Cour des comptes

ENTITIES AND PUBLIC POLICIES

THE BACK END OF THE NUCLEAR FUEL CYCLE

Radioactive materials and waste, from reactor exit to disposal

Public thematic report

Summary

July 2019

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Introduction

The back end of the nuclear fuel cycle: a subject that has long been absent from public debate

This report on the back end of the nuclear cycle is part of a series of Court publications on public nuclear energy policies, including the 2005 report on the decommissioning of nuclear facilities and radioactive waste management and the 2012 report on the costs of the nuclear power sector, updated in 2014. It covers all issues related to the back end of the cycle, namely the reprocessing of spent fuel and the disposal of waste. This is both a technical and very sensitive subject, and the interactions between these themes have long been absent from public debate.

However, for the first time, the adoption of the National Plan for the Management of Radioactive Materials and Waste (*plan national de gestion des matières et déchets radioactifs* – PNGMDR), covering the period 2019-2021, is being preceded by a public debate, organised by the National Commission for Public Debate from 17 April the 17th to September the 25th, 2019[1].

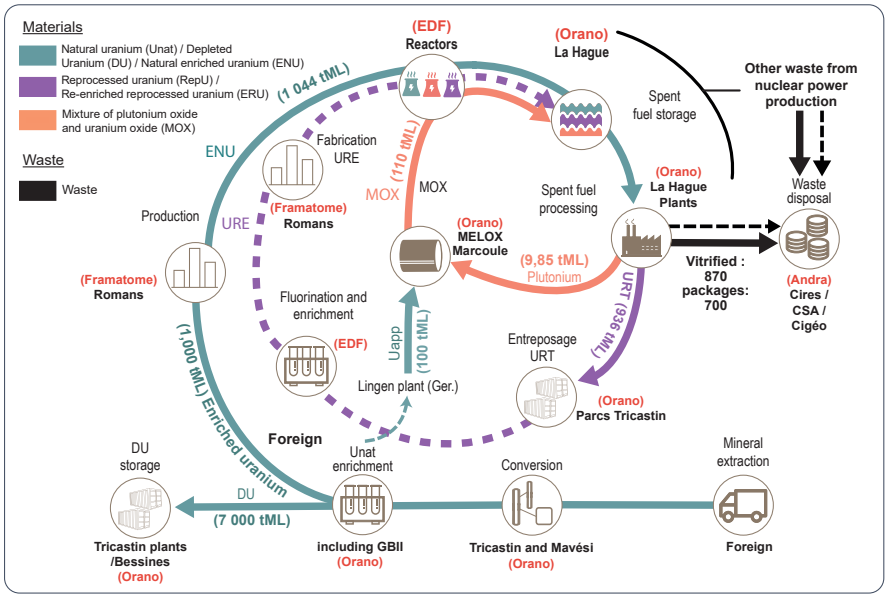
1 Order No. 2016-1060 of 3 August 2016 reforming procedures for public information and participation in the preparation of certain decisions that may have an impact on the environment states that the PNGMDR shall be put to public debate..

The close interaction between the front end and the back end of the cycle to be explained

The lion's share of the electricity produced in France (72% in 2018) is derived from nuclear energy, supplied by the country's 58 nuclear reactors. The nuclear fuel used in these reactors is primarily derived from natural uranium. The various stages of manufacturing, implementating, reprocessing, recycling, etc. of this fuel are collectively known as the «nuclear fuel cycle». The front end covers the operations from the mining of uranium to the use of the fuel in a reactor, while the back end refers to the operations from the exit of spent fuel from the reactor to the final disposal of radioactive waste from the management of these spent fuels.

In France, the front end of the cycle includes stages of reprocessing spent fuel and recycling the materials resulting from this reprocessing for the manufacture of new fuels. As such, the fuel cycle is said to be «closed», even if in reality it is only partially closed (because recycling of materials can only currently be implemented once), as opposed to the so-called «open» cycle used in other countries where spent fuel is disposed of directly without being reprocessed and recycled.

The French fuel cycle



N.B.: the flows indicated correspond to those for 2017. The dotted arrows correspond to non-operational stages in 2017.

Source: Cour des comptes according to Nuclear Safety Authority (Autorité de sûreté nucléaire – ASN) and the Institute for Radiological Protection and Nuclear Safety (Institut de radioprotection et de sûreté nucléaire – IRSN) documents

The close interaction between the front end and the back end of the cycle to be explained

France's choice to reprocess spent fuel has tangible consequences on all aspects of fuel cycle management. Indeed, upon exiting the reactor, spent fuel is stored pending reprocessing. By the end of the reprocessing process, recyclable materials – such as plutonium, used in the production of MOX[2] fuel – have been separated and radioactive substances have been packaged as vitrified waste for long-term disposal. The discharge of spent fuel from nuclear power plants therefore depends on the reprocessing capacity of this fuel, as well as on the interim storage capacity available pending this reprocessing (the availability rate of storage pools was evaluated at 13.3% at the end of 2016). This balance between reactor fuel discharges and their reprocessing can only be maintained if a sufficient number of reactors use MOX fuel, failing which the French plutonium stock would increase.

Maintaining this balance is a key parameter in nuclear power generation planning. This parameter must therefore be taken into account in the various Multiannual Energy Programmes (*programmation pluriannuelle de l'énergie* – PPE), that were introduced by the Energy Transition for Green Growth Act (*loi de transition énergétique pour une croissance verte* – LTECV) of 2015. This consideration is all the more important as the objective of reducing nuclear power's share of electricity production to 50%, in the context of an ageing of nuclear fleet, will lead to significant changes in nuclear fuel cycle flows.

Substantial investment – in the existing reactor fleet and in material and waste interim storage facilities – are therefore required over the next decade. This investment must take into account the feedback effects between the front end and back end of the cycle. Possible alternatives for this investment were not discussed during the 2018 public debate on the PPE[3] and the choices proposed in the plan published in January 2019 are based on choices that were not explained to the general public. Greater transparency on this subject would make it possible to fully appreciate the prominence of back end fuel cycle issues among the determinants of nuclear infrastructure development choices.

2 Fuel combining depleted uranium oxide and plutonium derived from the reprocessing after use of enriched natural uranium fuel.
3 Order No. 2016-1060 of 3 August also states that the PPE shall be put to public debate.

A need for expertise made more acute by long time scales

The time scales of nuclear projects are very long (some projects are implemented over several decades or even over more than a century) and the waste's radioactivity can persist for thousands of years. Decisions taken today in the nuclear field thus have consequences for many generations to come. These are therefore choices with a strong ethical dimension. In this regard, the law also provides to «prevent or limit the burden that will be borne by future generations».

A debate on short-, medium- and long-term decisions to be made on the front end of the nuclear fuel cycle must be based on economic and environmental data. However, some of these data are missing in order to be able to compare the different scenarios. In particular, the environmental assessment of the «closed» cycle still needs to be expanded. The economic comparison of the various possible scenarios for the development of the cycle (maintaining the current cycle, abandoning reprocessing, developing fast-neutron reactors to complete the cycle closure, etc.) has not been carried out in an exhaustive way for the situation in France. These data are essential, with back end operations of the nuclear cycle accounting for about 10% of the cost of nuclear electricity production, and the dates for decisions to be made on the renewal of the spent fuel reprocessing facilities at La Hague fast approaching.

Choices must also be informed by a more in-depth assessment of public policy alternatives than those available today. On this basis, it is important that the evaluation capacities of the Ministry for the Ecological and Inclusive Transition be strengthened in order to assess more accurately and comprehensively the technical, economic, financial and environmental aspects of radioactive materials and waste management issues.

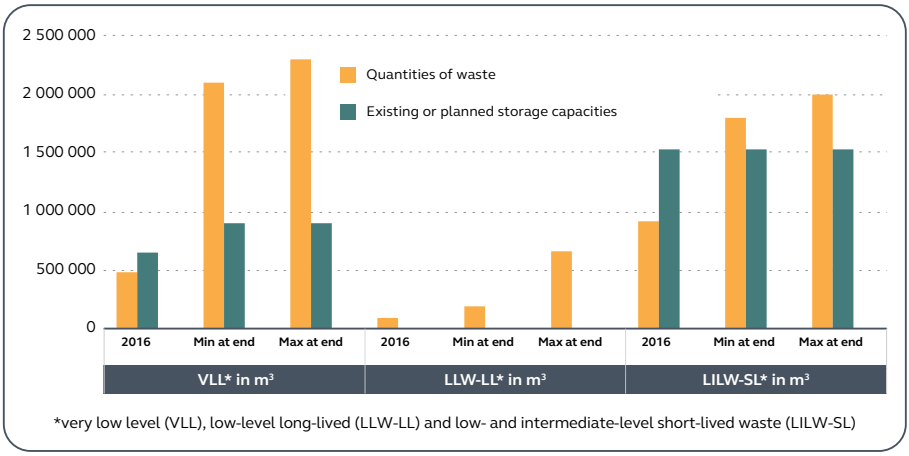
Anticipating growth in volumes and costs des substances radioactives

In the nuclear field, the implementation of decisions requires long lead times. Therefore, although time frames are long, decision-makers need to make decisions now regarding the management of radioactive substances for tomorrow. Decisions made under the PNGMDR should thus enable the management of the many radioactive substances resulting from the fuel cycle. The reprocessing of spent fuel does not prevent the existence of large quantities of radioactive substances in France that have to be managed. Back end cycle operations involve, on the one hand, the interim storage of radioactive materials, pending their reuse and, on the other hand, the final disposal of radioactive waste that is not reusable. At the end of 2016, France had more than 400,000 tonnes of heavy metal from radioactive materials and 1,620,000 m^3 of radioactive waste. While nearly 91% of this waste is referred to as «very low level» or «low- and intermediate-level short-lived" waste, some of it, known as «high-level and long-lived" waste, is particularly radioactive and contains radioelements, the lifetime of which can be as long as several hundred thousand years. This high-level waste represents approximately 0.2% of the total volume of radioactive waste present in France, and nearly 95% of the radioactivity of this waste.

However, there is a risk of tension for certain solutions for the interim storage of materials pending reprocessing and waste pending disposal, as well as for certain solutions for the final disposal of waste. In order to plan investment in this area as best as possible, existing storage and disposal capacities must be reconciled with current and prospective quantities of materials and waste, using the national inventory of radioactive materials and waste produced by the National Agency for Radioactive Waste Management (*Agence nationale pour la gestion des déchets radioactifs* – ANDRA).

Anticipating growth in volumes and costs

Comparison of current and projected quantities of the least radioactive waste* with current and projected storage capacities



*very low level (VLL), low-level long-lived (LLW-LL) and low- and intermediate-level short-lived waste (LILW-SL)

N.B.: "At end" quantities refer to the quantities generated following the decommissioning of nuclear installations authorised at the end of 2016. The «min and max at end» quantities correspond to the minimum and maximum values of the different scenarios in the national inventory. Disposal capacities are those committed to date and not at end. Quantities of intermediate- and high-level long-lived waste are not shown in this graph.

Source: Cour des comptes compilation

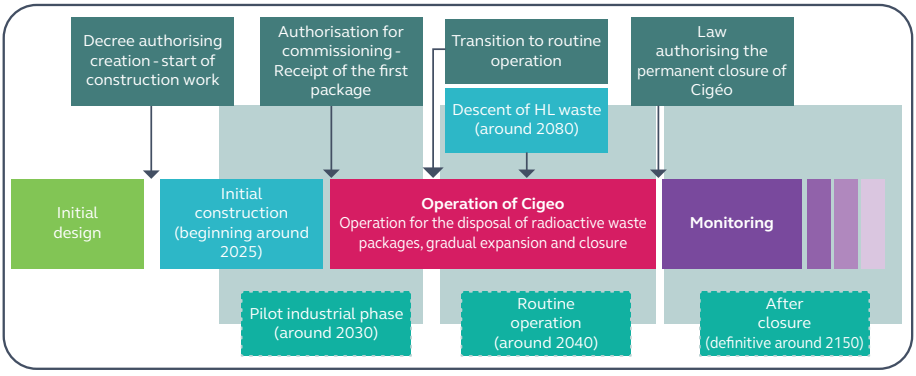
The need to plan this investment is all the more acute as projections of storage and disposal costs, excluding deep geological disposal of waste, show an increase in their amounts. Cumulative investment in the main disposal (excluding geological disposal) and interim storage sites, which amounted to €255 million between 2014 and 2017, could amount to nearly €1.4 billion between 2018 and 2030, and could increase by a further €1.5 billion between 2030 and 2050. This investment would also lead to an increase in operating costs of more than 90% between current and projected amounts in 2050.

In addition to these costs, there are the costs of recovery and conditioning of so-called «old» radioactive waste (some of which is more than 50 years old), the conditioning of which no longer meets current safety requirements. The total cost of future operations to recover this waste, which has increased significantly in recent years, was €7.8 billion for the French Alternative Energies and Atomic Energy Commission (Commissariat à l'énergie atomique et aux énergies alternatives – CEA), EDF and Orano as at 31 December 2017. Two thirds of these costs are the responsibility of the CEA. This is due to agreements on the distribution of responsibilities between operators for the recovery of old waste and the decommissioning of the oldest nuclear facilities, which are now at a standstill. This heavy burden, which weighs on the CEA, has led this institution to define an order of priority for projects, which will not, however, enable it to meet the legislative deadline of 2030 for the recovery of some of this waste.

Cigéo, a non-standard project, the cost of which must be updated regularly

In addition to the aforementioned figures, the main component of future nuclear waste management costs is the Cigéo project to dispose of medium- and high-level long-lived waste in a deep geological layer. This is the first project to implement this disposal method, which is currently the reference solution worldwide. Cigéo is an «non-standard» project, particularly in terms of its dimensions and technical requirements – it is a 500-metre deep disposal facility designed to store radioactive waste for several hundred thousand years, in 15 km^2 of useful surface spread over underground galleries – but also in terms of its 120 year operating life (waste filling period) and monitoring beyond.

Main temporal phases of Cigéo



N.B.: the stages are presented subject to obtaining the necessary authorisations.
Source: Cour des comptes according to ANDRA

The costs of Cigéo were estimated from a 2012 design, projected over a century and a half.

At this stage of the project's development, uncertainty as to costs is unavoidable, particularly with regard to the impact of future raw material and labour prices, technical innovations, etc. It is therefore impossible to claim to know the "exact cost» of Cigéo. However, a precise sum must be quantified in order to determine the financial amounts to be provisioned by nuclear operators to meet these future costs (charges and provisions, secured

Cigéo, a non-standard project, the cost of which must be updated regularly

by dedicated assets – see below). Thus, an increase of €1 billion in the cost estimate of Cigéo would have an impact of around €300 million on EDF's provisions and dedicated assets and around €25 million for Orano.

Based on the various assessments carried out by nuclear operators (mainly EDF) at €19.2 billion and ANDRA at €34.5 billion (subsequently revised to €30 billion), the cost of the project was set at €25 billion in 2016 by order of the Minister of Energy. However, this estimate is likely to change as the project progresses. The analysis of the parameters used to determine the cost of the project has led the Court to recommend that a method that takes into account the risks and opportunities of the project in a more realistic way than that initially adopted be implemented during the next revision of the cost of Cigéo.

Moreover, given its lifetime, the Cigéo project will inevitably be affected by future public policy developments. Thus, decisions on changes in the scope and nature of the waste to be disposed of are likely to have a significant impact on the project, in terms of volumes and costs. For example, the cost of disposing of used MOX and URE[4] in Cigéo alone is estimated at over €5 billion. Even if adaptability studies should make it possible to find the answer to evolving needs, estimating the impact of different energy policy scenarios on the cost of Cigéo would make it possible to inform strategic decisions on the management of radioactive materials and waste and to anticipate project developments.

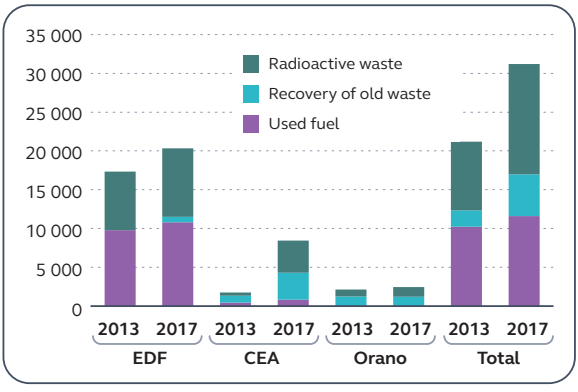
4 Fuel elaborated with re-enriched uranium oxide derived from the reprocessing after use of enriched natural uranium oxide fuel.

Future expenses the financing of which must be better controlled

Securing future expenditure on the management of radioactive materials and waste (including expenses relating to Cigéo, but also those linked to the interim storage of spent fuel, for example) is the responsibility of producers, in accordance with the «polluter-pays» principle. Given the very long-term duration of nuclear liabilities, the legislator has put in place provisions to guarantee the ability of operators to fulfil them. The operators (EDF, Orano and the CEA) must therefore establish accounting provisions to be in a position to meet their future expenses, some of which must also be secured by the creation of dedicated assets. The objective is to prevent or limit the burden passed on to future generations, but also to the community, since the State is ultimately responsible for radioactive substances.

Total future gross costs for the management of radioactive materials and waste as well as spent fuel was €69 billion at the end of 2017, for all operators combined. Provisions calculated on the basis of gross expenses amounted to €31 billion, and provisions to be covered by dedicated assets amounted to €21 billion. These expenses and provisions are up sharply, by nearly 40% compared to 2013.

Amount of provisions per operator (€ million, 2013 and 2017, excluding decommissioning)



N.B.: for EDF in 2013, waste management expenses include the costs of recovering old waste: it was only in 2017 that these expenses were first individualised in EDF's accounts.

Source: Cour des comptes according to Directorate General for Energy and Climate (Direction générale de l'énergie et du climat – *DGEC) and operators data.*

Future expenses the financing of which must be better controlled

In return for the responsibility entrusted to them in terms of the assessment and provisioning of future expenses, operators are subject to ex-post control by the administrative authority formed jointly by the ministers in charge of the economy and energy. This control is all the more important as the decisions taken by operators to ensure the financing of future expenses weigh heavily on their income statements and balance sheets. However, it seems that public authority controls need to be developed in order to better assess the data produced by operators and the decisions they take based on these data.

The difficulty of taking into account uncertainties about the future of radioactive materials

The responsibility of the owners of radioactive substances is exercised primarily in the classification of these substances as reusable materials or non-reusable waste. Maintaining a certain number of radioactive substances as «material» is based on a set of expectations regarding French nuclear power policy, technological developments, industrial strategies, economic conditions, etc. Since 2016, the ministers in charge of energy and nuclear safety have been able to reclassify materials as waste and waste as materials. This possibility, which has not yet been implemented, should rest on a doctrine shared with operators, based, for example, on the balance between industrial prospects for reuse and the quantities of substances held and to be held.

This clarification is all the more desirable as there are inconsistencies between the classification of radioactive substances by operators, on the one hand, and the decisions taken by these same operators on the gross costs and provisions for the management of these substances, on the other hand.

As such, today, spent MOX is considered to be material as it is intended to be recycled, either in fast-neutron reactors, in several decades' time, or in the next generation of reactors – EPR reactors – in the shorter term, if it were decided these should be built. Due to historical and prudent choices, however, for accounting purposes, this spent MOX fuel is treated by EDF as waste and is as such provisioned and covered by dedicated assets for its disposal, up to €656 million, even though it is intended to be reused.

However, these prospects for reuse are subject to significant technical and economic uncertainties. Yet, the fact that spent MOX maintains the status of material means that is not taken into account in Cigéo's reference inventory, i.e. that the actual preparation of its deep disposal is not been carried out. Consideration should therefore be given to setting the next deadlines by which this question regarding the future of spent MOX should be asked again.

The question of coherence between the real industrial prospects of material reuse and their current classification also arises for reprocessed uranium (RepU). The entire stock of RepU is considered reusable, while the recovery of this material, as of 2023, will not be sufficient to bring about a reduction in the quantities currently disposed of before at best the middle of the century. Establishing a provision for disposal, covered by dedicated assets, for the quantity of RepU that

The difficulty of taking into account uncertainties about the future of radioactive materials

will not be reused in the coming decades – the amount of which can be estimated at between €500 million and €1 billion – would protect against the risk of leaving future generations with the burden of managing these stocks of substances.

Decisions on the management of radioactive substances require difficult trade-offs between the short-term interests of operators and the State shareholder on the one hand, and the long-term interests of the community, for which the State, ultimately responsible for radioactive substances, is the guarantor, on the other. The Court's recommendations therefore aim to increase the transparency of the terms of these choices, primarily by specifying the conditions for the exercise of the administrative authority's missions and by supplementing its capacity to anticipate long-term decisions.

Recommendations

1. Complete the national inventory by reconciling interim storage and disposal capacities with current and prospective quantities of materials and waste (DGEC, ANDRA, 2021).

2. Estimate the cost of Cigéo for each of the four scenarios of the national inventory of radioactive materials and waste (DGEC, ANDRA, 2020).

3. Update the costs of the Cigéo reference scenario by more realistically taking into account the risks and opportunities of the project (DGEC, ANDRA, 2020).

4. Clarify the doctrine of use, by the ministers in charge of energy and nuclear safety, of Article L. 542-13-2 of the Environmental Code relating to the classification of radioactive substances as materials or waste (MTES, 2019).

5. Reflect the real industrial prospects of the reuse of radioactive materials in the constitution of provisions and dedicated assets (DGEC, DG Treasury, 2019).

6. Define the milestones in the implementation of the Cigéo project, which should lead to an update of the reference inventory, particularly in the case of disposal of spent MOX and RepU (ANDRA, 2020).

7. Explain, in public debates on the PPE and the PNGMDR, the interactions between the front end and the back end of the nuclear fuel cycle (DGEC, 2019).

8. Standardise the prospective scenarios of the national inventory of radioactive materials and waste, the «impact cycle» files, the PPE and the PNGMDR, primarily by identifying a common reference scenario (DGEC, 2019).

9. Extend the implementation period of the PNGMDR, taking into account the feedback from the first public debate (MTES, 2020).

10. Strengthen the capacity to counter-analyse operator data and studies and to carry out cost-benefit studies of scenarios for the development of the nuclear power sector (MTES, 2019).