>
<td>£822</td>
<td>-</td>
<td>822</td>
</tr>
<tr>
<td></td>
<td>Dungeness A</td>
<td>£875</td>
<td>17</td>
<td>99</td>
</tr>
<tr>
<td></td>
<td>Heysham Point A</td>
<td>£175</td>
<td>-</td>
<td>175</td>
</tr>
<tr>
<td></td>
<td>Hunterston A</td>
<td>£132</td>
<td>-</td>
<td>132</td>
</tr>
<tr>
<td></td>
<td>3rd Sury</td>
<td>£954</td>
<td>129</td>
<td>954</td>
</tr>
<tr>
<td>Research Sites Restoration Limited</td>
<td>Harwell and Winfrith</td>
<td>£1,203</td>
<td>-</td>
<td>1,203</td>
</tr>
<tr>
<td>Friction</td>
<td>£164</td>
<td>29</td>
<td>-</td>
<td>29</td>
</tr>
<tr>
<td><strong>NDA Central Liabilities &amp; Group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electricity Sales</td>
<td>£3.767</td>
<td>-</td>
<td>3,767</td>
</tr>
<tr>
<td></td>
<td>NDA Total</td>
<td>£45,083</td>
<td>8,026</td>
<td>9,079</td>
</tr>
</tbody>
</table>

We should therefore be cautious about the scope of costs to be taken into consideration: either only identified costs such as "decommissioning and clean-up" costs, or both plus "operations costs" but adjusted to reflect "commercial revenues".

---

\(^{246}\) NDA 2006 strategic report, p 6.
The discounted cost\(^{247}\) in the United Kingdom amounts to £2.4 million/MW\(^{248}\), i.e., €2.78 million/MW. Compared to the power of the nine decommissioned French power plants (3,659 MW with various technologies), the cost would reach €10.1 billion. Currently, for these nine reactors with total installed power of 3,659 MW (among eleven decommissioned installations), EDF’s provisions amount to €1.8 billion plus another €1.5 billion, or €3.3 billion, which represents a unit cost of €0.9 million/MW.

6.2: British Energy’s power plants in service and the Nuclear Liabilities Fund (NLF)

The table below presents the dismantling costs, in present value, of British Energy’s power plants in service.

<table>
<thead>
<tr>
<th>Plant name</th>
<th>Type of reactor</th>
<th>Number of reactors</th>
<th>Overall power MW</th>
<th>Present value of dismantling costs (€M, March 2010)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dungeness B</td>
<td>GCR</td>
<td>2</td>
<td>1040</td>
<td></td>
</tr>
<tr>
<td>Hartlepool A</td>
<td>GCR</td>
<td>2</td>
<td>1190</td>
<td></td>
</tr>
<tr>
<td>Heysham A</td>
<td>GCR</td>
<td>2</td>
<td>1160</td>
<td></td>
</tr>
<tr>
<td>Heysham B</td>
<td>GCR</td>
<td>2</td>
<td>1240</td>
<td></td>
</tr>
<tr>
<td>Hinkley point B</td>
<td>GCR</td>
<td>2</td>
<td>840</td>
<td></td>
</tr>
<tr>
<td>Hunterstone B</td>
<td>GCR</td>
<td>2</td>
<td>860</td>
<td></td>
</tr>
<tr>
<td>Sizewell B</td>
<td>PWR</td>
<td>1</td>
<td>1188</td>
<td></td>
</tr>
<tr>
<td>Torness</td>
<td>GCR</td>
<td>2</td>
<td>1205</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>8723</td>
<td>3934</td>
</tr>
</tbody>
</table>


The NLF provides funding for the future decommissioning costs of BE’s power plants. It covers the decommissioning of the facilities, in addition to spent fuel and waste management operations. It excludes (i) spent fuel management costs, stemming from historic contracts prior to the creation of this structure, which will be directly financed by the UK

\(^{247}\)The NDA's discounted rate, inflation excluded is 2.2 percent, that of the NLF 3 percent and that of EDF nearly 3 percent.

\(^{248}\)£ 10 billion/4,182 MW; exchange rate: €/£1.16/ as of 31 December 2010.
government and (ii) the costs for spent fuel management to be contracted which will continue to be borne by BE.

The evaluation, discounted at 3 percent of these costs relating to BE’s power plants in service amounts to €3.9 billion\(^{249}\) for the year ended 31 March 2010.

The discounted value in the United Kingdom therefore amounts to £0.45 million/MW\(^{250}\), or €0.5 million/MW on the basis of end March 2010 data. This amount cannot be taken as the reference cost since it is discounted, it must therefore be compared to the aggregate installed power for the 58 French reactors, i.e., 63,130 MW\(^{251}\), or €31.8 billion\(^{252}\). But it includes spent fuel and waste management costs. To correct this scope, a calculation consisting in comparing the EDF provisions for spent fuel transportation and recycling costs, for the evacuation and disposal of wastes stemming from the decommissioning and the back end portion of provisions for last core, can be used to make the comparison more pertinent. The discounted cost, established on the basis of UK costs thus corrected would be €23.3 billion for the 58 reactors, i.e., roughly €46 billion of gross costs, to be compared to the €18.1 billion estimated by EDF.

\(^{249}\) Source: Nuclear Liabilities Fund Annual report March 2010, pp 4 and 32.

\(^{250}\) £3,934 million/8723MW

\(^{251}\) Source: Elecnuc – “Les centrales nucléaires dans le monde”- 2010 edition- CEA

\(^{252}\) Exchange rate as of 31/12/2009: £1 corresponded to €1.126 and inflated between 2009 and 2010.
Annex 19: Funding and coverage of future costs – International comparisons

In the United States: differentiated funding for spent fuel disposal and for dismantling

Funding for spent fuel disposal costs

In the United States, the Nuclear Waste Fund was created in 1982 by Congress (Nuclear Waste Policy Act) which laid down the principle that the users of power generated by nuclear energy should finance the management costs of spent nuclear fuel. So, a tax initially set at 0.1 cent per kWh used, was levied to feed the fund, between 1983 and 2010. The fund now has a total amount ranging between $21 billion and $25 billion for the retained scope. In 2010, the fund received total revenues of $750 million from the tax.

The fund was created with the intention of building a permanent disposal site in Yucca Mountain in 1998. However, the opening has been delayed on several occasions and now the very principle is controversial.

Furthermore, from 1987 onwards, the conditions for using this fund were changed: the resources from the tax are now assigned to the federal budget and the site's development programme must therefore obtain its funding from the budget every year.

So, as recently observed by Blue Ribbon, the commission created in the US in 2010 to examine the future of US nuclear energy, the programme is subject to budget constraints and uncertainties "which the creation of the fund was supposed to avoid". It recommended that the revenues currently collected by the Federal State should be directly assigned to the funding of the waste management programme and that the Nuclear Waste Fund whose funds are currently considered as revenue for the federal budget should be given autonomous management. The related expenditures would therefore not be contingent on annual budget authorizations, even if it means raising the margin of the US budget deficit. It considered these measures as urgent, pointing out that each year of delay raises its potential cost by approximately $500 million.
We have no details about the investments of the Nuclear Waste Fund. Until 1999, the sums were invested in US treasury bonds. The federal budget for 2009 indicated interest revenues of $1,173 million for an amount of $21,542 million.

**Funding for dismantling costs**

The Nuclear Regulatory Commission\(^\text{253}\) (NRC) requires nuclear reactor operators to report every two years at least on the funds accrued to fund the dismantling of facilities. When the facility is in the last five years of its license or five years away from scheduled decommissioning, the reports are required every year.

Operators have several options for demonstrating the financial feasibility of dismantling:

- pre-payment: they can make a deposit in the early stages of the dismantling operation on a dedicated fund separate from their accounts;
- the guarantees of a related company, insurance or collaterals: this is a guarantee, in different legal form, that the dismantling cost will be borne by another entity in case the operator defaults;
- a disaster fund: it's a separate account, external to the operator's accounts, intended to receive, over the years, funds for the dismantling, in the event where the operator recovers the sums from the public (through rate making regulation or non-bypassable charges).

There is no available data on the current level of funds accumulated for this purpose. It is possible that the ongoing extension of the durations of operation as well as the five year deadline granted before the final shutdown to accrue the funding for the dismantling operation tends to lighten the burden felt by American operators.

This funding system is therefore less restrictive than the French system; however, it does not indicate how the immediate dismantling of a facility would be funded if it were to be decommissioned earlier than planned.

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\(^{253}\): US equivalent of the French *Autorité de Sûreté Nucléaire*
In Sweden

In Sweden, a financial contribution is due by each operator under the nuclear power programme's dismantling funding. It ranges between 0.11 and 0.22 eurocents by kWh.

Since 1996, two funding regimes have been successively in force: first the provisions and contributions were managed in a decentralized manner by the operators and second, the funds were outsourced and a public organization was appointed to manage them. The funds were deposited on an account with the Central Bank which must remunerate them at a 4 percent rate of return until 2020 (money-market rates) and 2.5 percent afterwards.

The operators cannot use these resources save for the purpose of reimbursing expenses incurred to cover dismantling or waste treatment operations.

In Germany

- With respect to the funding of dismantling expenditures, the German law on nuclear energy stipulates that operators should warrant that they are capable of releasing funds, for the full amount of the provisions accrued on an annual basis, when the dismantling operations begin.

  The development of an external and independent fund fed by the operators has been planned but has not been adopted so far. The operators are currently free to use the financial resources of the accrued provisions for their investment operations. The provisions are not necessarily hedged by financial assets.

- With respect to the funding for waste treatment, the works are funded by the generators of wastes. Every year, the federal office for radiation protection levies a prefunding tax on generators of radioactive wastes, for the construction of two disposal sites (Gorleben and Konrad). The expenditures are billed to them at the end of the year and include R&D expenditure for each site, expenditures for the acquisition of land, planning, exploration, construction and maintenance.
In the United Kingdom

*Financing for dismantling: an £ 8 billion fund for British Energy's reactors*

The Nuclear Liabilities Fund or NLF was created in March 1996, during the privatization of British Energy. The purpose of the Fund is to finance the final dismantling of eight nuclear reactors as well as the costs linked to the long-term management of spent fuel from these power plants.

The Fund received an initial endowment from the government of £228 million. British Energy was then required to make subsequent payments of £4 million pounds into the fund every quarter. Until the company was acquired by EDF in January 2009, the Fund could receive each year a share (65 percent) of the company's free cash flow.

The Fund had also received the company's stock as an endowment. It subsequently sold 28 percent of the stock on the market, thereby obtaining an additional sum of €2.3 billion. EDF acquired the balance of the stock held by the NLF in January 2009, for a total of £4.4 billion. In March 2009, the NLF's assets were estimated at £8.3 billion, and the British government estimated that any additional costs would be borne by the national budget.

*Funding for the disposal of wastes from new reactors*

The assumption that the wastes generated by the new reactors would be disposed of in the same facility as the old wastes is the most probable scenario, as this would reduce the amount of fixed disposal costs.

A public call for bids was organized in March 2010 on a method for determining a waste disposal price. On this basis, in December 2010, the British Government defined a method for covering the cost of transfer to the deep disposal of waste from new power plants in the future geological disposal facility. This cost will be capped to minimize the uncertainty weighing on operators. In other terms, the corresponding cost will be borne by operators within the limits of a cap set by the British Government.
Annex 20: Civil liability insurance in the nuclear sector – international comparisons

1 - The situation in Germany

The liability of the operator of a nuclear facility stems from the 1960 Paris convention, ratified by Germany on 30 September 1975, and from the complementary Brussels convention of 1963, ratified on 1st October 1975, as completed by the provisions of the German law on Nuclear Civil Liability, the Atomgesetz of 1959, amended in 1985 and 2002.

The nuclear facility operator has unlimited liability for damages caused in Germany, unless the accident is due to war, uprising or a natural disaster in which case liability is limited to the State's guarantee, which amounts to €2.5 billion (cf. 2002 amendments).

The nuclear facility operator must have two financial guarantee tranches:

- the first provided by an insurance policy, purchased from DKVG, the German nuclear pool, of €256 million.
- The premium is €700,000 /year for a large reactor. The insurance policies do not cover claims filed after ten years, nor extraordinary natural events; the second provided in joint and several responsibility by all operators for a total of €2.24 billion. A solidarity agreement has been reached between the four companies that operate all German nuclear power plants. Each partner to the solidarity agreement accepts responsibility towards the other partners and agrees to contribute to the total amount of the financial portion of power plant operators, set at €2.5 billion. The amount of each partner's guarantee is determined on the basis of the number of shares that it holds in each of the 17 power plants currently in service. As each power plant is organized as a limited capital company, if the company is incapable of paying the required amount after the first tranche, the payment will be made by the holding parent. If the parent is also unable to pay, then the solidarity of the other operators comes into play for their respective amounts (E.ON: 40.6 percent, RWE : 28.9 percent, EnBW: 22.6 percent, Vattenfall: 7.8 percent). The partners are required to submit every year to the regulatory authorities, a certificate from a chartered accountant confirming that they are financially capable of meeting their liabilities in this respect.
With respect to damages caused outside Germany, the operator's maximum liability is determined according to the reciprocity principle, meaning that it depends on the equivalent advantages offered to Germany by the State in which the damage occurred. Towards States that do not operate nuclear facilities on their territory, the liability is capped at the maximum amount stipulated by Brussel's complementary convention.

**Diagram: NCL Germany**

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Source: CGIET/IGF
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2 - The situation in the United States

The civilian nuclear liability mechanism in the United States is governed by the "Price Anderson Act", dating from 1957 (the US is not a party to the agreement on complementary damages, not yet in force). The "Price Anderson Act" proposes an objective and limited liability and covers nuclear reactors, research reactors, the nuclear facilities of the US Department of Energy (DOE) and transport activities. It also covers the private as well as the public sector. US law does not channel liability on the operator but organizes an indemnification mechanism for victims based on the operator.

**Objective and limited liability**

Operators must have coverage in two tranches:

- 1st tranche: $375 million coverage purchased by each operator and supplied by the American Nuclear Insurers (ANI);

- 2nd tranche:

  based on pooling and the solidarity of operators, supplied in the form of an amount of $117,495 million/reactor in case of an incident and collected through annual payments of €17.5 million. This second tranche is for covering indemnifications since they are not paid by the first tranche. An agreement is reached between ANI and the operator concerning the collection of retrospective premiums, subject to the approval of the NRC (Nuclear Regulation Commission). Operators are required to submit proof to the State that they have the two covers required by the "Price Anderson Act". The State makes this financial guarantee a prior condition for granting licenses for nuclear facilities.

The law covers damages to persons and to goods and preventive evacuations (see amendment of 1988). The costs of restoring the environment are covered by the ANI policies if the NRC describes the event as an "Extraordinary Nuclear Occurrence", a notion introduced by the amendments of 1966).

**Single jurisdiction**

The "Price Anderson Act" recognizes the authority of federated States to regulate the issues of civilian nuclear liability unless the legislation of the federated States is incompatible with federal provisions.

The authority to examine third-party liability issues belong to the United States Court of the district where the accident occurred.
With respect to accidents outside the United States, the law only covers contractual activity, carried out on behalf of the DOE, to the extent where it involves materials belonging to the US Government. The courts in the district of Columbia have jurisdiction on such matters.

Diagram: NCL United States

Source: CGIET/IGF
3 – Capped amounts of nuclear civil liability in Europe

NUCLEAR CIVIL LIABILITY IN EUROPE
(juin 2011)

European Union member state européenne
Non-nuclear state
State with electronuclear facilities in the process of dismantling and planning on building new power plants
State with a nuclear accession programme (more or less advanced)
Nuclear power plants in Eastern Europe
Limit of States parties to the Vienna convention
Limit of States parties to the Paris Convention
Amount of the operator's liability (in € million)
Unlimited amount due to the absence of national legislation
Unlimited amount decided by national legislation
Amount to be determined
Responses
from the government
departments & agencies and
other stakeholders
**Contents**

Joint reply from the following French ministers:
- Ecology, Sustainable Development, Transport and Housing;
- the Economy, Finance, and Industry;
- the Budget, Public Accounts, and State Reform, this minister also being the spokesperson for the French Government;
- Higher Education and Research; and
- Industry, Energy, and the Digital Economy 379

Minister for the Interior, Overseas France, Local Authorities, and Immigration 390

Chairperson of the Board of Directors of the French Institute for Radiological Protection and Nuclear Safety (IRSN) 391

Chairman of the French Alternative Energies and Atomic Energy Commission (CEA) 392

CEO of AREVA 401

Chairperson of the National Committee for the Evaluation of Funding for the costs of dismantling basic nuclear installations and spent fuel and radioactive waste management (CNEF) 407

Chairperson of the French Energy Regulatory Commission (CRE) 408

President of the French National Association of Local Information Commissions and Committees (ANCCLI) 422

Chairperson of the French Nuclear Safety Authority (ASN) 423

Chairperson of the French Parliamentary Office for the Evaluation of Scientific and Technological Choices (OPECST) 428

CEO of Electricité de France (EDF) 429

Chairperson of the Board of Directors of the French National Radioactive Waste Management Agency (ANDRA) 433

Chairperson of the French High Committee for Transparency and Information on Nuclear Safety (HCTISN) 435
In a letter dated 17 May 2011, the French Prime Minister requested the Cour des Comptes to audit the costs of the nuclear sector, including the costs relating to dismantling the facilities and to insuring the sites. Such is the subject addressed by the present draft report, which calls for the following observations from us.

Firstly we would like to congratulate the Cour des Comptes for the in-depth and thorough work done, presented particularly clearly and accessibly despite the difficulty of the subject. The Cour des Comptes has, in particular, done an exhaustive and detailed survey of the various past, present, and future costs of the nuclear power sector. The report gives an overall picture that makes it possible to prioritize the various costs and to relate them to one another.

The report thus responds very precisely to the request from the Prime Minister who wanted to shed as much light as possible on a topic that is being hotly debated and on which our fellow citizens have high expectations. The Cour des Comptes Report leads, in particular to five conclusions that we make our own:

- the audit by the Cour des Comptes does not show any cost that is not taken into account within the overall economic regulation of the nuclear sector;
- the choice of the method for assessing the cost of using the nuclear assets is decisive for the calculation of the full cost of the nuclear sector. The current economic cost method is based on an assessment of the cost of rebuilding today and identically the historic fleet of power plants. Conversely, the method proposed by the Champsaur Commission is based on an accounting estimate of the residual share of the capital invested in the nuclear power fleet. In order to set the initial price of regulated access to historic nuclear power, the French Government chose this method on the recommendation of Mr Champsaur’s Report and of the Commission de Régulation de l’électricité (Electricity Regulation Commission), while nevertheless taking into account the effects of additional investment in the nuclear power fleet for further improving its safety. Without validating the method per se, the Cour des Comptes confirms that
the Champsaur Commission’s method is in tune with the rationale behind setting the price for Accès Régulé à l’Electricité Nucléaire Historique (ARENH, Regulated Access to Historic Nuclear Energy). The calculation of the Cour des Comptes, taking account of the initial available data, backs up the choice that the Government made to set the ARENH price at a level slightly higher than the level recommended by the Champsaur Commission to take into account the impact of the Fukushima accident.

- the calculation of the production cost is relatively insensitive to the uncertainties about the future dismantling costs or waste management costs, the total cost varying by about 5% if those costs were to double;
- taking into account the civil liability risk in the event of nuclear accident does not change decisively the assessment of the costs of nuclear power generation;
- the spending using public funds (monitoring and research activities) and the revenue from the tax on nuclear facilities are deemed by the Cour des Comptes to be of “similar” orders of magnitude even though there is no direct budget appropriation from that revenue to that spending.

These conclusions are important for our fellow citizens. They back up the economic analyses of the French Government relating to the full production cost of our nuclear power fleet, and they back up the resulting decisions. Admittedly, the regulation of the sector should be consolidated as knowledge of the costs is honed down: the Cour des Comptes makes recommendations to that effect, which will feed into the future work by the Government, in particular in the context of preparing the decree setting the method of calculating the price of Regulated Access to Historic Nuclear Energy (ARENH) pursuant to Article L. 337-6 of the Code de l’énergie (Energy Code).

To take up but a few of the recommendations of the Cour des Comptes:

- the audits initiated by the Direction Générale de l’Énergie et du Climat (DGEC, Directorate General for Energy and Climate) to establish a technical appraisal of how the dismantling quotes were calculated will indeed be conducted as soon as possible;
- the work in progress on determining the quote for waste disposal/storage will indeed be completed by the end of 2012, after the “outline phase” that is currently under way;
- regarding insurance for nuclear power operators, the bill ratifying the “ordonnance” (order) of 5 January 2012 on codification of nuclear acts, will increase the compensation ceilings. Those ceilings will be brought into compliance with the amounts stipulated by the protocol of 2004 amending the Paris Convention and ratified by the
French Parliament in 2006. This measure is currently deferred until all of the European countries have voted the same measure into their national laws. Belgium, Italy, and the United Kingdom have yet to enact the ratification.

However, after reading the Cour des Comptes Report, we are bound to make a few remarks whose purpose is to supplement the observations made by the Cour des Comptes, and, in certain rare cases, to call for those observations to be revised.

On the cost of production and, in particular, on the cost of capital

The Cour des Comptes has rightly noted that the calculation of the cost of capital for any given year depends on the distribution of that cost over the operating period. The Cour des Comptes thus presents several methods, corresponding to various measurements and conceptions of costs, some of which vary over time.

The current economic cost (CEC) method is based on an assessment in 2010 euros of the effort made in the nineteen eighties. It makes it possible to give an idea of the investment effort that would need to be made today to reconstruct a fleet of power plants identical to the historic fleet, and to remunerate the capital in tune with the initial investment in constant euros, plus the provisions for dismantling. It is not necessarily in keeping with the timeline of the depreciations and costs borne in the past. Furthermore, it assumes constant remuneration of capital, over a period of 40 years, which does not correspond to the fact that, as noted by the Cour des Comptes, the nuclear power fleet is, in book terms, amply amortized.

In the specific context of the regulations put in place by the New Organization of the Electricity Market (NOME) Act that aims to cover the full cost of the historic fleet to the exclusion of renovating or replacing it, the estimate of the method used by the Champsaur Commission (whose report has been made public) stands out in that past remunerations are taken into account, with the choice having been made to base it on an accounting approach. That method means that, over the regulation period, namely from now until 2025, the non-amortized remaining capital is remunerated. The Cour des Comptes points out rightly that the calculation of the Champsaur Commission method is also forward-looking in that it takes account of the future increase in investment costs for maintaining the fleet in a proper condition, for extending its service life, and for improving its safety, those costs being presented in the report. As regards improving safety, the figures in the Champsaur report were calculated without taking into account the additional safety assessments, on which the ASN gave its opinion on 3 January 2012, but the calculation of the Cour des Comptes, taking account of the initial available elements, backs up the choice made by the French Government to set the ARENH price at a level slightly higher than the level recommended by the Champsaur Commission to take account of the impact of the Fukushima accident.
Thus, while the CEC represents the theoretical annual average cost of a fleet as rebuilt today identically to the historic fleet and thus adopts an “economic value” for the asset for the purpose of measuring the cost of the invested capital, the Champsaur Commission method makes it possible to isolate the “cost remaining to pay” for the historic fleet. Both do indeed concern the remuneration of the initial investment, but the Cour des Comptes was quite right to emphasize these fundamental differences.

**On accounting for the long-term expenses**

The Cour des Comptes considers that a financial accretion expense for the provisions for dismantling facilities and for managing spent fuels and waste should be taken into account as an annual nuclear power production cost.

The regulations on hedging long-term expenses are analysed in depth by the Cour des Comptes and require long-term expenses to be hedged by dedicated assets for amounts corresponding at any given time to the discounted expenses, it being specified that the management of those assets should make it possible to achieve a yield not less than the rate adopted for discounting the expenses. By means of this yield, the initial contribution, possibly corrected for subsequent contributions consequent upon reassessments of quotes or on alterations of discount rates, suffices per se to hedge the gross expenses disbursed at the end of operation.

Thus, by adding a financial accretion cost to the cost for setting up the provisions, the approach followed by the Cour des Comptes leads to a “gross” dismantling cost being adopted, which is not representative of the reality of the costs ultimately borne by the sector, those accretion costs being hedged by the investment earnings from the dedicated assets.

By way of illustration, it might be noted that adopting an accretion expense without neutralizing its amount with investment earnings would lead to a situation at the end of the period where: i) the sum of the gross costs accounted for would admittedly be equal to the total gross cost of the dismantling and waste management operations; ii) but the revenue generated in the meantime by the portfolio of assets would constitute surplus cash flow available at the end of the period for an amount not less than the total of the accretion expenses.

This presentation by the Cour des Comptes indirectly represents a shift compared with the conclusions of its report of January 2005 on dismantling nuclear facilities and on radioactive waste management: “with the discounting of the provisions, since the future burden is spread over a period going from the cost-generating event to the year of payment of the services, one way of ensuring that spread-out fair funding is obtained would be to secure it by a dedicated asset amount equal to the discounted provision.”

We observe that the Cour des Comptes has incorporated the accretion expenses into its calculation of the production costs, explicitly for waste and spent fuel management, which amounts to increasing the operating expenses identified by the Cour des Comptes by an annual amount of €740 million, and
implicitly for the dismantling and last-core costs, because it takes into account the gross expense in the calculation of the initial investment to be remunerated and not the discounted provision at the time of building the fleet.

The Cour des Comptes could have shown these expenses specifically in the calculations presented, and could have pointed out that they were, in principle, hedged for each financial year by the investment earnings from the dedicated assets that represent an amount that is at least equivalent. Although that expense does indeed represent an inevitable cost, its funding is nevertheless secured by design by the earnings from the dedicated assets set up at the time at which the future expense was generated.

The amounts of €18.4 billion and €3.8 billion that are adopted for the dismantling and last-core expenses of the fleet in service do indeed represent an overall amount over the life span, but, on the basis of a real discount rate of 3%, correspond to an initial provision at the time of construction of €4.5 billion. The initial investment cost for the current fleet should be reduced accordingly, the difference being funded by the earnings from the initial provision. It is then a figure of €100.5 billion rather than €118.2 billion that should be taken into account as the initial investment amount to be remunerated.

These corrections would result in isolating, in the totals shown by the Cour des Comptes, an amount of €2 per MWh for the full cost accounting (FCA) method and an amount of €5 per MWh for the CEC method, corresponding to the accretion expenses funded, in principle, by the earnings from the dedicated assets.

On the quotes presented by EDF for dismantling

The Cour des Comptes has conducted an international comparison of quotes for dismantling nuclear reactors. The Cour des Comptes emphasizes the limitations of such an exercise, related to the diversity of the regulations, to the differences in scope of the quotes, or to the differences in technology, while also indicating that the final assessment of the production costs, which includes hedging these long-term expenses, is relatively insensitive to variations in the quotes and that the Dampierre survey presented by EDF constitutes a sound basis that the Cour des Comptes also recommends should be used. In that respect, it agrees with its preceding conclusions, in the same report in 2005: “the provisions are now the fruit of very scrupulous and detailed calculations: although criticizable under-valuations were made over the preceding decades, it is no longer the case today.”

The work of the Cour des Comptes confirms the need for in-depth and regular inspection of the assessments presented by the operators. Such is the work of the Government, who, in 2011, thus defined a multi-year programme of audits that is being implemented. The DGEC has thus put in place a programme of audits with the three main nuclear operators, focussing, in particular, on management of residual technical uncertainties.
and of technical contingencies, the validity of the economies of scale taken into account in the extrapolation of the Dampierre survey, and the international comparison of dismantling costs. The reports from these audits will be put on line as they are produced. The first of the audits is to focus on the residual technical uncertainties and on the engineering contingencies. Its report will be available at the end of 2012.

We also have a protective legislative and regulatory framework. The Act of 28 June 2006, and its Article 20, is protective because any changes in quotes are borne by the nuclear operators. Our system guarantees firstly that the provisions for long-term nuclear expenses and the secured dedicated assets are monitored, and secondly the fact that any changes in quotes are borne by the nuclear operators.

Finally, we note that the Cour des Comptes highlights that the calculation of the product cost is relatively insensitive to uncertainties relating to the future dismantling or waste management costs. This enables us to envisage monitoring them over time with serenity.

On management of radioactive materials and waste

As regards waste management, the Cour des Comptes reports the debates in progress on the future costs of the deep geological repository. However, at this stage, the current figures based on the quote of 2005 are the only possible basis for calculating the provisions for the operators. 2011 has been a pivotal year for the deep geological repository project, with a project review being organized. At the end of that review, ANDRA began an “outline phase”. At the end of this phase, at the end of 2012, the minister in charge of energy will have to determine the cost of this storage/disposal project, pursuant to the law, prior to launching a public debate in 2013.

The French Government will be watchful to ensure that that quote constitutes a realistic and credible reference, on the basis of a technical project developed by ANDRA and taking the safety constraints fully into account.

The Cour des Comptes has also raised the issue of the status of certain materials, such as MOX fuels or fuels based on irradiated reprocessed uranium, or on depleted uranium. In the eyes of the law, these are materials rather than waste because use of them is planned or envisaged. This is described in the French National Radioactive Materials and Waste Management Plan (PNGMDR) for 2010-2012. But it cannot be excluded that such materials might one day be considered as waste. We emphasize that the recommendations of the Cour des Comptes regarding these materials are consistent with the PNGMDR for 2010-2012, which does indeed make provision for conducting “as a precautionary measure, studies on the possible waste management solutions in the event that these materials are qualified as waste in the future.”
As recommended by the Cour des Comptes, the costing for the provision entered by EDF for direct disposal of irradiated MOX and ERU fuels will be updated. The Cour des Comptes observes that “it is not certain that the repository as it is currently designed could accommodate these fuels”, ignoring the fact that that design is in progress and that the National Radioactive Materials and Waste Management Plan requires ANDRA to ensure “that the disposal and storage concepts remain compatible with the assumption of spent fuel being stored directly.”

On the dedicated assets
The Cour des Comptes considers that “in terms of diversification and of liquidity, the use of RTE securities for constituting the dedicated funds is debatable.”
As regards bringing RTE into EDF’s portfolio of dedicated shares, the Cour des Comptes mentions the argument used by EDF who considers that the “flow of dividends represents the economic advantage of this assignment” and it concludes that “it is indeed the sum of the value of the dedicated assets and of the profits of the investment thereof that should hedge the provisions as a whole.” That conclusion ignores the fact that, if a sale were to take place after 30 years, the share would, in the meantime, already have yielded 80 percent of its value as seen from today. The realization value after a century corresponds, seen from today, only to a tiny fraction of the entered value. We would also point out that, given the schedule for the expenses, the disbursement scenarios do not require these securities to be sold.
Pursuant to the Act of 28 June 2006, the French Government is particularly watchful to ensure that the liquidity of the dedicated assets is sufficient, i.e. sufficient in view of needs and not total at all times. The Government confirms that it considers that the inclusion of RTE securities in the dedicated assets is positive in terms of diversification and that that inclusion does not pose any difficulties in terms of liquidity.

On the costs of the EPR
On page 226, the Cour des Comptes estimates that, with a service life of 60 years, the cost of the Flamanville EPR could be from €70 per MWh to €90 MWh, and emphasizes “that these costs are not the costs for a standard EPR, for which costs are even more difficult to forecast”.
We agree with the analysis of the Cour des Comptes regarding the difficulty of foreseeing the cost of a standard EPR. The Cour des Comptes has gone back over the cost of building the current nuclear power fleet in exhaustive tables that show the major savings that are possible, even if they are not systematic, between the first plant units and the subsequent plant units on the same site (e.g. Tricastin 1.2 and Tricastin 3.4, Dampierre 1.2 et Dampierre 3.4, Gravelines 1.2 and Gravelines 3.4, Paluel 1.2 and Paluel 3.4) or
between the first-of-a-kind and the subsequent constructions of the same series (e.g. Paluel as against Saint Alban and Belleville, or Chooz as against Civaux). In addition to these savings, there can also be the effect of faster construction on the amount of the interest during the construction.

On the service life of the power plants

The Cour des Comptes notes, in conclusion, that the service life of the power plants is a strategic item of data. It observes that, “by the end of 2020, 12 reactors representing 10,900 MW will have reached a service life of 40 years, and 22 reactors out of 58 will have reached their fortieth year in service by 2022”. It deduces from this that 6 or 7 EPRs need to be built by 2020 and 11 need to be built by 2022, and it recommends that focuses for the medium-term energy policy be drawn from this, be made public, and be usable by all of the players in the sector.

We would draw your attention to the report on multi-year investment in electricity generation that was made public in June 2009 and the to the corresponding order of 15 December of the same year. With the equivalent documents for gas infrastructures and heat generation, it constitutes our roadmap for energy. In addition to the “Grenelle round-table” objectives of keeping demand down and of developing renewable energies, it explicitly takes the assumption of a central scenario of extending the service life of the current nuclear power fleet to beyond 40 years, and it concludes that, in view of the absolute priority given to nuclear safety, it is necessary to have room for manoeuvre so as to guarantee safe supply while also preserving the capacity to take any decision relating to the safety of the fleet. These considerations justified the construction of the EPR of Flamanville and the preparation of the file for launching construction of an EPR at Penly.

In addition, at the end of 2009, the Government asked EDF and the ASN to outline the approach to examining the fourth ten-yearly reviews. The issues and stakes of extending the service life will thus be gradually honed down. We would point out, in particular, that the standing advisory committee is to meet soon to address the safety focuses beyond 40 years. The work schedule defined by the ASN will enable us to have reliable technical details by 2015 as to the technical feasibility of our nuclear reactors operating beyond 40 years. We would remind you that our reactors are subjected to in-depth safety reviews every ten years through the ten-yearly inspections, and this is an asset of the French nuclear safety model.

The problems raised by the Cour des Comptes were therefore identified in the multi-year investment programme that will updated during the next term of the legislature, pursuant to law.
**On past research spending**

The Cour des Comptes rightly indicates that the past research costs should not be incorporated into the calculation of the production costs of the current fleet. The Cour des Comptes points out that that spending is in the operating expenses of the operators or in the spending funded from public funds. **This argument should be taken further**: independently of it being taken into account as operating expenses elsewhere, the research spending that enabled the reactors of the current fleet to be developed constitutes non-recurrent spending that would not need to be repeated if it were desired to re-build an identical fleet, and for which it is not therefore necessary to rebuild the capital. Therefore, that spending should be excluded from the calculation of the production cost.

Moreover, in its recapitulative table, the Cour des Comptes includes in the investment spending not only the research and development spending related to the current nuclear power sector (€43 billion), but also the research spending related to the fast-neutron sector (€12 billion) and the spending related to Superphénix (€12 billion). Insofar as the main aim of the Cour des Comptes is to present the costs related to electricity generation, the table should distinguish between research spending related to the nuclear power sector (€43 billion) and spending on the fast-neutron sector (€24 billion).

In addition, as the Cour des Comptes rightly points out in the chapter on past spending, the €12 billion for the prototype fast-neutron reactor Superphénix (Superphoenix) does not strictly speaking constitute research spending but rather it is a sui generis case of intermediate spending between research and electricity generation.

**On future research spending**

The presentation of future research spending calls for a series of remarks:

Firstly, the chapter on future research spending covers spending of different types: future spending related to current production (dismantling, waste management, etc.) that is the subject of the report, and spending on research and development for the future generations that is, for the most part, unrelated to current production and is therefore not relevant per se to the scope of the report. Future research should be considered only insofar as it might have an impact on the amount of the spending related to current production. **These two categories of future**
expenditure should be separated more clearly and the emphasis should be put on spending related to current production.

The report by the Cours des Comptes devotes a boxed text section to nuclear fusion research in the context of ITER, and that research is also mentioned in the conclusions about future research. It seems to us that these discussions about ITER are out of place in the report devoted to the costs of the nuclear power sector. Fusion is still at the fundamental research stage and funding for it is through investments in major international scientific instruments funded by the French State, and in which France is playing a major role as host country. Contrary to what is indicated, the long-term aim of ITER is not to “generate civilian electricity”. The purpose of ITER is to demonstrate the technical and scientific feasibility of using fusion energy as a future source of energy production. It will serve in particular to test the key technologies necessary to the pre-industrial prototype DEMO. That prototype, designed to demonstrate the industrial feasibility of fusion electricity generation is expected only in about 2040 depending on the scientific results provided by ITER.

Moreover, the current presentation shows research into future generations only in terms of costs, which is an extremely limited way of looking at such research. Firstly, in the long term, such research will lead to new nuclear power solutions, the economics of which will have to be analysed in an overall manner. Secondly, nuclear research has a strong strategic and political dimension in terms of combating global warming, security of supply, and energy independence. These aspects appear only in separated and non-costed manner in the externalities mentioned in Chapter IV.

Furthermore, future nuclear research should be looked at in the broader context of the Stratégie Nationale de la Recherche et de l’Innovation (SNRI French National Research and Innovation Strategy) one of the priority focuses of which is to secure a carbon-free energy future with a balance between nuclear research and research into renewable energies. This balance is to be found in the “investments for the future” programme because the “nuclear sector of tomorrow” programme that has been allocated €1 billion covers the respective programmes devoted to setting up institutes of excellence for low-carbon energies, and to “low-carbon energy and green chemistry” demonstrators, for a total amount of €2.35 billion.

As regards research into Generation IV, the Cour des Comptes rightly reports that, in the context of coordination at Generation IV Forum level, France has chosen to concentrate on sodium-cooled or gas-cooled fast-neutron reactors. However, France is continuing, in particular at the
CNRS (French National Scientific Research Centre), to research other systems. The R&D for the fast-neutron systems also includes developing new processes for processing spent fuels from the systems in question. Finally, it could be useful to mention in the report that France, with the Astrid prototype, is fully in tune with European strategy, and with the Strategic Energy Technology (SET) Plan presented by the European Commission.
REPLY FROM THE MINISTER FOR THE INTERIOR, OVERSEAS FRANCE, LOCAL AUTHORITIES, AND IMMIGRATION

1 – On protection for nuclear power plants

This first part of the report seems to me to be a faithful reflection of the gendarme forces committed to protecting these sites. I note, in particular, in the conclusion of the Cour des Comptes that invoicing at the real cost confirms that the cost of the dedicated protection is borne in full by the operator.

However, I would emphasize that the operational contract between the gendarmerie and EDF is not permanent and can change depending on the threats that are identified, revision possibilities being expressly provided for in the agreement.

3 – On planning

Plans Communaux de Sauvegarde (PCSs, commune-level local emergency plans) are mandatory for communes (municipalities) located within the boundaries defined by a Plan Particulier d’Intervention (off-site emergency plan) and not only for communes within whose territories a nuclear facility is located. It is therefore all of the communes that are included, even partially, within an off-site emergency plan zone, and not only those in which the facilities are located, that must have a PCS.

4 – On crisis management

The revised budget law of 20 December 2001 put in place a first programme of decontamination systems, following the nine-eleven attacks, and anthrax-related threats. That programme was supplemented by a three-year programme for 70 mobile decontamination units (UMDs) that were developed to cope with chemical risks and were tested by the Direction Générale de l’Armement (French Directorate General for Armament) in the context of European testing of chemical substances.

That equipment was thus acquired initially to cover chemical risks rather than nuclear risks. However it can be shared between the various risks and be used in the event of industrial, chemical, or nuclear accident.

It is therefore inexact to incorporate the total cost of the above-mentioned three-year programme into the cost of civilian nuclear power.
REPLY FROM THE CHAIRPERSON OF THE BOARD OF DIRECTORS OF THE INSTITUT DE RADIOPROTECTION ET DE SURETE NUCLEAIRE (IRSN, FRENCH INSTITUTE FOR RADIOLOGICAL PROTECTION AND NUCLEAR SAFETY)

This very full draft report illustrates well the sensitivity of costs to the expected changes in performance in terms of nuclear safety. For this reasons, it appears to me to be advisable, as proposed by the report, to identify the potential costs (even if it is currently difficult to put figures to them) associated with the consequences of a nuclear accident leading to radioactive release into the environment. The IRSN intends to continue the research it has started on this subject.

Beyond this general comment, the draft report calls for a remark from me on the boxed text section entitled “Research and creating value”, which presents the main data relating to developing added value for knowledge acquired through research programmes in the form of industrial activity creation, enterprise creation, or patents. It seems to me that, as the Cour des Comptes rightly highlights in Chapter IV of the report, research dedicated to safety and to radiological protection (the costs of which are also indicated) thus creates value to a significant extent, by reducing the probability of incidents and accidents. Even though a figure cannot be put to that value, in my view it fully justifies continuation of these research programmes to which the IRSN is strongly committed. More mundanely, the Institute is also developing the added value of its own portfolio of knowledge, with 7 patents active and generating licence fees.
REPLY FROM THE CHAIRMAN OF THE COMMISSARIAT A L’ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES (CEA, FRENCH ALTERNATIVE ENERGIES AND ATOMIC ENERGY COMMISSION)

The CEA has read the report and would like to emphasize the high degree of pertinence of the financial and technical information given in it, apart from a few remarks and suggestions for corrections presented below, and to which it would like to draw the attention of the Cour des Comptes. It thanks the Cour des Comptes for having heard it attentively as it did all of the stakeholders and their usually diverse positions, the identities of whom are given in Annex 4 of the Report.

The CEA has taken good note that, in its introduction, the report points out that “its ambition is only to measure the costs, without making any judgement as to their levels”. In the CEA’s opinion, that objective is fully achieved. The CEA would like to emphasize that the report is of very great interest, the report being particularly rich in summarized information giving overall pictures, such information being hitherto scarce and not enabling those who so wished to make statements on faithful and non-partisan bases about the full cost of our country’s choice of nuclear fission technology for a large fraction of its electricity generation. For its part, the CEA would like to emphasize that, in order to grasp these costs whose orders of magnitude are not familiar to most of our fellow citizens, faced with the figure of 227.8 billion euros (2010 value), which is deemed to cover all of the nuclear power investment costs for the last 50 years, and of which only 118.2 billion euros is to be included in the cost of the current power plant fleet, the reader should be aware that that investment, and annual operating expenses of 10 billion euros made it possible, in 2010, to generate more than one-third of France’s primary energy needs, and should compare it to the 48 billion euros spent in 2010 (in 2011 this figure will probably be more than 60 billion euros) solely to purchase fossil fuels for generating about one half of our primary energy needs.

The CEA has taken note of the methodological principles adopted; it recognizes the pertinence of those principles with regard to the objective. It notes with satisfaction that, in the costing given for research, the 12 billion euros representing the investment for Super Phénix (Superphoenix) is not included. Everyone knows that that investment, which admittedly experienced some technical difficulties during the early years in operation, was unable to be productive on an industrial scale as planned mainly for political reasons that cannot be attributed to the sector, and even less so to its research component. The good grasp of the Cour des Comptes in limiting itself to the costs related to electricity generation, while identifying the amount of this investment that was lost for the reasons indicated, has rightly led it not to
include this amount in the recapitulative sum of the research investment spending.

The CEA wishes to draw the attention of the Cour des Comptes to the fact that it is the owner operator or merely the owner not of 43 civilian-use basic nuclear installations (INBs) but rather of 37 such installations. At 31 December 2010 we had 20 basic nuclear installations actually in service, 3 that had been shut down (INB 18, Ulysse; INB 25, Rapsodie; and INB 71, Phénix), but for which no dismantling authorizations had yet been given, 3 for which creation authorizations had been given and were being built but that were not yet in service (INB 169, MAGENTA; INB 171, AGATE; and INB 172, R.H) and 11 for which final decommissioning and dismantling decrees have been issued. The CEA has taken good note that the investments corresponding to these basic nuclear installations were entered into accounts as research investments. It should be clear that the area covered by the report pursuant to Article 20 of the French Act of 2006 on transparency regarding nuclear safety is distinct from the inventory of the basic nuclear installations, but that it is consistent with the table relating to the costs of dismantling the CEA installations.

In the list of the installations of which the CEA remains owner and operator, but that are made available to the IRSN, there is the Silène installation that handles criticality and associated radiation protection issues for civilian purposes. Located at Valduc, it is undergoing a renovation project within an international framework.

The CEA notes with interest the proposal to implement a “standard nomenclature for research expenditure” recognized by the operators. However it emphasizes that rigidity in managing this information should be avoided so as to preserve the advantage of the greater transparency that such standardization would offer. The data collected regularly to satisfy the requests of the International Energy Agency (IEA) could serve as a basis for this development, while also acknowledging that that collection should be improved.

The CEA confirms that, as far as it is concerned, the data relating to climate, to radiobiology, and to radio-toxicology is included in the IEA survey, but that, according to it, that spending cannot be attached directly to nuclear power and that, furthermore, the associated amounts are extremely small compared with the amounts for the other sections of the IEA report. These amounts, which were subtracted with the consent of the Cour des Comptes were nevertheless disclosed to it in September 2011 and are recalled in an annex (they have been available since 1994).

As regards the origin of AREVA, the following points should be noted. It was COGEMA (Compagnie générale des matières nucléaires), incorporated in 1976 that came from the Productions Division of the CEA being transformed
into a subsidiary, and not AREVA in its entirety which was formed from CEA-Industrie, holding company of the CEA shareholdings, and from all of the subsidiaries or shareholdings of that company. Various companies come from businesses or activities of the CEA being transformed into subsidiaries:

- SOVAKLE, incorporated in 1957, by transferring the property management activities of the CEA; this company was privatized in 2001;
- Technicatome (Société technique pour l’énergie atomique), incorporated in 1972 for the purpose of building on-board nuclear steam supply systems; this company today belongs to the AREVA Group and is called AREVA TA;
- CISI (Compagnie internationale des services informatiques), incorporated in 1972 by subsidiarizing the computer department; this company was privatized in 1997;
- ORIS Industrie, incorporated in 1985 by subsidiarizing the ionizing radiation department; this company, which became CIS bio international, was privatized in 2000.

The CEA also took shareholdings in companies in which it contributed to developing the activities and that became parts of the AREVA Group: FRAMATOME (which became AREVA NP); and COMURHEX. INTERCONTROLE.

It should be noted that the “specialized service” put in place by the CEA, namely the “Local Security Teams”, present on the five civilian centres of location comprises a staff of slightly more than 500 employees who are experienced and armed, and whose specificity is to perform three missions:

- access control, caretaking, surveillance and physical protection of the facilities and centres;
- fire prevention and protection; and
- first aid for victims.

These employees do specialized training that is regularly updated, and they work in shifts round the clock so that they can accomplish their various missions. It is the only system, together with the one originally created on the same model and that AREVA NC has, that is capable of coping with any eventuality. Its cost is in proportion to the security needs of the sites of the CEA.

The CEA considers that the point devoted to “public spending on safety and transparency” should be supplemented by a paragraph on spending on transparency for the public establishments (CEA and ANDRA) and for the
companies (EDF, AREVA) who are nuclear facility operators and therefore have transparency obligations whose cost is not assessed in the report.

In particular, these establishments have to establish and make available to the public annual reports on nuclear safety and radiation protection for each of their nuclear facilities or for each of their nuclear sites (Article L. 125-15 of the Code de l’Environnement, the French Environment Code), and they also have to satisfy requests for direct access by the public to the nuclear information concerning their facilities or transport of radioactive substances (Article L. 125-10 ibid.). In order to comply with these obligations, the operators in question must put in place an appropriate organization and appropriate structures, which contribute to informing the public, pursuant to the provisions of the “TSN” Act of 5 January 2012. It should be emphasized that no other activity of the energy sector is subjected to such transparency obligations and thus to the corresponding costs.

It should be remembered that the dedicated fund for dismantling the civilian facilities of the CEA was set up in June 2001 and that it was contributed to when AREVA was set up in September of the same year. Furthermore, the CEA does not think that it can be said that the table, while admittedly showing “an upward trend in the costs for dismantling the facilities of the CEA over the last decade”, “reflects the insufficiency of the evaluations at 31 December 2001”, suggesting that that evaluation was of poor quality. That assessment, which is particularly complex for a very heterogeneous power plant fleet, was performed within successive boundaries with a learning-curve rationale, because the return on industrial experience was very limited. The 2001 evaluation was of the best quality possible in 2001, in the context of the time. The CEA wishes, on the contrary, to emphasize the pertinence of the its policy in being watchful to capitalize on the diagnostic and industrial experience of the first facilities and indeed of the first complex research sites fully cleaned up and dismantled in France and more broadly in Europe, so as to draw from that experience without delay a robust methodology for evaluating the costs, margins and contingencies necessary for complying with the legal obligations with the 2011 schedule on bases now considered as being stabilized. The Cour des Comptes also explicitly notes the conscientiousness with which CEA has estimated its dismantling costs. The CEA acknowledges the fairness of that observation.

The Cour des Comptes rightly points out that “the reference solution for recycling these materials [recycled uranium and depleted uranium] is therefore indeed to use them in Generation IV reactors”, which would “then represent several millennia of consumption”. It should be emphasized that that reference solution would also achieve either the stabilization of the plutonium inventory, or a gradual reduction thereof, possibly almost down to zero, if that was desired, thereby reducing accordingly the expenses for managing ultimate waste by storing it underground.
The Cour des Comptes indicates that “under current conditions, storage of depleted uranium represents about 76,000 m³, which corresponds to a volume comparable to the volume of all of the waste that is to be stored in the deep geological repository”. Although that is quantitatively correct, the CEA considers that, in order to enable the issues to be properly understood, the report should emphasize that the radioactivity and the chemical toxicity of depleted uranium bears no relation to the radioactivity and chemical toxicity of the waste that is currently scheduled for deep geological disposal: the ratio in terms of radioactivity per unit volume is about one million! It is clear that the costs of final storage/disposal of these materials will therefore bear no relation to the costs of deep disposal of the ultimate products of fission and of the minor actinides under the conditions under which such disposal is considered as being possible for such products and actinides.

It is particularly surprising to read that “if depleted uranium were to be considered as a waste rather than a recyclable material, France would have to dispose of radioactive waste of foreign origin”, suggesting that therein lies a problem. Given that we import all of the natural uranium that we use, everything that results therefrom and that is not deemed to be a recyclable material is therefore “waste of foreign origin”. This situation does not pose any difficulty for what is today considered as ultimate waste. There is doubtless confusion here with the requirements of the 2006 Act on sustainable management of nuclear waste and materials, which stipulates that it is not possible to store nuclear waste of foreign origin, i.e. to import waste that can in no way become recyclable material, and to store such waste finally in France (however, it is possible to import such waste for the purpose of processing it, packaging it, and returning it transformed in this way to the country of origin). But there is no particular legal problem with importing recyclable nuclear materials of which a fraction is to become ultimate waste after energy has been generated. The above-cited paragraph is thus incomplete and would benefit from being rewritten. The CEA sees no obstacle, unlike what the conclusions of the report would suggest concerning depleted uranium, to research being done to examine the various hypotheses for sustainable management of this material (depleted uranium), if it were not fully recycled. That would avoid leaving uncertainties as to the financial impact, which the CEA considers as small compared with the other issues, of sustainable and safe management of depleted uranium.

The Cour des Comptes raises the question of the future of plutonium, in the event that the public authorities stop MOX. For the time being, in accordance with 2006 Act on sustainable management of nuclear waste and materials, the reference solution for managing plutonium is indeed MOX, combined with processing spent fuels and recycling recyclable materials, firstly in thermal neutron reactors, and secondly in fast neutron reactors, the industrial viability of which admittedly remains to be established. That is
precisely the purpose of the ASTRID programme that was entrusted to the CEA by the French Government and by the French Parliament in 2006 and then in 2011. It is clear that, if the public authorities were to decide to discontinue the MOX solution, the immediate consequences would, from the point of view of the CEA, be of two types: firstly processing of spent fuels would be ceased immediately and they would thus need to be considered as ultimate waste to be stored in a deep repository with the inevitable ensuing increase in the costs of managing waste from the nuclear power sector; then it would be necessary for the plutonium currently resulting from the reprocessing and not yet used for producing MOX fuel to be recombined with depleted uranium or with recycled uranium so as to produce an equivalent to spent MOX fuels that might subsequently suffer the same fate as MOX fuels.

The same remark as the remark made about depleted uranium is applicable to thorium. The Cour des Comptes reports that the “the PNGMDR appears to doubt that thorium is genuinely recyclable”. The CEA would emphasize that the Cour des Comptes would appear to making the assumption that thorium is part of the nuclear power sector, whereas, to the best of its knowledge, at no time in France has such an option been envisaged by the public authorities otherwise than by enabling solely paper research to be undertaken on such an option that, to date, has led to the conclusion that, in the foreseeable future, there was no advantage for France to pursue such an eventuality. Management of thorium would not therefore seem to be a relevant topic for the present report.

The Cour des Comptes briefly addresses the issue of very low-level waste, in particular in relation to dismantling basic nuclear installations (INBs). Clearly the volume generated by the cleanup/decontamination operations for the basic nuclear installations and thus the related costs will be highly dependent on a choice that remains to be made. Either it continues to be assumed that there is no threshold to the residual quantity of radioactivity maintained on the site of the former basic nuclear installation, once the operations are complete and that the quantities of very low-level waste envisaged in the report are a reasonable estimate that can but increase due to the uncertainties attached to it, in view of the current state of the analyses of each basic nuclear installation, or else it is accepted, as advocated by the CEA and as is the case in all of the other nuclear countries, that it is possible to maintain a residual level of radioactivity, and the reduction could be very significant. The residual radioactivity should not, for any assumption of subsequent use of the site, lead to an annual dose of greater than 0.3 mSv for the general population or for the users of the site, i.e. one tenth of the average radioactivity that our fellow citizens receive, and that everyone agrees to consider as not inducing a significant additional health risk beyond living risks in general. It should be recalled that many of our fellow citizens harmlessly receive annual doses that are thirty times higher The CEA is doing a quantitative survey of the effects of such a policy in order to assess
its financial effects, without that having the slightest negative consequences in health and environmental terms. This issue is related to the position adopted by the CEA, as rightly reported by the Cour des Comptes.

The Cour des Comptes rightly emphasizes that the provisions for cleanup/dismantling, and then for storing the ultimate waste are sensitive to the discount rate adopted and to the performance of the financial markets, due to the fact that they are associated with long-term operations. This sensitivity is a concern for the CEA, while it also considers that the choices made currently are the most reasonable possible in view of the available financial information, whether it relates to the past or to the future.

The report indicates that the framework agreement between the State and the CEA leads to “partial re-budgeting of the funding for the long-term expenses” of the CEA” and “places the State as the ultimate fund provider for long-term nuclear expenses”. The Cour des Comptes appears to be forgetting that the CEA is a public establishment, whose civilian nuclear installations have been funded almost entirely by the State, and that the CEA does not have any revenue from earnings for funding these expenses. It is therefore perfectly logical that use is made both of some of its assets (Areva securities), created through the investment represented by those installations, and also of direct State subsidies.

It is mentioned that “the components [of the nuclear reactors] are subjected to extreme stresses”. The choice of this term “extreme” might be a source of misunderstanding. It is important to note that, while these stresses are admittedly dissimilar to many stresses to which other industrial facilities are subjected, they were taken into account as of the design stage of the nuclear facilities, and attentive monitoring of the effects of such stresses on the components has proven them to be perfectly in line with the expected behaviour patterns, and, in many respects, they are more favourable than was initially imagined, thereby make it reasonable to assume that the lives of the facilities can be extended to beyond the initially scheduled term.

Throughout the report, the Cour des Comptes has identified the ITER programme and the research into fusion as not coming under the costs of the current nuclear power sector. At the CEA, this work comes under the Physical Sciences Division at the fundamental research unit and not under the Nuclear Energy Division, thereby confirming this position.

In the part on “nuclear risk and insurance”, the information and the observations that the Cour des Comptes presents on this complex subject are consistent with the CEA’s vision, and are particularly useful for properly situating the issues.
The general conclusion chapter is particularly interesting. The CEA notes as consistent with the information available to it and with its own vision that the total research investment at national level over the last 50 years is estimated at €201055 billion, that the investment for building the 58 reactors in service is estimated at €201096 billion, that the investment cost for the EDF first-generation power plants that are now shut down is estimated at €201015 billion, and that the investment cost for the facilities of the Areva cycle is estimated at €201015 billion. As regards the annual maintenance costs for the current nuclear power plant fleet, the order of magnitude is €2010 1.7 billion, and the amount for the operating expenses is €2010 8.9 billion. Including the spent fuel management expenses, the annual amount for all of the operating expenses can be estimated, as proposed by the Cour des Comptes at €201010 billion. Taking all of these costs into consideration leads to confirmation of a production cost per MWh for the current nuclear power plant fleet of about €201050. If it is considered that the commercial value is €201070 per MWh for the 420 TWh per year of electricity generated by the facilities that were the subject of these investments and of these production costs, these amounts should be compared with the some €201030 billion of value thus created annually, for a minimum term of 30 years and doubtless for 40 or more years. The CEA has also taken good note that full replacement of the current fleet with Generation III power plants would lead to a production cost per MWh for the fleet of about €201075, thus showing the degree to which extending the lives of the current power plants is pertinent, subject to it being guaranteed that they remain fully safe, and without replacement of the current power plants with Generation III power plants before the currently envisaged term of 40 years putting an end to the competitiveness of nuclear power in France.

One of the most important and clearest conclusions of the report is how little the cost of nuclear-generated electricity is sensitive to developments in future expenses, subject to the administrative rules governing how nuclear power operates remaining stable.

The CEA supports the recommendation of the Cour des Comptes for additional research to be done into the externalities of each of the main energy sectors, and is ready to contribute to such research.

The CEA shares the point of view of the Cour des Comptes that power plant life is a strategic variable. It fully supports the four recommendations of the Cour des Comptes resulting from this observation.
The CEA is also favourable to the recommendation relating to regular updating of the survey that was the subject of the report and would be watchful to assist such updating as well as possible if it were to be decided.
REPLY FROM THE CEO OF AREVA

Publication by the Cour des Comptes of a report on the costs of the nuclear power sector is an initiative welcomed by AREVA. Produced at the request of the French Prime Minister, the report gives an overall picture of the past, present, and future costs of the nuclear power sector, and clarifies the way in which those costs are covered and hedged.

Nuclear power contributes significantly to limiting CO₂ emissions.

I note that the report highlights the significant contribution made by nuclear power to the security of France’s electricity supply, and to limiting the CO₂ emissions of the electricity sector. Even though the combat against climate change appears to have been relegated to the background, it is worth remembering that the nuclear power sector produces very low CO₂ emissions, unlike electricity-generating technologies based on fossil fuels (nuclear power emitting about 50 times and 30 times less CO₂ than the coal-fired and gas-fired power sectors respectively). The case of Denmark, which has no nuclear power sector, seems to me emblematic: the share of wind power in the Danish electricity mix is the highest in Europe at 19 percent. But the share of coal is 48 percent, and the share of gas is 19 percent. As a result, the CO₂-intensiveness of electricity generation in Denmark is 7 times as high as in France, and 63 percent higher than the European average.

Nuclear-generated electricity costs less to generate than electricity generated by renewable or fossil energies.

The Cour des Comptes has shed light on the costs of nuclear power. Despite the efforts to reduce the cost of generating electricity from renewable energies – in which AREVA is actively involved in the fields of off-shore wind power, biomass power, and concentrated solar power – those electricity generation sectors will remain more expensive than the conventional sectors for many years yet. According to the estimates of the Commission de régulation de l’énergie (CRE, the French Energy Regulatory Commission), the development of the renewable-energy power plant fleet in France will take the annual amount of the subsidies up to 6.6 billion euros by 2020. That amount is significantly higher than the estimates for investments related to the safety of the nuclear power plant fleet after Fukushima – which are estimated at about 10 billion euros over about 10 years, i.e. 1 billion euros per year. The electricity production costs of the fossil power sectors are in excess of €70 per MWh and will increase due to rising hydrocarbon prices and to increasing taxation on CO₂ emissions. According to the Cour des Comptes, nuclear power costs are currently less than €50 per MWh, and will rise only moderately: nuclear power should therefore remain sustainably competitive.
The safety investments recommended by the ASN do not undermine the cost advantage of the nuclear power sector.

In its recently published report, the Autorité de sûreté nucléaire (ASN, the French Nuclear Safety Authority) recommends investments for improving the safety of the French nuclear reactors. EDF estimates the cost of the measures for bringing its power plant fleet into compliance at no more than 10 billion euros. That amount represents about 5 percent of the electricity production cost of the current power plant fleet, and in the range 2 percent to 3 percent of the price of electricity (the share of electricity generation in the electricity bill is about 40 percent for residential consumers and about 60 percent for businesses). Thus, those extra costs will not significantly undermine the economic viability of the current nuclear power plant fleet. The same applies to the investments necessary for extending the lives of the reactors. It is incumbent on the ASN to rule on whether or not reactor lives should be extended beyond 40 years after looking at safety considerations. From a strictly economic point of view, the report emphasizes that it would be costly to shut down prematurely the power plants that are already amortized, that are cost-effective, and that generate low-cost electricity, in order to replace them with more costly electricity generating capacities. The report also points out that no investment in substitute capacities has yet been launched or even scheduled. Thanks to its nuclear power plant fleet, France enjoys an electricity price that is about 40 percent lower than the European average: in this respect, nuclear power is a central factor in the competitiveness of businesses, in safeguarding industrial employment and in upholding purchasing power in France. These benefits for the French economy can be added to the positive externalities of the nuclear power sector in terms of the CO2 emissions from the electricity sector.

AREVA is already successfully drawing teaching from the first EPR construction projects.

The Cour des Comptes stresses the uncertainties of the cost of the EPR. The EPR technology developed by AREVA guarantees the highest level of nuclear safety. The EPR is the first Generation III reactor under construction in the world. As with all first-of-a-kind projects, the costs and lead times of the first EPR sites in Finland (Olkiluoto 3) and in France (Flamanville 3) are higher than expected. However, AREVA is already drawing all of the possible teaching from these sites. That valuable return on experience has enabled the two EPRs being built in China on the Taishan site (Guangdong Province) to reduce considerably the number of hours of engineering on the nuclear steam supply system (a reduction of -60 percent between the Finnish and the Chinese EPRs) and thus the associated costs, to reduce significantly the lead time required to manufacture the large components by improving the production processes, and to improve construction schedule reliability by reducing the lead times for procurement from suppliers. As a result, the Taishan site is being built strictly to the
ambitious schedule (the total construction time should be 40 percent down on
the construction time for the Finnish EPR), and to cost forecasts. Currently
the proposals by AREVA for new nuclear reactors in Europe are much lower
than the estimates for the Olkiluoto 3 and Flamanville 3 projects.

The standard EPR is competitive compared with the alternative
sectors.

AREVA estimates that the electricity production cost of the standard
EPR will be in range €50 per MWh to €60 per MWh. That estimate takes into
account the technical characteristics of the EPR: availability 92 percent
higher than the availability of the current power plant fleet, overheads
amortized over power (1,630 MW) greater than that of the preceding
generation of reactors, fuel consumption nearly 10 percent lower than that of
the preceding generation, service life of 60 years... Its technical and
economic characteristics make the standard EPR competitive in Western
Europe compared with the conventional sectors (gas and coal) and compared
with the renewable energy sectors for building new electricity-generating
capacities.

The dismantling cost is not a hidden cost.

Some say that certain costs of the nuclear power sector are not taken
into account, tending to distort comparisons of the full costs of the various
electricity generating sectors. I note that that preconceived idea is
demolished by the Cour des Comptes. Dismantling of nuclear facilities is
often a spectre that looms large in this respect. Some say it will swallow up
money and others say it is technically unfeasible. While the report
emphasizes certain limitations – inherent to ex ante forecasting – in the
estimates for the cost of dismantling nuclear facilities in France, it does not
fundamentally challenge the estimates of the operators. In its conclusions, the
Cour des Comptes highlights the low impact of an increase in the cost of
dismantling EDF’s nuclear power plant fleet on the cost of producing
electricity, even using the gloomiest assumptions. Thus, an assumption of the
quotes for dismantling doubling would give rise to an increase of only 5
percent in the cost of producing electricity from nuclear energy.

AREVA is funding all of the costs of dismantling its facilities.

AREVA operates fuel-cycle nuclear facilities, in particular on the sites
of Le Tricastin, La Hague, and Marcoule. The costs of dismantling those
facilities are not burdens to be borne by future generations because they are
fully funded through dedicated assets. Well before the 2006 Act that requires
it, AREVA put in place dedicated funds of financial assets whose valuation is
monitored by independent experts and is annually audited by the Group’s
auditors. Periodic re-estimation of the future dismantling costs is a
requirement that AREVA has imposed on itself by conducting three-yearly
reviews of quotes for the facilities in service, and yearly reviews for the
quotes for the dismantling and waste recovery and conditioning work that is
in progress. Those reviews make it possible to take developments in the economic, technological, and regulatory parameters into account as they happen. In addition, the sensitiveness analyses conducted on the dismantling costs do not incorporate the favourable effect of the “learning-curve”: dismantling the latest units will be less costly than dismantling the first ones. In addition, for the latest facilities, the issue of dismantling was taken on board as of the design stage. As regards the facilities operated by AREVA, this applies particularly for UP2/800 and UP3 (La Hague), George Besse II (Tricastin), and Melox (Marcoule).

**AREVA has skills and experience in dismantling.**

Finally, the experience acquired by AREVA in the field of dismantling will enable the dismantling costs of the nuclear sites of the Group and of its customers to be optimized. The dismantling “business” is now occupying 1,500 members of staff who are trained in all of the trades from project management, design engineering, and cleanup/dismantling to site operation or waste management. Beyond its major historic presence in France in various projects (in particular at the Hague for AREVA, Marcoule on behalf of the CEA or Superphénix (Superphoenix) on behalf of EDF), AREVA has also deployed its know-how in the United States for the Department of Energy (DOE), or in Germany.

**The deep repository for disposing of nuclear waste is a general-interest project for France.**

The report concludes that the forecasts for spent fuel management are reliable. The only major unknown quantity concerns the cost of deep disposal/storage. ANDRA’s quote for the project firstly calls for a remark on the method. Responsible management of the waste produced by 50 years of service of the French nuclear power plant fleet is a general-interest issue. The missions assigned to the future site, the accompanying technical specifications, and the related costs should be a collective and transparent choice, and in particular the result of concerted action by the relevant entities, all of whom are public: ANDRA, EDF, AREVA, the CEA, and the ASN. Some assert that involving the operators EDF, AREVA and the CEA in the work of ANDRA would be morally harmful. On the contrary, it follows from a principle of good governance, given the long-term financial issues underlying this project indirectly for the community. The idea is to put the expertise of the public sector operators, including AREVA, at the service of technically and economically optimizing the project. Similarly, co-ordination between all of the public players in the nuclear power sector, in particular between the ASN and ANDRA is essential in order to guarantee a solution that is industrially and economically optimal for each category of waste.
The cost of nuclear-generated electricity is relatively insensitive to the cost of deep disposal/storage.

In view of its importance; the deep repository project requires the best practices to be applied in terms of design and of cost optimization. Regarding the uncertainty of the future expenses related to geological storage, we should keep things in proportion: the report by the Cour des Comptes considers that the cost of producing electricity is only marginally sensitive to variations, even large variations, in the cost of deep disposal. Taking the latest ANDRA quote (i.e. doubling of the cost of disposal) as an assumption, the Cour des Comptes concludes that the annual cost of producing electricity would increase by only 1 percent.

The cost of deep disposal would increase substantially if France were to discontinue spent nuclear fuel processing and recycling.

Processing and recycling makes it possible to recycle recyclable materials and to divide the volume of waste by 5 and the radiotoxicity of the waste by 10. The report considers that direct storage of any given volume of spent fuel would cost twice as much as storing the same volume after it has been processed. This extra cost for direct storage lies in the lower range of the ANDRA estimates. If we refer to the quotes established by ANDRA in 2003, discontinuing of processing, leading to direct storage of spent fuels, would increase the overall cost of disposal by a factor of 3.5 in the upper range.

The choice of processing and recycling is strategic for France.

The advantage of processing and recycling is now established. It consists in recovering substances that still have high energy potential from the spent nuclear fuels taken from the reactors, with a view to re-using those substances. Processing and recycling today generates a saving of nearly 20 percent in natural resources. Recycling plutonium in the form of MOX fuel should not be demonized, in particular since the use of MOX fuel contributes to combating nuclear proliferation by “burning” in the reactor the plutonium coming from spent fuels. The EPR can currently operate with 50 percent MOX fuel. The project for an EPR that is 100% MOX-fuelled is progressing. It is in processing and recycling that the industrial and technological leadership of the French nuclear power sector is the strongest. The unique expertise that France has gives it a significant competitive edge, with China, Russia and India having chosen to go down the route of the closed fuel cycle, i.e. processing and recycling.

The costs of the nuclear power sector are not being passed on to future generations.

Although the costs of the nuclear power sector are generally well defined, periodically reviewing the future expenses of the sector is essential. In this regard, I consider that AREVA has been exemplary. The uncertainties
about the costs of dismantlement and of nuclear waste management require particular watchfulness. However, the report shows that the cost of producing electricity from nuclear energy is very insensitive to variations, even large variations, in such costs. Thus, the uncertainties about these two items do not give rise to a risk of undermining the cost advantage that nuclear power procures for France as regards electricity generation. Conversely, the volatility of the prices of hydrocarbons and of CO₂ give rise to substantial uncertainties about the electricity production cost of gas-fired or coal-fired power plants. In the event gas prices double (which is quite possible given the volatility observed in the past) the electricity production cost of a power plant of the Combined Cycle Gas Turbine (CCGT) type would increase by about 60 percent. Similarly, a doubling of the price of CO₂ mechanically generates a rise of about 30 percent in the electricity production cost of a coal-fired power plant. An electricity producer then has no choice but to pass that cost ultimately onto its customers.

I take from the Cour des Comptes report that, in spite of some residual uncertainties, the costs of nuclear power are estimated correctly and are not passed on to future generations. Moreover, they are lower and more predictable than the costs of alternative solutions for generating the electricity that France needs. It is essential to base analyses on the facts, and to be as objective as possible about the always controversial and often emotional subject of the costs of nuclear power. In this respect, the Cour des Comptes has placed an important marker in the public debate about France’s energy policy.

Given the strictly confidential nature of this disclosure, it has not been possible for me to receive the observations of the National Committee for the Evaluation of Funding for the costs of dismantling basic nuclear installations and spent fuel and radioactive waste management (CNEF) who, in its session of 7 June 2011, asked me to lead its work.

Therefore, at this stage, the document does not call for any reply.
REPLY FROM THE CHAIRPERSON OF THE COMMISSION DE RÉGULATION DE L’ENERGIE (CRE, THE FRENCH ENERGY REGULATORY COMMISSION)

The memo enclosed with the present letter constitutes the reply from the CRE to the draft report.

In the first part, this reply contains an analysis of the three methods of assessing the cost of the nuclear power sector that are presented by the Cour des Comptes, of the economic principles that they reflect, and of the objectives that they pursue, in particular about the issue of evaluating and taking into account the cost of capital. This analysis concludes with a few proposals for amending the draft report, essentially intended to define more precisely the scope and the field of application of the costs resulting from the three methods, in particular in view of the Regulated Access to Historic Nuclear Energy (ARENH) prices, which the CRE will have the task of calculating as from 8 December 2013.

In the second part, the memo makes a more detailed examination of the Current Economic Cost (CEC) method, proposed by EDF, and in particular of the limitations of that method.

The final part is devoted to evaluating and taking into account the long-term expenses relating to EDF’s nuclear power plant fleet – dismantling, deconstruction, and waste management, the CRE considering that it is necessary to reprocess some of the waste.

Observations of the Energy Regulatory Commission on the draft public report on the topic of the cost of the nuclear power sector, written by the Cour des Comptes

1. The various methods described by the Cour des Comptes in its draft report do not pursue the same objectives

In its report, the Cour des Comptes mentions three methods of evaluating the cost of nuclear power:

→ the method presented by Mr Champsaur in his report of March 2011, and taken up to a large extent by the CRE in its deliberation of 5 May 2011 giving an opinion on the draft order setting the ARENH price at €42 per MWh at 1 January 2012;

→ the Full Cost Accounting (FCA) method originally designed for calculating a production cost (electricity generation cost) over the entire EDF power plant fleet, and making it possible to replace it;

→ and finally the Current Economic Cost (CEC) method proposed by EDF.
Although the Cour des Comptes points out in part I-A of the general conclusion of its draft report that those methods pursue different objectives, it appears to the CRE important to explain precisely what those objectives are, which is the purpose of the following paragraphs.

1.1 The “current economic cost” reflects what a supplier would consent to pay to EDF for renting its historic nuclear power plants rather than rebuilding them. It includes, by design, replacing them at the end of their lives.

The Cour des Comptes points out, in b of Annex 12 of its draft report that “in view of the allotted time, only the CEC method was able to be reviewed in depth” for calculating the cost of producing electricity from nuclear energy. That method consists in summing:

- A capital annuity, representative of the economic value of the nuclear power plant fleet, expressed by a constant “rent” in constant euros, and whose calculation formula results from applying the CEC method explained below:

- Actual operating costs (fuel costs, other external consumption costs, taxes and duties, staff expenses, other operating expenses and earnings, and support and central function costs);

- Future maintenance costs for the nuclear power plant fleet, accounted for as fixed assets.

A CEC method is based on a “make or buy” rationale. As indicated by the French Electronic Communications and Postal Sector Regulator (ARCEP) that method “aims to render neutral for client operators the decision to rent the infrastructure or to rebuild it”. It is thus based on defining a “rent”, paid by a client operator or holder of the infrastructure throughout the life of the asset, which, in the present case, translates as what a supplier would consent to pay for using the existing nuclear power plant fleet rather than rebuilding it. That method de facto enables the owner of the nuclear power asset to be reimbursed and remunerated for its investments, at their value as reassessed at the end of their lives, i.e. to replace the nuclear power asset at the end of its service life at its reassessed value.

1.2 The Full Cost Accounting (FCA) cost of electricity production reflects the impact of the erosion in the purchasing power of money (due to

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254 The “Consultation sur les méthodes de valorisation de la boucle locale cuivre” (“Consultation on the methods of valuation of the copper-wire local loop” by ARCEP (2005) presents a comparison of various possible different methods of valuating an asset, and in particular of the current economic cost method.
inflation) while preserving a cost accounting structure, and implies replacement of the electricity-generating fleet.

The FCA method is a method proposed by EDF and built on the basis of traditional accounting rules with linear depreciation of the asset at its gross acquisition value. Into this basis for accounting, EDF incorporates the impact of the erosion in the purchasing power of money by revaluing the asset every year and then calculating an extra capital cost allowance corresponding to the additional depreciation that should have been accounted for to enable the asset to be amortized linearly at its reassessed value.

The FCA method cannot be used to establish the ARENH price. The annual revaluation of the asset presupposes that the revaluated capital is recovered at the end of the life of the asset and thus that it is possible to replace the asset, even though Article 366-8 of the Code de l’Énergie (French Energy Code) stipulates as explained in detail below in point 1.3.2 that the replacement should be taken into account in the final price of the electricity for the consumer and not in the ARENH price.

1.3 The ARENH price reflects the full cost of the French nuclear power plant fleet, already partially amortized, exclusive of the cost of replacing it. The approach thus differs radically from the CEC and FCA methods.

1.3.1 The legislative framework makes provision for the economic benefits of nuclear power to be transferred from the electricity producer EDF to the end consumer.

Implementing regulated access to historic nuclear energy (ARENH) is the result of thinking over a long period by the public authorities about how the electricity market should be organized in France in order to comply with the principle of an open market and free competition. The Commission sur l’organisation du marché de l’électricité (Commission on organization of the electricity market), chaired by Mr Paul Champsaur, put forward its guidelines in its report of April 2009.

That report states, in particular, that “if the price of electricity should make it possible to fund the necessary investments and to encourage virtuous behaviour, it is legitimate for the French consumer to benefit from the competitiveness of the French electricity generating capacities”.

Based on the conclusions of that commission, the legislator enacted the Act of 7 December 2010 on the New Organization of the Electricity Market (“NOME” Act). That Act, which has subsequently been codified in the Code de l’Énergie (French Energy Code), provides that “in order to guarantee freedom of choice in selecting an electricity supplier while also enabling the attractiveness of France and all consumers to benefit from the competitiveness of the French nuclear power plant fleet, regulated and
limited access to historic nuclear power, generated by the nuclear power plants mentioned in Article L. 336-2, is opened for a temporary period defined in Article L. 336-8 for all operators supplying end consumers residing in the home country of continental France or grid operators for their losses.

This regulated access is granted on economic terms equivalent to those resulting for EDF of using its nuclear power plants mentioned in Article L. 336-2255.

That article expresses the fundamental principles underlying the setting up of the ARENH, those principles being described in the statement of reasons for the NOME Act: "the French Government considers it inviolable to maintain electricity prices based on the economic conditions of the French power plant fleet, and in particular on its high proportion of nuclear power, which is not reflected in the prices observed on the European wholesale electricity markets. [...] This bill will thus contribute to putting in place targeted and effective regulation of the electricity market that will enable consumers to continue to benefit from the investment made in developing nuclear power, while also fully developing innovation and choice for the consumer”.

The legislator thus clearly indicates that the purpose of the ARENH system consists in passing on to the consumer the economic advantage represented by the French nuclear power plant fleet in its current state, i.e. while taking account of the fact that it is already partially amortized, and therefore, while taking account of its real electricity production cost for EDF.

1.3.2 Until any application of the revision clause provided in its Article L. 336-8, the French Energy Code excludes any taking into account of replacement of the generating facilities

The ARENH price is built from the costs relating to the historic nuclear power plant fleet. In its Article L. 336-2, the Code de l’énergie specifically indicates that the power plants to be taken into account for calculating the ARENH price are the ones that were commissioned before 8 December 2010, i.e. the 58 power plant units currently in service, excluding de facto any project for replacement or new power plants such as the EPR project in progress for Flamanville 3 and limiting the scope of the ARENH price to the existing power plant fleet.

Article L. 337-14 of the Code de l’énergie identifies the costs that the ARENH price should cover. That price should take into account:

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255 Article L. 336-1 of the “Code de l’énergie”.
1 Remuneration for capital taking account of the nature of the activity;
2° The operating costs;
3° The costs of maintenance investments or investments necessary for extending the authorized service life;
4° Forecast costs related to the burden of long-term expenses on operators of basic nuclear installations mentioned at I of Article 20 of Act No. 2006-739 of 28 June 2006 on sustainable management of radioactive waste and materials”.

Furthermore, the possibility of taking replacement of the power plants into account in the ARENH price has been formally ruled out by the European Commission.

Finally, Article L. 336-8 of the same code stipulates that the French ministers for energy and for the economy may, before 31 December 2015, and then every five years, on the basis of reports by the Commission de régulation de l’énergie (Energy Regulatory Commission) and by the Autorité de la concurrence (French competition authority), “progressively take into account the costs of developing new electricity-generating capacities in the price of electricity for end consumers, and put in place a specific system making it possible to guarantee setting up of appropriate financial resources for replacing the nuclear power plant fleet.”

Thus, replacement of the nuclear power plant fleet may be taken into account progressively in the price of electricity for end consumers – and not in the ARENH price – by the public authorities.

1.3.3 In conclusion, the current economic cost method and the calculation of the ARENH price pursuant to the provision of the Code de l’énergie differ radically in their purposes

The ARENH price is defined as a value representative of the cost of producing electricity from nuclear energy in the specific context of the French nuclear power plant fleet while taking account of the historic advantage that it offers. This price cannot therefore be separated from the intrinsic historic elements of the fleet.

A second Commission, chaired by Paul Champsaur, was set up at the request of the French Government to address the methods of setting the ARENH price. Its report, published on 7 July 2011 on the website of the French Ministry for Ecology, Sustainable Development, and Housing, also specifies that “the nuclear power plant fleet is now 26 years old: it is therefore economically middle-aged. The past investments have already been paid back in part by the sale of electricity since the middle of the nineteen eighties”.
The draft report by the Cour des Comptes studies the current economic cost method. Since the cornerstone of that method is staggered reimbursement, over the entire life of the asset, of the capital initially invested, at its reassessed value, that method leads to a level of valuation of the asset that is detached from the historic elements that are considered in determining the ARENH price.

The CEC method therefore pursues a purpose different from the one pursued in determining the ARENH price in compliance with the provisions of the French Energy Code, in that it endeavours to determine an electricity production cost that reflects the value that an economic player entering the nuclear energy procurement market might give to EDF’s historic nuclear power plant fleet, and not the value that any French consumer might give to the same fleet pursuant to the NOME Act, which gives the consumer the possibility of benefiting from the economic advantage offered by the nuclear power plant fleet that is already partially amortized. That Act also stipulates that the ARENH price should cover the costs related to extending the service lives of the reactors, where applicable, but not the cost related to replacing the nuclear power plant fleet at the end of its life. By valuating the electricity-generating asset by means of an economic method reassessing the historic power plant fleet at its present-day value, the CEC method participates implicitly to some extent in replacing it at the end of its life, and therefore differs structurally from the approach adopted by the Champsaur Commission. Furthermore, the approach of that commission is based on valuating a nuclear power plant fleet that is already partially amortized, pursuant to the statement of reasons for the NOME Act, and may not de facto ignore the reality of how the nuclear power plant fleet was handled in the past, while the method developed herein by the Cour des Comptes must be understood to cover the entire life of the fleet.

In subsidiary manner, the CRE considers it important to remember that the CEC method cannot and must not be compared with the exercise of setting the regulated sales price for electricity, that exercise being based on the principle of covering the real costs, as they are borne every year by the operator. These two exercises are quite different: the CEC method attempts to give a snapshot at a given time of the overall average cost of the nuclear power plant fleet, using a calculation methodology that is applicable throughout the life of the fleet, whereas setting the regulated sale price year after year, which is necessarily dynamic, must aim for the costs borne year after year to be actually covered ultimately over the entire life of the fleet. The past rules for changing regulated electricity sale prices have not necessarily coincided with the CEC method for calculating the overall average cost. In addition, even when the methods might have coincided, the underlying assumptions would not have been the same (life spans, long-term expenses).
1.4 Other observations

The CRE would point out that there is no relationship between the full cost of historic nuclear-generated electricity, which must be covered by the ARENH price and for assessment of which the CRE established the relevant method to be used in its opinion of 5 May 2011, and the requirement of convergence with the Tarif règlementé transitoire d’ajustement au marché (TaRTAM, the Transitional Regulated Tariff for Balancing Markets). It therefore considers that it is important to remove any reference to that tariff in the description of the method.

2. The CEC method reviewed by the Cour des Comptes presents characteristics that directly influence the bearing of its results

2.1 The CEC method has certain weaknesses

2.1.1 The high sensitiveness of the CEC method to the rate of remuneration of capital and, conversely, its lack sensitiveness to the length of life of the asset are its two main weaknesses

The respective sensitivities to discount rate and to length-of-life are explained in Annex 12 of the draft report by the Cour des Comptes, and they highlight the difficulty of using the CEC method in valuating the nuclear power plant fleet. The extreme sensitivity to Weighted Average Cost of Capital (WACC) weakens the results and the insensitivity to length of life gives a poor reflection of the reality of lengthening the use of the nuclear power plant fleet.

Although the EDF historic nuclear power plant fleet differs in various aspects from the copper-wire local loop, an essential utility that there is no point in duplicating, it does have a property in common with that utility, namely its very long and very uncertain life, in comparison to traditional industrial assets. A CEC method is thus no better suited to the nuclear power plant fleet than it is to the copper-wire local loop for which ARCEP asserted that it seemed that such a method “should not be adopted for the local loop and for unbundling, due to the presence of assets having lengths of life that are long and uncertain”.

2.1.2 The CEC method does not take into account past investment made in the nuclear power plant fleet

The “rent” is the same regardless of whether the asset is dilapidated or recently renovated, because it is determined on the basis of the initial investment. Regardless of the past investments made in the nuclear power plant fleet, the amount of the “rent” remains unchanged.
2.1.3 The CEC method does not express the financial impacts induced by lengthening the service life of the nuclear power plant fleet

Lengthening the service life has a major impact on the valuation of the nuclear power plant fleet, in particular on its residual value, which is not transcribed by the "rent" of the CEC method. In this respect, the CRE subscribes to the analysis of paragraph b) of Annex 12 of the draft report by the Cour des Comptes.

Lengthening the service life also has the following consequences:

- A reduction in the annual provisions made for depreciation (capital cost allowances), which has a significant impact on EDF's accounts.

- A deferral of the disbursement of money set aside for hedging (covering) long-term expenses, which therefore reduces the amount of the provisions to be set aside.

The cash-flow effects induced by lengthening the service life, briefly described above, are not passed on in the CEC method, even though they have impacts on the economic value of the nuclear power plant fleet.

2.2 All of these elements limit the use of this method for the historic nuclear power plant fleet under uncertain operating and length-of-life conditions

The CRE considers that the drawbacks mentioned above in paragraph 2.1 raise the question of the legitimacy of using the CEC method for a historic nuclear power plant fleet whose life span is currently unknown.

It considers that these weaknesses should be recalled in the general conclusion of the draft report.

3. The handling of future expenses in the method proposed by the Cour des Comptes calls for debate both on substance and on form

The future expenditure corresponds to expenses that are definite or that are highly likely to be required, and that will not need to be disbursed until relatively long times into the future. In the context of operating a nuclear power plant fleet, such expenditure corresponds to spending related to (i) dismantling the reactors once they have reached the ends of their lives; (ii) managing or processing the fuel present in the reactor at the time it was permanently shut down, or the “last-core”; (iii) managing and processing the spent fuel unloaded from the reactors at the end of each production cycle, and finally (iv) expenses for long-term management of radioactive waste, be it reprocessed spent fuel or pieces or parts resulting from dismantling the reactors.

Since this spending should not need to be made until points in time that are remote from the points in time at which the need for it appears (after
the reactor is permanently shut down for dismantling costs, last-core expenses, and some of the expenses for long-term management of radioactive waste, at the end of each production cycle for the spent fuel management expenses, and the remainder of the expenses for long-term management of radioactive waste), a time lag appears that needs to be expressed in the accounts by discounting these expenses and setting aside provisions corresponding to their discounted values. Every year, an accretion charge classified as a financial expense increases the amount of the provision so as to mark the fact that the date at which the disbursement of the spending is approaching. This mechanism is also well explained in part I-B-2 of the report’s chapter dealing with future expenditure.

3.1 The choice of incorporating the expenses for long-term management of radioactive waste into the operating expenses is debatable

The asset base to be considered for calculating the “rent” is, due to the sensitivity of the calculation to the amount for that base, an important point to consider. The Cour des Comptes describes the items that it has chosen to include in this asset base in part I-A of its general conclusion.

The Cour des Comptes has chosen to include in this basis for the “rent” all of the expenses related to the original construction of the nuclear power plant fleet. It also includes the forecasts for deconstruction and last-core costs established by estimating the future expenses that will be represented by dismantling and by managing and/or processing the fuel present in each reactor when it is shut down, as the reactors are decommissioned.

This choice of incorporating the future expenses is based on the obligation imposed by the Act of 2006 relating to sustainable management of radioactive waste and materials on any nuclear power operator to set aside provisions for the future expenses related to deconstruction, and to cover/hedge these expenses by setting up dedicated assets satisfying liquidity and good-management criteria.

The Cour des Comptes has already addressed the history of the setting up of these provisions and of the dedicated assets that are attached to them in its report on dismantling nuclear facilities and on managing radioactive waste published in January 2005. That report sheds light in particular on how the dedicated assets have been being set up progressively via an obligation written into the contracts between EDF and the French State since 1997.

In practice, the dedicated assets were not therefore set up on commissioning the power plant units whose dismantling they cover, but rather much later in view of the large sums they represent, in a manner
spread over several years\textsuperscript{256}. The method used in the present survey by the Cour des Comptes, by being based on the principle of the replacement cost, does not take into account the accounting past of the nuclear power plant fleet. It therefore appears logical to take all of the assets necessary for the electricity generating activity into account in the asset base to be remunerated with the “rent”. In this respect, the dedicated assets covering the dismantling, for an original value equal to the discounted deconstruction costs should rightly be taken into account.

However, the Cour des Comptes has chosen not to take account of the dedicated assets related to long-term management of radioactive waste. And yet the future expenses covered by those assets are also addressed in the Act of 28 June 2006. In its report, the Cour des Comptes takes these items into account in the operating expenses by including in the costs related to nuclear fuel the net amounts set aside as provisions and the financial accretion expenses attached to these two items. This approach (although as it currently stands it contains an error that is discussed below) can be justified if it is desired to reconstruct a full fuel cost incorporating all of the manufacturing, reprocessing and long-term management costs. Conversely, in a method such as the CEC method, in which the “rent” is based on an estimate of the value of the power plant fleet, it would be more consistent to incorporate all of the dedicated assets into the base for the calculation.

The Cour des Comptes justifies not taking the dedicated assets into account in the asset base by the fact that they are accounted for as operating expenses\textsuperscript{257}. However, the asset representing the forecast cost of the deconstructions and the asset corresponding to reprocessing of the last cores are incorporated in the asset base for calculating the “rent”, even though the same legislation, relating to covering them, applies to all three of these future expenses. There is indeed therefore tied-up capital intended for funding the setting up of a portfolio of financial assets dedicated to covering/hedging these long-term radioactive waste management expenses.

The CRE therefore deems it preferable to handle the costs of long-term management of radioactive waste within the asset base involved in calculating the “rent” rather than as current operating expenses. The advantages of such handling compared with how the Cour des Comptes has handled them would be:

- to comply as well as possible with the legal framework governing any nuclear power plant operator;

\textsuperscript{256} It is recalled that EDF currently has a time limit extending until 30 June 2016 within which to set up all of the dedicated assets pursuant to Article 20 of the Act of 28 June 2006, amended by Article 20 of the Act of 7 December 2010.

\textsuperscript{257} cf. Section I-B-3 of the report’s chapter on future expenditure.
to ensure consistency in accounting for dedicated assets for
covering long-term expenses because all three points constituted by
dismantling the power plants, by reprocessing the last cores, and by
long-term management of radioactive waste would then be handled
in similar manner;

- to ensure consistency between dismantling and last-core processing
costs and the share of the radioactive waste from those two
operations in long-term management expenses;

- to have the nature of those expenses correspond to the funds
committed for funding them, i.e. the tied-up capital for acquiring the
dedicated assets.

Naturally, it can be noted that the expenses for long-term management
of radioactive waste, which are going to materialize through the construction
and the management of a storage/disposal site such as the one currently
being envisaged on the site of Bure, and through conditioning and packaging
the waste for storage on that site, will not all be pushed further into the future
if the service life of the nuclear power plant fleet is extended. An extension in
the lives of the power plants will produce two main effects: (i) it will increase
the quantity of waste from spent fuels at distant points in time; and (ii) it will
defer the management of the waste from dismantling to dates even further
away in time. Through the effect of discounting, those additional future
expenses will weigh to only a small extent and will give rise to only a small
increase in the expenses for long-term management of radioactive waste.
This aspect should thus be addressed specifically in the context of a
calculation with an assumption of a lengthening in the life of the fleet.

3.2 Taking accretion expenses on the provision for long-term
management of radioactive waste into account in the operating expenses
leads to overvaluation of those operating expenses

Respecting the choice of the Cour des Comptes to incorporate the
expenses for long-term management of radioactive waste into the operating
expenditure and taking its analysis further, the CRE is led to make another
remark relating to taking the accretion expenses into account in the
operating expenses.

In the context of setting aside provisions for long-term future
expenses, the gross amount of these expenses is, as provided for by law258 and
as authorized by the accounting regulations, discounted in order to show up
the remoteness in time of the disbursement of the expenditure. The Cour des
Comptes, in constructing the operating expenses related to nuclear fuel, has

258 cf. Article 3 of the Decree of 23 February 2007 relating to securing the funding for
nuclear expenses.
chosen to incorporate the net operating provisions and the accretion expenses relating to the provisions for long-term future expenditure 259.

Setting aside net operating provisions represents an increase in the final gross expense (be it for taking account of a new item of expenditure or indeed for a reassessment of the expected cost) and it is therefore legitimate to incorporate such provisions into that cost. Conversely, the accretion expenses should not appear therein.

The expenses for long-term management of radioactive waste are, like the deconstruction expenses and a fraction of the last-core expenses, covered by a portfolio of dedicated assets. The discount rates for the provisions must, as required by the regulations 260, be no more than the average yield expected from the hedging assets, i.e. the covering assets. By way of simplification, it is considered, when projecting ourselves into the future, that the yield on the dedicated assets is equal to the discount rate on the provisions.

By means of the hedging/covering mechanism, the provisions set aside correspond to the amount of the dedicated assets that the firm must acquire to cover the new expense observed and, conversely the amounts drawn back from provisions corresponding to the sale of dedicated assets in order to cover the expenditure at the time it needs to be made. Accretion expenses reflect the yield on the dedicated assets, plus or minus the variations in the real yield observed on those assets. It should also be noted that accretion expenses make it possible not to penalize the firm from a tax point of view by wiping out the financial earnings generated by the yield on the dedicated assets.

Two options are possible ultimately for handling accretion expenses corresponding to the yield of a portfolio of dedicated assets such as those related to the provisions for long-term management of radioactive waste:

the Cour des Comptes may choose to have all of the items appear; it is then necessary to incorporate: (i) the net operating provisions set aside (or drawn back), expressing the purchase (or sale) of hedging assets; (ii) the accretion expenses; and finally (iii) the financial earnings corresponding to the yield on the dedicated assets and offsetting the discount expenses;

or else it may decide to simplify the calculation by only taking into account the net operating provisions set aside (or drawn back), while specifying that the accretion expenses are covered by the

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259 cf. Section I-B-3 of the report’s chapter on future expenditure.
260 Article 3 of the above-mentioned Decree of 23 February 2007 provides that “this discount rate may not exceed the yield, as anticipated with a high degree of confidence, of the hedging assets ... “.
financial earnings corresponding to the yield on the dedicated assets.

As the method of the Cour des Comptes currently stands, the accretion expenses taken into account in the calculation of the operating expenses should be reduced by the amount of the accretion expenses on the provisions for long-term management of radioactive waste covered by the dedicated assets, i.e. €2010313 million so as to consider only the discount expenses on the provisions for spent fuel management that are not covered by a dedicated asset, for an amount of €2010427 million. The impact of this correction is €20100.8 per MWh.

3.3 The amount for the future expenses that is used in the asset base for the “rent” should be discounted to reflect the capital invested in covering/hedging those expenses

In part I-A of the general conclusion of its report, the Cour des Comptes lists the items taken into account in the capital investment to be considered. It mentions the amounts of the construction investments that have been made (including interest during construction), the maintenance investments, and finally the future expenditure related to dismantling. The grand total is €2010118.2 billion excluding annual maintenance investment assessed at €20101.7 billion.

However, that figure of €2010118.2 billion represents the sum of two elements: past spending for €201096 billion and future spending for €201022.2 billion. If both of those elements need to be reduced to 2010 value in order to do the calculations in constant euros, the future expenditure must also be discounted at the rate defined by law261 (3 percent real) over a period equal to the life of the reactors (40 years).

The amount of the future spending used by the Cour des Comptes corresponds to the gross future expenses, namely the total amount that would have had to be disbursed for dismantling the nuclear power plants in 2010, the year used as a reference by the report. As recalled in paragraph 3.1 of the present memo, the future expenses related to dismantling should be covered by dedicated assets set up, unless authorized otherwise by derogation, at the time of commissioning each reactor for an amount equal to the future items of expenditure that they cover at their discounted value.

The cover/hedging thus requires the owner of the power plant to acquire a portfolio of dedicated assets for which the initial value increased year after year of its cumulative yield will ultimately make it possible to set up a reserve of liquidity that is sufficient to pay for the expenses covered. By means of this mechanism, the legislator ensures that the owner of the power

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261 cf. Article 3 of the Decree of 23 February 2007 and Article 3 of the Order of 21 March 2007, both relating to securing funding for nuclear expenses.
plant will be financially able to dismantle the plant and to manage the radioactive waste.

The owner is thus constrained to invest capital equal to the discounted amount of the dismantling costs and last-core costs at the time of commissioning the power plant. The difference between the invested capital and the amount of the future gross expenses corresponds to the expected yield from the portfolio of dedicated assets.

In the calculations of the Cour des Comptes, although the gross dismantling and last-core expenses are indeed corrected for inflation, they are not discounted, thereby leading to remuneration of capital that the owner of the power plant has never had to invest. Discounting the dismantling and last-core expenses gives an amount of €20105.3 billion. The amount of €2010118.2 billion thus includes fictitious capital of €201016.9 billion.

The CRE thus recommends altering the amount of the investment taken into account for calculating the “rent” of the method of the Cour des Comptes by discounting the future expenditure in compliance with the legal and accounting framework so as not to overvalue the initially invested capital. That correction gives a reduction in the “rent” by about €20101.4 billion, i.e. €20103.3 per MWh.
REPLY FROM THE PRESIDENT OF THE ASSOCIATION NATIONALE DES COMITÉS ET COMMISSIONS LOCALES D’INFORMATION (ANCCLI, FRENCH NATIONAL ASSOCIATION OF LOCAL INFORMATION COMMISSIONS AND COMMITTEES)

You passed on an excerpt from the draft public report on the costs of the nuclear power sector, for which the ANCCLI has no observation to make apart from a few editing proposals for changes of wording.
REPLY FROM THE CHAIRPERSON OF THE AUTORITÉ DE SURETÉ NUCLÉAIRE (ASN, FRENCH NUCLEAR SAFETY AUTHORITY)

The ASN considers that this report is extremely interesting, addresses fundamental issues, and raises subjects of concern that are shared by the ASN.

1. Importance of social, organizational, and human factors

As the ASN recalls in its opinion of 3 January 2012 enclosed with the present letter, nuclear safety cannot be reduced to an accumulation of technical measures; nuclear safety is based mainly on humans.

Managing the organization of work and of human resources, and the interactions between humans in their working environment, play an important part in preventing and managing incidents and accidents. They constitute what is commonly known as “social, organizational and human factors”. They are essential elements in nuclear safety, the costs of which are given in detail in the report by the Cour des Comptes.

The ASN thus pays particular attention to social, organizational and human factors. The ASN will be attentive to the replacement of the staff and of the skills of the operators, which is an essential point during the coming period in which major generational changeover will take place simultaneously with considerable work following the Fukushima accident, and will also be attentive to the organization of the use of subcontracting.

2. Research

The ASN emphasizes the importance of research, in particular in the field of nuclear safety and of radiation protection, in order to have robust technical expertise based on the best available knowledge.

The ASN thus considers that, regardless of the energy options taken, investment in nuclear safety and radiation protection research should remain substantial. That spending could be incorporated into the standardized classification of expenditure in order to be clearly identified.

In addition, the ASN recalls that it wishes to be consulted on the focuses for nuclear safety and radiation protection research. In order to take its decisions, it must have quality expertise based on the most recent scientific and technical data. Pursuing this logic, the issues that the ASN will have to address ten, fifty, and twenty years from now should be anticipated, and, as of now, the research programmes enabling it to have the necessary knowledge by the desired time should be constructed. To this end, in 2010, the ASN set up a scientific committee chaired by Ashok Thadani, former Director of the Office of Nuclear Regulatory Research at the United States Nuclear Regulatory Commission (NRC).
Currently, the ASN considers that the main nuclear safety and radiation protection research operators (CEA, IRSN, ANDRA, EDF, and AREVA) have knowledge that is diversified and of the best possible scientific level. However, it believes it is necessary to reinforce the resources and the skills of the other public-funded research bodies (CNRS, etc.) so as to back up its expertise and the independent expertise upon which the “commissions locales d'information” (CLIs, local information committees) might call.

Finally, as regards research into the nuclear reactors of the future, the ASN recalls the importance, reinforced after the Fukushima accident, of comparison in terms of safety between the various types of fourth-generation or “Generation IV” reactors, and of the aim for those reactors of attaining a safety level superior to the safety level of the EPR.

3. Clarity of the cost of inspection for nuclear safety and radiation protection

The ASN shares the conclusions of the Cour des Comptes, as expressed on page 69 about the need to review the complex budgetary organization for inspection for nuclear safety and radiation protection that clouds the overall clarity of the cost of such inspection, and that gives rise to difficulties in terms of budgetary preparation, choices, and implementation.

In its Opinion No. 2011-AV-0135 accompanying the present letter, the ASN renews its request for a budgetary programme to be set up devoted to inspection for nuclear safety and radiation protection in France, including, in particular, budget appropriations for expert assessments by the technical support team of the IRSN, and funded directly by the “INB” tax on basic nuclear installations.

This funding by the INB tax, or by any other contribution levied on nuclear operators, will make it possible to guarantee sustainable funding for inspection for nuclear safety and radiation protection to match the high level of the stakes. It follows on from the reform of funding for inspection for nuclear safety and radiation protection that was initiated by the revised budget act No. 2010-1658 of 29 December 2010, which instigated an additional contribution to IRSN budget appropriations through a contribution paid annually by operators. Furthermore, the ASN would remind the reader that the INB tax has, since 2000, been replacing the licence fee or charge and the stakeholder contributions (fonds de concours) intended to fund the safety expenditure of the ASN and of the IRSN. In addition, as noted by the Cour des Comptes in its report on page 76, the amount of this tax is greater than the amount of the public spending related to security, nuclear safety, and transparency.
4. Future expenditure

• Expenses related to dismantling nuclear facilities

The ASN also considers that the lack of assessment of the uncertainties and of justification of the level of contingencies induces a risk of underestimation of the financial costs of dismantling. The ASN thus attaches great importance to auditing the operators, as instructed by the DGEC, pursuant to Article 13 of Decree No. 2007-243 of 27 February 2007.

• Future expenses for radioactive waste management

Given the financial stakes of managing medium-level and high-level long-lived waste and given the very considerable uncertainties associated with putting a figure to the cost of that management, the ASN considers that a reassessment of the costs should be conducted without waiting for 2015. It also considers that it is necessary for those reassessed costs to be available for the public debate scheduled in 2013.

Financial coverage/hedging for future expenses

The ASN recalls the importance of the principle of financially covering nuclear expenses, as defined by the Act of 28 June 2006: “operators of basic nuclear installations shall set up the provisions relating to the (future) expenses and shall assign the necessary hedging assets exclusively to covering those provisions (...), it being stipulated that those hedging assets should have a degree of security and of liquidity sufficient for them to serve their purpose”.

In this respect, the ASN shares the concern expressed by the Cour des Comptes on the subject of the derogations that have been granted and that enable other types of assets to be recognized as hedging assets for covering nuclear expenses (RTE securities for EDF’s future expenses, AREVA securities, and above all receivables from the French State for the future expenses of the CEA).

Asked for its opinion on the draft decree No. 2010-1673 of 29 December 2010 that authorized those derogations, the ASN recalled in a letter sent to the Director General for Energy and Climate, enclosed with the present letter, that it considered that it was essential to maintain a sufficient level of robustness and of liquidity for the assets dedicated to covering the dismantling costs.

For the ASN, we should therefore be watchful to ensure that the system established through legislative and regulatory channels is stabilized in order to preserve its credibility, its soundness, and its clarity; otherwise some dismantling might not be able to be undertaken in due time.
5. The cost of a nuclear accident

The ASN emphasizes the importance of the subject addressed; whatever the efforts made for nuclear safety, the possibility of a nuclear accident in France can never be excluded; it is therefore essential to anticipate what actions would be necessary in such an event, in particular as regards paying compensation to the victims.

- Cost of a nuclear accident

The ASN shares the conclusions of the Cour des Comptes about the need to assess the cost of a nuclear accident in more depth. The preliminary estimates of the IRSN show that an average cost lying in the range €70 billion for a moderate accident on one nuclear power reactor similar to the accident that occurred on Three Mile Island in 1979 to €600 billion to €1000 billion for a very serious accident like the accidents at Chernobyl or Fukushima. It is important for research and surveys to be developed at national and international levels in transparent manner and with all sides being heard so as to assess the economic scale of a major accident for a country or group of countries. Such research and surveys could be based, in particular, on the precedent of the Fukushima accident.

- Ceilings on nuclear civil liability

The ASN considers that the current ceilings for the nuclear civil liability of operators (€91 million) are very insufficient and should be reviewed in order to enable victims to be compensated properly (population and industrial sectors affected by the accident). The ASN considers that it is urgent for the revision of these amounts as provided for by the protocols of 2004 to be brought into application, while also emphasizing that the new ceiling (€700 million) still only represents one percent of the cost of a moderate accident.

- Implementing financial guarantees

The ASN shares the concerns of the Cour des Comptes on the operational implementation of such guarantees in the event of a nuclear accident. Thinking on the subject was begun as part of the work of the steering committee for post-accident management of a nuclear accident (CODIRPA) that, since 2005, under the supervision of the ASN, has brought together representatives of the public authorities, of civil society, of operators and of insurers. Initial elements of doctrine have been established; it is up to the relevant ministries, operators and insurers to implement them.

6. Service lives of the nuclear power plants

It should be emphasized, as the Cour des Comptes does in its report on page 273, that the scenario implicitly adopted today is one in which the
service lives of the reactors are extended beyond 40 years, since the substitute electricity production capacities have not been anticipated.

This situation could, in the coming years, lead to a conflict between nuclear safety and security of energy supply.

The ASN recalls that, if so authorized, continued operation of the reactors beyond forty years will require attentive monitoring and inspection of the non-replaceable equipment (vessels and containment buildings) and significant improvements to the safety level of the current reactors, in particular as regards the risk of a serious accident, with, as a reference, the safety objectives of the new reactors (EPRs) and while taking on board the return on experience from the Fukushima accident. The ASN will ask for the nuclear facilities that cannot achieve these safety objectives to be shut down.

It is therefore essential to prevent insufficient electricity-generating capacities or the state of the grid from leading to situations in which the priority given to safety would be in contradiction with the principle of security of energy supply. In view of the time scales involved (several tens of years for replacing electricity production capacities), the ASN emphasizes the importance of anticipating the replacement of the electricity production capacities regardless of the mode of generation that is chosen, and regardless of the mode of distribution of the electricity grid.

Power plant service life is a strategic factor and should not be transformed into an adjustment variable.
REPLY FROM THE CHAIRPERSON OF THE OFFICE PARLEMENTAIRE D’EVALUATION DES CHOIX SCIENTIFIQUES ET TECHNOLOGIQUES (OPECST, THE FRENCH PARLIAMENTARY OFFICE FOR THE EVALUATION OF SCIENTIFIC AND TECHNOLOGICAL CHOICES)

The paragraph relating to the French Parliamentary Office for the Evaluation of Scientific and Technological Choices (OPECST) does not call for any comment on its substance.
In reply to your letter of 14 December, I am honoured to be able to give you my observations regarding the draft public report on the costs of the nuclear power sector. Please find appended a certain number of remarks and proposals for alterations that we would suggest you make, and formulations of some of our positions that we would ask you to include in the public report.

Firstly, I would like to emphasize the quality of the work done, the depth of the analyses conducted, and the constructive nature of the exchanges that we have had with your teams.

The central issue of this report is to determine the cost of electricity production for the existing nuclear power plant fleet. This cost that you assess at €49 per MWh in 2010 by using a pertinent economic approach confirms our own assessments and inspires me to make two observations:

It is greater than the electricity production share in the current regulated sale prices for electricity.

It remains substantially less than the cost of electricity production using any other current or future means, thereby justifying that we try to take best advantage of the existing nuclear power plant fleet for as long as possible, which will enable it to be replaced with the best possible technologies that will have reached maturity industrially.

This approach using the current economic cost is the only one of the methods studied by the Cour des Comptes that satisfies the requirements of the “NOME” Act, which, in its Article 1, specifies that “the [ARENH] purchasing conditions reflect the economic conditions under which electricity is produced by the nuclear power plants”. It makes it possible to reflect the industrial reality of the electricity sector, which is a highly capital-intensive industry that has very long cycles. In addition, it makes it possible, as you point out, to “include the cost of rebuilding the initially invested capital” reassessed to take account of inflation, no more and no less.

Any method assessing this cost on the basis of a net book value of the amortized asset, in particular if it does not take account of inflation, should clearly be disqualified. It would lead to structurally increasing the debt and would pass on the burden to future generations who will also have to bear the increased cost of the technologies for replacing the power plant fleet, regardless of the energy mix adopted in the future.

You also assess the cost of a standard Generation III reactor. We emphasize that industrialization of this reactor is in progress, through the return on experience between our various projects, and that that cost will, in
any event, remain competitive compared with the cost of conventional facilities.

We would also like to let you have our remarks on the following points:

1. Service life

Regarding the service life of the current nuclear power plant fleet, EDF is confident that it has the capacity to achieve the technical conditions necessary for operating its plant units up to service lives of 60 years. The benchmark data available to EDF backs up this confidence in its capacity: to date, 60 American power plants have already had their licences extended from 40 years to 60 years. The French Act of 13 June 2006 ("TSN" Act) makes continued operation dependent every ten years on a favourable opinion from the French Nuclear Safety Authority (ASN). We have started technical discussions with the ASN on the longer term, with the prospect of service lives of 60 years. For an industrial programme of that scale, it is necessary to be able to look ahead further than 10 years.

In addition, as regards the vessels and the containment buildings, they undergo very severe testing at every ten-yearly inspection, with a view to absolute compliance with safety requirements, under the independent supervision of the ASN.

2. Dismantling the power plants

Regarding deconstruction of our power plants that are in service, the provisions that EDF has set aside are validated by a detailed estimate of the costs of deconstructing a power plant known as the "Dampierre survey". The Dampierre survey is an extremely thorough and documented survey incorporating the return on experience from the deconstruction operations in progress on our first-generation power plants, and the return on experience from the operations conducted by other operators, in particular American operators, and as you yourself have emphasized, that survey is an extremely conscientiously conducted piece of work.

Moreover, the interpretation that you make of the international benchmark seems to us to be inappropriate. In particular, the reprocessing that you have done on the German and English estimates strongly underestimates the correction to be made for spent fuel management. Finally, I would remind you that the deconstruction costs will enjoy the same standardization effect as the effect we enjoyed during the construction of the power plant fleet: on average, the French power plants have cost half as much as the American power plants.

3. Storage/disposal of waste

As regards the provision for geological storage of radioactive waste, the report, in its formulations, seems to consider more or less implicitly that
that provision should ultimately be increased, on the basis of the 2009 ANDRA file. However, a process of consultation between the various stakeholders is in progress under the auspices of the public authorities, and the ANDRA project has now developed with the experience of the three operators (EDF, AREVA, and the CEA) having been taken into account. The 2009 file is no longer current today, and ANDRA should propose a new design file with new figures by the end of 2012. For that purpose, ANDRA will use an external prime contractor and will continue the exchanges begun with the nuclear operators on the issues of design and industrial production. It is on the basis of the new file that the French Minister for Energy will ultimately decide on discounting of the 2005 reference cost used in our forecasts, after hearing the opinions of the ASN and of the nuclear operators. The international benchmark, produced in in-depth manner by a third-party expert, that we have passed on to you and that I would like to included in the report, constitutes a useful element in appraising this cost, with regard to the international comparison items presented in the report that do not concern the countries that are most advanced on this issue, and could lead to a skewed interpretation given the different scopes covered by the estimates, in particular as regards the waste inventories.

4. Dedicated assets and RTE

As regards the “dedicated assets”, EDF fully assumes responsibility for managing them, pursuant to law, and our management of them is sound, prudent, and offers good performance. Our portfolio yields performance comparable to that of the best management companies. Since 2001, its performance has, eight times out of ten, been higher than its reference index, in a financial environment that has been particularly complex. Moreover, EDF considers that the expected yield should appreciate over a period consistent with the duration of the commitments they make it possible to cover. Observing yields over a period of four years is not relevant, in particular when it measures years affected by an economic recession.

As regards assigning 50% of RTE securities to the dedicated assets, I would point out that:

This operation received all of the necessary administrative authorizations.

The diversification that it brings to our portfolio makes it possible to reduce its risk for the same performance: obtaining this very positive diversification for our portfolio, without contributing RTE securities, would have led to the paradoxical obligation of acquiring other infrastructure assets that were more risky and outside France.

RTE is a regulated asset whose revenue comes from the users of the grid. The regularity of the dividends paid by RTE guarantees the stability of the value of the security and its level of liquidity.
This operation therefore in no way and at no time scale whatsoever leads to transferring to the French State any burden of funding for nuclear expenses.
REPLY FROM THE CHAIRPERSON OF THE BOARD OF
DIRECTORS OF THE AGENCE NATIONALE POUR LA GESTION
DES DÉCHETS RADIOACTIFS (ANDRA, THE FRENCH NATIONAL
RADIOACTIVE WASTE MANAGEMENT AGENCY)

Among these observations, I would like to give particular emphasis to the following points:

* On the assessment of the costs of storage in the Centre industriel de stockage géologique (Cigéo, Industrial Geological Repository): by the end of 2012, Andra will let the French Directorate General for Energy and Climate (DGEC), the nuclear operators, and the French Nuclear Safety Authority (ASN) have a new estimate range for the cost of the Cigéo repository, based on the outline research for the project.

- On handling of spent fuels: pursuant to the French Act of 28 June 2006, spent fuels taken from nuclear power reactors are considered as radioactive materials, for which subsequent use is planned or envisaged after processing. The feasibility of storing them has nevertheless been verified by Andra in the course of its 2005 File. The French National Radioactive Materials and Waste Management Plan (PNGMDR) for 2010-2012 also asks Andra to verify that the storage concepts would remain compatible with the assumption of storing the spent fuels if those materials were to be considered as ultimate waste. The preliminary technical and economic assessment of spent fuel storage that was conducted in 2003 could be updated early in 2013 on the basis of inventory scenarios to be defined with the French State and with the nuclear operators and on the basis of the new assessments of the cost of Cigéo.

- On the future needs for storage capacity: the forward-looking inventories are regularly updated when the national inventory is updated (next update in 2012). They show that the forecast inventories to be stored are ultimately greater than the capacities of the repositories in service (CSFMA, and CSTFA). Before considering creating new repositories, the efforts to reduce the volumes of waste to be stored (by compacting, processing, recycling, etc.) should be continued, and the possibilities of extending the capacities of existing repositories should be examined.
- On managing low-level long-lived waste: pursuant to the French National Radioactive Materials and Waste Management Plan (PNGMDR), Andra will submit a report to the French Government by the end of 2012 on the various management scenarios being studied for low-level long-lived waste and on the adaptations to be made to the site search approach, taking into account the recommendations of the Haut Comité pour la transparence et l’information sur la sécurité nucléaire (French High Committee for Transparency and Information on Nuclear Safety).

- On the dismantling costs: reinforced co-operation between Andra and the nuclear operators for defining dismantling strategies aiming to minimize the volumes of waste produced and the hazardousness thereof could contribute to reducing the costs.
I am honoured to inform you that I do not wish to make any reply to this disclosure.
### Glossary

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<tr>
<th>Acronym</th>
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<tbody>
<tr>
<td>NEA</td>
<td>OECD Nuclear Energy Agency</td>
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<tr>
<td>AFSSAPS</td>
<td>Agence française de sécurité sanitaire des produits santé (French Agency for the Safety of Health Products)</td>
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<tr>
<td>IAEA</td>
<td>International Atomic Energy Agency</td>
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<tr>
<td>ANCLI and ANCCLI</td>
<td>Association Nationale des Commissions (et des Comités) Locales d’Information (French National Association of Local Information Commissions (and Committees))</td>
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<td>ANDRA</td>
<td>Agence Nationale pour la gestion des Déchets Radioactifs (French National Radioactive Waste Management Agency)</td>
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<td>APEC</td>
<td>Atelier Pour l’Entreposage du Combustible de Superphénix (Superphénix Fuel Storage Facility)</td>
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<td>APM</td>
<td>Atelier pilote de Marcoule (procédé de vitrification) (Marcoule Pilot Facility (vitrification process))</td>
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<tr>
<td>ARS</td>
<td>Agence Régionale de Santé (Regional Health Agency)</td>
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<tr>
<td>ASN</td>
<td>Autorité de Sûreté Nucléaire (French Nuclear Safety Authority)</td>
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<tr>
<td>Radioactive Cleanup</td>
<td>All operations aimed at reducing the radioactivity of a facility or site, particularly by decontamination or by the removal of materials.</td>
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<tr>
<td>Fuel Assembly</td>
<td>Nuclear fuel component consisting of fuel rods held in place by a metal frame</td>
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<tr>
<td>ARENH</td>
<td>Regulated Access to Historic Nuclear Energy (tariff)</td>
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<tr>
<td>ASTRID</td>
<td>Advanced sodium technological reactor for industrial demonstration (Generation IV programme)</td>
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<tr>
<td>Becquerel (Bq)</td>
<td>Unit of measure of nuclear activity (1 Bq = one nucleus decay per second)</td>
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<tr>
<td>C3P</td>
<td>Full Cost Accounting</td>
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<tr>
<td>CAS</td>
<td>Conseil d’Analyse Stratégique (Strategic Analysis Council)</td>
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<tr>
<td>CCE</td>
<td>Current Economic Cost</td>
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<tr>
<td>CEA</td>
<td>Commissariat à l’Energie Atomique et aux énergies alternatives (French Alternative Energies and Atomic Energy Commission)</td>
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<tr>
<td>CEFEN</td>
<td>Comité d’Expertise Financière des Engagements</td>
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<td>Acronym</td>
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<tr>
<td>CLI</td>
<td>Commission Locale d’Information (Local Information Committee)</td>
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<td>CNEF</td>
<td>Commission Nationale d’Evaluation du Financement des charges de démantèlement des installations nucléaires de base et de gestion des combustibles usés et des déchets radioactifs (National Committee for the Evaluation of Funding for the costs of dismantling basic nuclear facilities and spent fuel and radioactive waste management)</td>
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<tr>
<td>CRE</td>
<td>Commission de Régulation de l’Energie (French Energy Regulatory Commission)</td>
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<tr>
<td>Criticality</td>
<td>The level reached when the neutron production rate by fission is equal to the rate at which neutrons disappear through absorption and leakage to the outside</td>
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<tr>
<td>CSEN</td>
<td>Comité de Suivi des Engagements Nucléaires (Nuclear Commitments Monitoring Committee)</td>
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<tr>
<td>Curie</td>
<td>Former unit of measure of nuclear activity (1 Curie = 37 GBq)</td>
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<tr>
<td>Deconstruction</td>
<td>According to EDF: all operations carried out to achieve complete removal of a nuclear power plant (including final shutdown operations)</td>
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<tr>
<td>Dismantling</td>
<td>The stages following final shutdown of a nuclear power plant through to its decommissioning</td>
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<tr>
<td>DGEC</td>
<td>Direction Générale de l’Energie et du Climat (General Directorate for Energy and Climate)</td>
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<td>DGEMP</td>
<td>Direction Générale de l’Energie et des Matières Premières (ancien nom de la DGEC) (General Directorate for Energy and Raw Materials (now the DGEC))</td>
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<tr>
<td>DGPR</td>
<td>Direction Générale de Prévention des Risques (General Directorate for Risk Prevention)</td>
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<td>DGRI</td>
<td>Direction Générale de la Recherche et de l’Innovation (General Directorate for Research and Innovation)</td>
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<td>DGSCGC</td>
<td>Direction Générale de la Sécurité Civile et de la Gestion des Crises (General Directorate for Civil Protection and Emergency Response)</td>
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<td>DGSNR</td>
<td>Direction Générale de la Sûreté Nucléaire et de la Radioprotection (General Directorate for Nuclear Safety and Radiation Protection)</td>
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<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>DOE</td>
<td>Department Of Energy (United States)</td>
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<tr>
<td>DREAL</td>
<td>Direction Régionale de l'Environnement, de l'Aménagement et du Logement (Regional Directorate for the Environment, Town and Country Planning and Housing)</td>
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<tr>
<td>DSC</td>
<td>Direction de la Sécurité Civile (Directorate for Civil Protection)</td>
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<tr>
<td>SDR</td>
<td>Special Drawing Right</td>
</tr>
<tr>
<td>ECS</td>
<td>Evaluation Complémentaire de Sureté (Complementary Safety Assessment)</td>
</tr>
<tr>
<td>EDF</td>
<td>Electricité De France</td>
</tr>
<tr>
<td>EPR</td>
<td>European Pressurized Reactor</td>
</tr>
<tr>
<td>EPRUS</td>
<td>Etablissement de Préparation et de Réponse aux Urgences Sanitaires (Health Emergency Preparedness and Response Agency)</td>
</tr>
<tr>
<td>FTE</td>
<td>Full-Time Equivalent (used to measure staffing levels)</td>
</tr>
<tr>
<td>EURATOM</td>
<td>European Atomic Energy Community</td>
</tr>
<tr>
<td>LLW</td>
<td>Low-Level Waste (radioactive waste)</td>
</tr>
<tr>
<td>FARN</td>
<td>Force d’Action Rapide Nucléaire (Nuclear Rapid Response Force)</td>
</tr>
<tr>
<td>Fission</td>
<td>Splitting of a heavy nucleus – generally on impact with a neutron – into two smaller nuclei, accompanied by the emission of neutrons, radiation and the release of a considerable amount of heat.</td>
</tr>
<tr>
<td>GIF</td>
<td>Generation IV International Forum</td>
</tr>
<tr>
<td>GW</td>
<td>Gigawatt symbol unit of power. 1 gigawatt = 1 million kilowatts.</td>
</tr>
<tr>
<td>GWh</td>
<td>Gigawatt hour: unit of energy corresponding to 1 million kilowatt hours.</td>
</tr>
<tr>
<td>HLW</td>
<td>High-Level Waste (radioactive waste)</td>
</tr>
<tr>
<td>HCTISN</td>
<td>Haut Comité à la Transparence et à l’Information sur la Sécurité Nucléaire (French High Committee for Transparency and Information on Nuclear Safety)</td>
</tr>
<tr>
<td>HFDS</td>
<td>Haut Fonctionnaire de Défense et de Sécurité (Senior Defence and Security Official)</td>
</tr>
<tr>
<td>IAS</td>
<td>International Accounting Standards</td>
</tr>
<tr>
<td>ICEDA</td>
<td>Installation de Conditionnement et d’Entreposage de Déchets Activés (Bugey) (Activated Waste Conditioning and Storage Facility (Bugey))</td>
</tr>
<tr>
<td>ICPE</td>
<td>Installations Classées pour la Protection de l’Environnement (Environmentally regulated)</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
</tr>
<tr>
<td>IFRS</td>
<td>International Financial Reporting Standards</td>
</tr>
<tr>
<td>INB</td>
<td>Installation Nucléaire de Base (Basic Nuclear Installation)</td>
</tr>
<tr>
<td>INSERM</td>
<td>Institut national de la Santé et de la Recherche Médicale (French National Institute of Health and Medical Research)</td>
</tr>
<tr>
<td>IPSN</td>
<td>Institut de Protection de Sureté Nucléaire (Institute for Nuclear Safety and Protection)</td>
</tr>
<tr>
<td>IRSN</td>
<td>Institut de Radioprotection et de Sûreté Nucléaire (French Institute for Radiological Protection and Nuclear Safety)</td>
</tr>
<tr>
<td>ITER</td>
<td>International Thermonuclear Experimental Reactor (nuclear fusion research programme)</td>
</tr>
<tr>
<td>kW</td>
<td>Kilowatt symbol, corresponding to 1,000 Watts</td>
</tr>
<tr>
<td>kWh</td>
<td>Kilowatt hour symbol; unit of measurement of work and energy corresponding to 1,000 Watt hours</td>
</tr>
<tr>
<td>LFI</td>
<td>Loi de Finances Initiale (Initial Budget Act)</td>
</tr>
<tr>
<td>LFR</td>
<td>Loi de Finances Rectificative (Revised Budget Act)</td>
</tr>
<tr>
<td>ILW</td>
<td>Intermediate-Level Waste (radioactive waste)</td>
</tr>
<tr>
<td>FS</td>
<td>Final Shutdown</td>
</tr>
<tr>
<td>CAPM</td>
<td>Capital Asset Pricing Model</td>
</tr>
<tr>
<td>MEDDTL</td>
<td>Ministère de l’Écologie, du Développement Durable, des Transports et du Logement (French Ministry of Ecology, Sustainable Development, Transport and Housing)</td>
</tr>
<tr>
<td>MESR</td>
<td>Ministère de l’Enseignement Supérieur et de la Recherche (French Ministry of Higher Education and Research)</td>
</tr>
<tr>
<td>mSv</td>
<td>A thousandth of a sievert (the average annual background exposure dose in France is 2.4 mSv/person)</td>
</tr>
<tr>
<td>HM</td>
<td>Heavy metal, i.e. all the uranium and plutonium isotopes contained in the fuel to be reprocessed</td>
</tr>
<tr>
<td>MOX</td>
<td>Mix of uranium and plutonium oxides to be used to produce nuclear fuel</td>
</tr>
<tr>
<td>IC</td>
<td>Industrial Commissioning</td>
</tr>
<tr>
<td>MSNR</td>
<td>Mission de la Sureté Nucléaire et de la Radioprotection de la DGPR (Nuclear Safety and Radiation Protection Mission)</td>
</tr>
<tr>
<td>MW</td>
<td>Megawatt symbol. Unit of power. 1 megawatt = 1,000 kilowatts</td>
</tr>
<tr>
<td>Acronym</td>
<td>Definition</td>
</tr>
<tr>
<td>---------</td>
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</tr>
<tr>
<td><strong>MWh</strong></td>
<td>Megawatt hour symbol. Unit of energy. 1 MWh = 1000 kWh.</td>
</tr>
<tr>
<td><strong>NOME</strong></td>
<td>New Organization of the Electricity Market (NOME law of 7 December 2010)</td>
</tr>
<tr>
<td><strong>CBRN</strong></td>
<td>Chemical, Biological, Radiological and Nuclear</td>
</tr>
<tr>
<td><strong>NRC</strong></td>
<td>Nuclear Regulatory Commission</td>
</tr>
<tr>
<td><strong>OECD</strong></td>
<td>Organisation for Economic Co-operation and Development</td>
</tr>
<tr>
<td><strong>OPECST</strong></td>
<td>Office Parlementaire d'Evaluation des Choix Scientifiques et Techniques (French Parliamentary Office for the Evaluation of Scientific and Technological Choices)</td>
</tr>
<tr>
<td><strong>OPRI</strong></td>
<td>Office de Protection contre les Rayonnements Ionisants (Office for Protection against Ionizing Radiation)</td>
</tr>
<tr>
<td><strong>Radioactive half-life</strong></td>
<td>Time taken for half of the atoms in a sample of radioactive substances to naturally decay</td>
</tr>
<tr>
<td><strong>PLF</strong></td>
<td>Projet de Loi de Finances (French budget bill)</td>
</tr>
<tr>
<td><strong>GNP</strong></td>
<td>Gross National Product</td>
</tr>
<tr>
<td><strong>PNGMDR</strong></td>
<td>Plan National de Gestion des Matières et des Déchets Radioactifs (French National Radioactive Materials and Waste Management Plan)</td>
</tr>
<tr>
<td><strong>PPI</strong></td>
<td>Multi-year investment programme</td>
</tr>
<tr>
<td><strong>P₀</strong></td>
<td>Plutonium</td>
</tr>
<tr>
<td><strong>EPP</strong></td>
<td>On-site Emergency Plan</td>
</tr>
<tr>
<td><strong>PWR</strong></td>
<td>Pressurized water reactor</td>
</tr>
<tr>
<td><strong>Radioactivity</strong></td>
<td>The property due to which certain bodies emit radiation and change into other bodies: radioactivity is characterized by the radiation emitted and the rate of transformation</td>
</tr>
<tr>
<td><strong>RCD</strong></td>
<td>Waste Recovery and Conditioning</td>
</tr>
<tr>
<td><strong>TPNL</strong></td>
<td>Third Party Nuclear Liability</td>
</tr>
<tr>
<td><strong>RCEN</strong></td>
<td>Civil liability for nuclear damage</td>
</tr>
<tr>
<td><strong>RCTN</strong></td>
<td>Nuclear Transport Civil Liability</td>
</tr>
<tr>
<td><strong>PWR</strong></td>
<td>Pressurized Water Reactor</td>
</tr>
<tr>
<td><strong>HFR</strong></td>
<td>High Flux Reactor</td>
</tr>
<tr>
<td><strong>RTE</strong></td>
<td>Réseau de Transport d'Electricité (French national grid company)</td>
</tr>
<tr>
<td><strong>SDIS</strong></td>
<td>Service Départemental d’Incendie et de Secours (“Département” fire and emergency services)</td>
</tr>
<tr>
<td><strong>Sievert (Sv)</strong></td>
<td>Unit of measure of dose equivalent, i.e. the quantity of ionizing radiation energy absorbed by one kilo of</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
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</tr>
<tr>
<td>VLLW</td>
<td>Very Low-level Waste (radioactive waste)</td>
</tr>
<tr>
<td>TSN</td>
<td>French Nuclear Security and Transparency Act (13 June 2006)</td>
</tr>
<tr>
<td>TWh</td>
<td>Terawatt hour symbol. Unit of energy corresponding to 1 billion kWh.</td>
</tr>
<tr>
<td>DU</td>
<td>Depleted uranium</td>
</tr>
<tr>
<td>ENU</td>
<td>Enriched Natural Uranium</td>
</tr>
<tr>
<td>GMGC</td>
<td>Graphite-Moderated Gas-Cooled (second generation reactor)</td>
</tr>
<tr>
<td>UP1 and 2</td>
<td>Marcoule reprocessing plants</td>
</tr>
<tr>
<td>ERU</td>
<td>Enriched Recycled Uranium</td>
</tr>
<tr>
<td>RU</td>
<td>Recycled uranium</td>
</tr>
<tr>
<td>SL</td>
<td>Short Lived (radioactive waste)</td>
</tr>
<tr>
<td>LL</td>
<td>Long Lived (radioactive waste)</td>
</tr>
<tr>
<td>MS</td>
<td>Marketable Security</td>
</tr>
<tr>
<td>WACC</td>
<td>Weighted Average Cost of Capital</td>
</tr>
</tbody>
</table>