French National Plan

for the Management of Radioactive Materials and Waste

2010 – 2012



SUMMARY

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE

Ministère
de l'Écologie,
de l'Énergie,
du Développement
durable
et de la Mer

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AUTORITÉ
DE SÛRETÉ
NUCLÉAIRE

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Foreword

Radioactive materials and waste must be sustainably managed for the protection of human health, safety and the environment.

The French national plan for the management of radioactive materials and waste (called French National Plan) is a privileged tool for the implementation of these principles over time under the legally devised framework. It presents a global vision of the management of radioactive materials and waste with the two-fold goal of ensuring the existence of management routes adapted to each category of radioactive substances over the short as well as the long-term and improving the consistency between the management routes.

Transparency, dialogue and consultation, notably with civil society representatives, must be at the core of the elaboration of public policies, especially for the management of radioactive materials and waste. The French National Plan falls within this framework : it results from exchanges in a pluralistic working group led by the Ministry of Sustainable Development (MEEDDM) – General Directorate for Energy and Climate (DGEC) – and the Nuclear Safety Authority (ASN). This working group is composed of environment protection associations, representatives of elected officials, as well as control and evaluation authorities working side by side with radioactive waste producers and managers.

Although radioactive materials and waste are already safely managed under the control of the ASN, an independent authority, it should be emphasized that the recommendations presented in this French National Plan are essential. It amounts to not only upholding the objectives and timetables fixed by the Parliament in 2006, but also and above all advancing further in the sustainable management of radioactive materials and waste by defining final long-term management solutions for all these substances. It is our responsibility to assume this obligation today to avoid overburdening future generations.

Pierre-Franck Chevet,
Director General for Energy and Climate (DGEC)

André-Claude Lacoste,
President of the Nuclear Safety Authority (ASN)

The purpose of the national plan for the management of radioactive materials and waste (French National Plan) is to make, on a regular basis, an exhaustive assessment of the radioactive substances management policy. It evaluates new needs and sets the objectives, notably in terms of research and studies.

The first edition of the French National Plan published in 2007 identified several types of materials and waste necessitating the implementation of new management routes or the improvement of existing ones. Edition 2010-2012 proposes to pursue and intensify the engaged actions. It is also the occasion to address topics overlooked or insufficiently treated in the previous edition.

The intent of this summary is to render the main items of the assessment and recommendations of the French National Plan accessible to the public concerned by or interested in the management of radioactive substances in France. The reader wishing to learn more about these topics may of course refer to the complete report of the French National Plan 2010-2012, which may be downloaded from the Internet sites of the Ministry of Sustainable Development and the ASN.

After laying down, in the first part, the context of the management of radioactive materials and waste in France, this summary will describe the existing radioactive materials and waste management routes, as well as the progress orientations, before presenting in the third part the long-term management methods under development for waste.

The management of radioactive materials and waste: main issues and principles

DEFINITION

Radioactivity
Radioactivity is a natural phenomenon during which unstable atomic nuclei are transformed after a series of disintegrations into stable atomic nuclei.These transformations are accompanied by the emission of "ionizing radiation". There are natural radioactivity sources (granite, cosmic radiation, etc.) and artificial radioactivity sources (nuclear reactors for electricity production, radiotherapy activities, etc.)

MILESTONE

The five economic sectors which produce radioactive materials and waste: electronuclear, defence, research, non-electro-nuclear industry, medical.

Vitrified high level (HL) waste container.

This first part presents reusable radioactive materials and waste: it specifies, in particular, where these substances originate, how they are classified and managed, what quantities are present in France, and to which legal framework they are submitted.

What is a radioactive material? Radioactive waste?

Among radioactive substances, some are considered to be reusable materials and others as waste.Thus, in the meaning of the Environmental code, "radioactive materials" are "radioactive substances which are intended for further use, after treatment if need be". In the nuclear electricity production process, for example, the fuel once spent, still contains materials which can be used. These materials are reprocessed for extraction, notably uranium and plutonium."Radioactive waste" is "radioactive substances for which no future use is prescribed or considered".

Where does the waste come from?

The radioactive materials and waste produced since the beginning of the 20th century have mainly originated from five economic sectors:

- **the electronuclear sector:** mainly nuclear electric power plants, plants of the fuel cycle front end (extraction and processing of the uranium ores, chemical conversion of uranium ore concentrates, and then enrichment and fabrication of the fuel) and the plants of the cycle back end (spent fuel reprocessing and recycling);
- **the defence sector:** mainly the activities linked to the deterrent force and the nuclear propulsion of some ships, as well as research activities;
- **the research sector:** research activities in the civil nuclear field;
- **the non electronuclear industry sector:** notably, the extraction of rare earths, the fabrication and utilization of sealed sources;
- **the medical sector:** therapeutic, diagnosis and research activities.

What are the various types of waste?

Radioactive waste is highly diversified: it contains substances that can be chemical or radioactive, and in more or less large quantities. Depending on their composition, they are therefore more or less dangerous for more or less a long time. This dangerousness is linked not only to their radioactive nature, but also in some cases to their chemical toxicity.

Various criteria may be used to classify radioactive waste. In France, the classification is based notably on two parameters:

- **the activity,** which corresponds to the number of disintegrations per time unit. In other words, it is the level of radioactivity. Depending on the quantity and the nature of the radioactive substances which the waste contains, it may have a very low, low, intermediate or high level of activity;
- **the lifetime,** which depends on the half-life of the elements contained in the waste. This half-life corresponds to the time it takes for half of the number of atoms of a radioactive element to disintegrate. Half-life varies with each radioelement's characteristics. After 10 half-lives, an element's level of radioactivity is divided by approximately 1000; generally, this duration of 10 half-lives is considered as the radioelement's "lifetime". All waste contains a mixture of short lived radioelements (radioactive period < 31 years) and long lived radioelements (radioactive period > 31 years), but, for simplicity, waste which contains a majority of short lived elements is called short lived waste, and conversely.

Hence, this classification allows distinguishing the following categories:

- **high level (HL) waste,** mainly originating from spent fuels after reprocessing. They are conditioned in glass packages;
- **intermediate level and long lived (IL-LL) waste,** also mostly originating from the reprocessing of spent fuels and the maintenance and operation activities of the processing plants. This waste is notably the cladding waste of the fuel assemblies, hulls and end-caps, as well as the technological waste (worn-tools, equipment, etc.), and the process waste originating from the processing of effluents, such as some sludge. It is conditioned in cemented or bituminised compact metal waste packages;
- **low level and long lived (LL-LL) waste,** essentially graphite and radium-bearing waste. The graphite waste originates mainly from the dismantling of the uranium natural graphite gas reactors. The radium-bearing waste originates mostly from non nuclear industrial activities (such as the processing of ores containing rare earths);
- **low or intermediate level and short lived (LIL-SL) waste,** originating mainly from the operation and dismantling of nuclear power plants, fuel cycle facilities, research centres and to a lesser extent from biomedical research activities;
- **very low level (VLL) waste,** mainly originating from the operation/maintenance and dismantling of nuclear power plants, fuel cycle facilities and research centres;
- **very short lived (VSL) waste,** originating mainly from the medical sector or research. They are stored on their utilisation site during the time it takes for their radioactivity to decay, before being eliminated in a conventional management route corresponding to their physical, chemical and biological characteristics.

Example of intermediatelevel and long lived (IL-LL) waste drums.

Some of the objects in our daily life dating for the most part from the mid-20th century can contain radioactivity. They are most often low level and long lived (LL-LL) waste. For example, the hands of some old alarm clocks were made luminescent by adding radioactive elements to the paint (this process has no longer been used for several decades).

Example of low or intermediate level and short lived (LL/IL-SL) waste originating from the exploitation of a laboratory.

Example of very low level (VLL) waste: pieces of metal and plastic coming from the dismantling of nuclear facilities.

Example of very short lived hospital waste.

KEY FIGURES

2 Kg of radioactive waste produced per year and per inhabitant in France

approximately **1** olympic size swimming pool of high level waste produced in France between the beginning of the utilisation of nuclear energy and the end of 2007

How to manage radioactive waste?

In practice, the previous classification allows associating a long term management route with each waste category, as shown in the table below.

<table>
<tr><th></th><th>VERY SHORT LIVED (HALF-LIFE < 100 DAYS)</th><th>SHORT LIVED (HALF-LIFE < 31 YEARS)</th><th>LONG LIVED (HALF-LIFE > 31 YEARS)</th></tr>
<tr><td>VERY LOW LEVEL (VLL)</td><td>Management by radioactive decay on the production site</td><td colspan="2">Surface Disposal (the Aube disposal centre for very low level waste)</td></tr>
<tr><td>LOW LEVEL (LL)</td><td rowspan="3">elimination in the conventional management routes</td><td rowspan="2">Surface Disposal (the Aube disposal centre for low or intermediate level waste)</td><td>Sub-Surface Disposal (under study in compliance with the act of 28 June 2006)</td></tr>
<tr><td>INTERMEDIATE LEVEL (IL)</td><td></td></tr>
<tr><td>HIGH LEVEL (HL)</td><td colspan="2">Deep repository (under study in compliance with the act of 28 June 2006)</td></tr>
</table>

A specific management method is set up for each category. The type of processing, the conditioning and the disposal method (after a possible temporary storage) are adapted to the dangerousness of the waste and its evolution over time.

The category/management route correspondence is not total, since the reality is a little more complex; in fact, the waste management route is not only determined by the activity and the lifetime. Other criteria are taken into account, notably the stability or the presence of some chemical elements.

Radioactive waste in a few key figures

A national inventory of radioactive materials and waste is elaborated, updated and published every three years by the National Agency For Radioactive Waste Management (Andra). The edition 2009 of the national inventory presents notably the materials and waste stocks at the end of 2007, as well as the forecasts for the end of 2030.

(IN EQUIVALENT CONDITIONED M3)	VOLUMES AT END OF 2007	ESTIMATED VOLUMES AT THE END OF 2030
IL-LL	2 293	5 060
LL-LL	82 536	151 876
LL/IL-SL	792 695	1 174 193
VLL	231 688	869 311
TOTAL	1 150 969	2 251 449

What is the legal framework?

The radioactive materials and waste management framework is defined by the act no. 2006-739 of 28 June 2006 related to the sustainable management of radioactive materials and waste. This act deals with the definition of a radioactive materials and waste management policy, the improvement of transparency and democratic control, as well as the funding and economic support policy. It prohibits the disposal in France of waste coming from foreign countries and organises the so-called orphan waste management.

The law stipulates that the management of these radioactive materials and waste must satisfy three fundamental principles: protection of human health, safety and the environment; prevention or limitation of obligations overburdening future generations; producer/payer principle, similar to the polluter/payer principle, which exists in environmental law.

The French National Plan organises the implementation of the research and studies on the management of radioactive materials and waste along the following three orientations defined by law:

- the reduction of the quantity and the harmfulness of the waste, notably the reduction at the source by spent fuel re processing and in the future possibly by separation - transmutation (cf. p. 21);
- the storage as a possible previous stage, notably for the ultimate waste waiting for disposal;
- the deep repository as a sustainable solution for ultimate waste which cannot be disposed of in a surface disposal or in a low depth disposal.

In the field of transparency and democratic control, the act confirms the role of the National Evaluation Commission in charge of evaluating the research on the management of radioactive materials and waste. It also provides for the regular organisation of debates by the High Committee For Transparency and Information on Nuclear Security (HCTISN).

KEY FIGURES

The HL waste existing at the end of 2007

0.2 % of the total volume of French radioactive waste

95 % of the total radioactivity of French radioactive waste

The LL/IL short lived waste existing at the end of 2007

69 % of the total volume of French radioactive waste

< 0.03 % of the total radioactivity of French radioactive waste

MILESTONES

1991: act related to the research on radioactive waste management (covering essentially high or intermediate level and long lived waste)

2005-2006: public debate on radioactive waste management

2006: act related to sustainable management of radioactive materials and waste (covering all reusable radioactive materials and waste), prepared after the evaluation of all the research conducted within the framework of the act of 1991

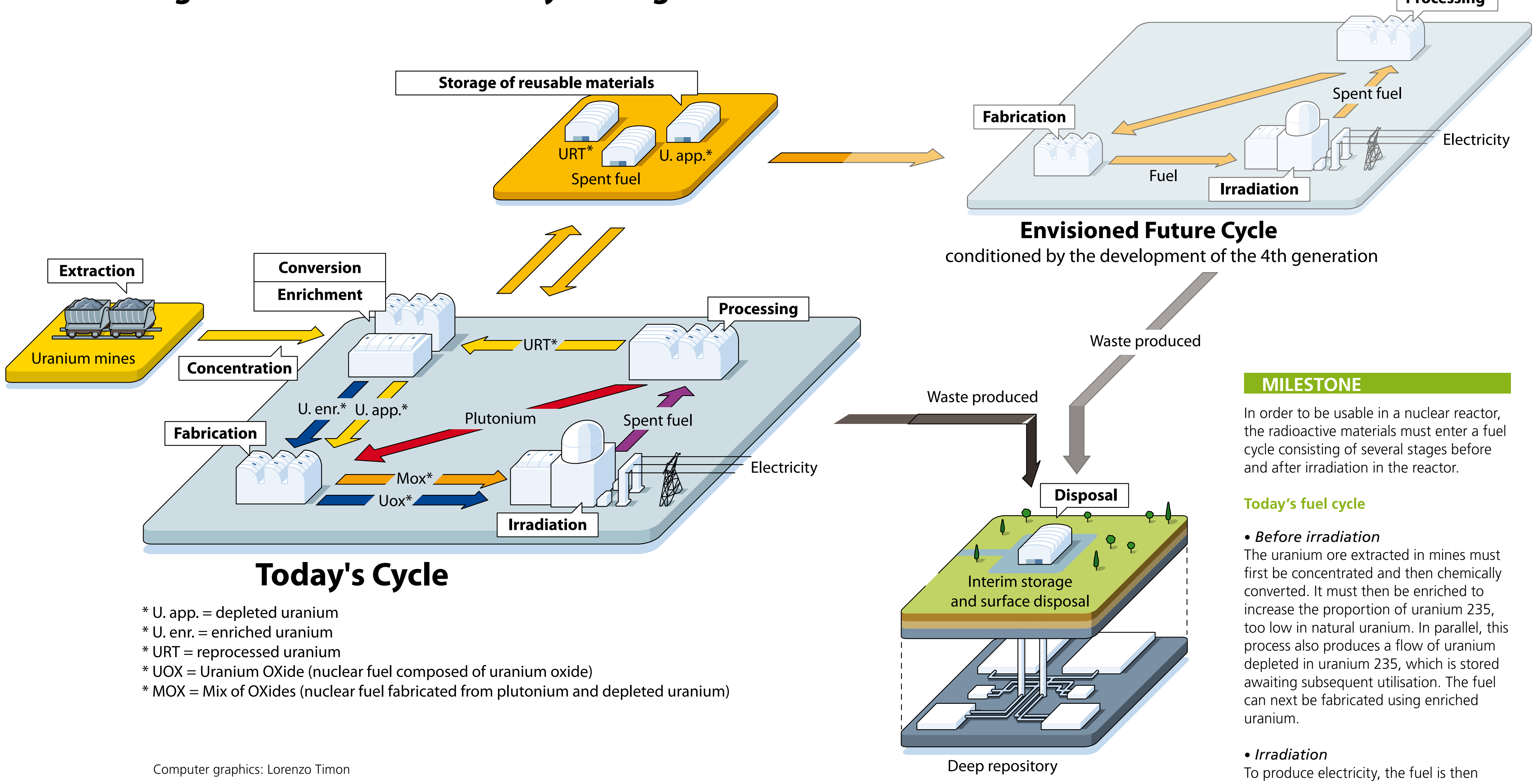
Future events:

2013: public debate on the reversible deep disposal centre after a location proposal by Andra

2015: law fixing the deep repository reversibility conditions

2025: beginning of the operation of the reversible deep disposal centre

General diagram of the nuclear fuel cycle stages



* U. app. = depleted uranium
* U. enr. = enriched uranium
* URT = reprocessed uranium
* UOX = Uranium OXide (nuclear fuel composed of uranium oxide)
* MOX = Mix of OXides (nuclear fuel fabricated from plutonium and depleted uranium)

Computer graphics: Lorenzo Timon

MILESTONE

In order to be usable in a nuclear reactor, the radioactive materials must enter a fuel cycle consisting of several stages before and after irradiation in the reactor.

Today's fuel cycle

• *Before irradiation*
The uranium ore extracted in mines must first be concentrated and then chemically converted. It must then be enriched to increase the proportion of uranium 235, too low in natural uranium. In parallel, this process also produces a flow of uranium depleted in uranium 235, which is stored awaiting subsequent utilisation. The fuel can next be fabricated using enriched uranium.

• *Irradiation*
To produce electricity, the fuel is then irradiated for approximately three to four years in the reactor.

• *After irradiatio*n
At the end of this stage, 96% of the fuel has still a high energy potential (uranium and plutonium). 4% of the fuel can no longer be reused and therefore constitutes waste.

The operation of spent fuel reprocessing allows extracting reusable materials in order to recycle them. Plutonium is recycled in the form of a fuel called MOX by also integrating depleted uranium, which can then be irradiated in French reactors. The uranium obtained from reprocessing can be re-enriched in order to be irradiated again in some French reactors.

The reprocessing operation also allows conditioning the waste originating from the spent fuels. This waste contains the major part of the radioactivity (other waste is produced in the various stages of the fuel cycle). This waste must be conditioned in view of its final disposal, which is the reference option for its long-term management.

Future fuel cycle

Another fuel cycle on which research is currently being conducted would allow in the future using the quantities of depleted uranium, reprocessed uranium and spent fuel stored today awaiting reutilisation. This cycle would consist of, in particular, so-called 4th generation reactors. This cycle would also produce radioactive waste.

Improving existing management routes

MILESTONE

Unlike a disposal centre, radioactive waste storage facilities are not designed to satisfy safety functions for a very long time, but only for a given duration.

Storage hall in the spent fuel reprocessing plant of Areva at La Hague.

This part gives an overview of the existing management methods at the end of 2009. It focuses on the orientations of improvement and the recommendations of the French National Plan for the radioactive materials and waste management routes:

- on a temporary basis (by means of storage facilities);
- and on a long-term basis: (i) radioactive material reuse processes; (ii) disposal of waste according to its nature (on-site, in conventional centres or in centres dedicated to radioactive waste).

Interim storage of reusable radioactive materials and radioactive waste

The storage of radioactive materials and waste consists in placing them temporarily in a facility, where they undergo a waiting, collecting, follow-up or observation period; during the waiting period, some short lived radioactive elements can decay. The storage facilities offer safety guarantees proportionate to the types and quantity of waste, taking into account the storage duration. The facilities require maintenance and human interventions. At the end of the storage period, the waste must be necessarily removed from the facility. This facility will be reused or dismantled at the appropriate time.

The storage centres for radioactive materials and waste mentioned in the French National Plan are classified into four categories:

- **short-term storage centres,** linked to the management of waste having a radioactive half-life less than 100 days. The objective is to wait until the waste activity has sufficiently decreased so that it can be transferred to a conventional management route. The main concerned sectors are nuclear medical services and research laboratories;
- **storage centres for radioactive materials pending reutilisation,** in particular for depleted uranium (on the Tricastin and Bessines sites), reprocessed uranium (on the Tricastin site), thorium-bearing materials of Rhodia and Areva (on the La Rochelle site and the CEA site at Cadarache);
- **old waste storage centres,** which do not any longer perfectly satisfy today's safety standards and must be improved or emptied on a more or less short-term schedule;
- **more recent waste storage centres,** which satisfy today's safety standards and for which it is necessary to confirm the adequacy to waste production forecasts.

This document details the last two categories covered by the French National Plan recommendations.

Historical waste storage centres

There are a number of old radioactive waste storage centres which do not any longer completely satisfy today's safety requirements. Operations for recovering the waste or improving and reinforcing the storage facilities must be programmed.

Historical radioactive waste storage centres include the facilities of Areva, the CEA and EDF. The waste stored in these facilities are intended for recovery operations. However, these operations may sometimes be difficult and fall frequently behind the announced schedules.

The main challenge in the upcoming years is to make sure, pending a complete destorage, that the safety level of the facilities remains acceptable and that the operators respect their engagements, notably in terms of deadlines.

Some very low level waste could in the past be stored directly on some nuclear sites if the waste activity level was deemed sufficiently low. This practice ceased after the ministerial order of 1999 was adopted.
The mound of very low level radioactive waste discovered at Bugey in 2006 is an example of this situation.

PLAN *The Plan's recommendation*

By mid-2010, nuclear operators should propose a programme in order to verify that in the perimeter of their facilities or their centres there are no historical waste storage centres which might have been unmentioned in the declarations to Andra for the national inventory established in 2009.

Radioactive waste can also be stored on sites classified for environmental protection. This is particularly the case of Rhodia, which stores on its site at La Rochelle, in addition to materials containing thorium considered to be reusable, various types of radioactive waste originating from extraction and reprocessing operations of ores for the separation of rare earths.

The first operations linked to the nuclear fuel cycle also led to the storage of approximately 300,000 tonnes of sludge on the Comurhex conversion plant's site at Malvési. Some of the basins containing this sludge are currently undergoing an administrative change in view of the classification of a part of the site as a nuclear facility.

Rare earth extraction process residues, Rhodia.

FOCUS

National inventory
The national inventory is regularly published by Andra. It indicates the radioactive materials and waste stocks (at the end of 2007 for the latest version published in June 2009), as well as the forecasts for the end of 2020, 2030 and at the end of the lifetime of the existing or authorised facilities (existing reactors, EPR being built at Flamanville, the plant at La Hague, CEA civil and defence facilities, etc.). This inventory also indicates the storage capacities for the various waste categories, as well as the storage needs for HL and IL-LL waste dedicated to deep repository. Finally, the inventory indicates the radioactive material stocks and the sites polluted by radioactivity.
www.andra.fr, title Éditions/Inventaire national.

DEFINITION

Radioactive materials
Radioactive materials are reusable radioactive substances, or, in other words, radioactive substances which are intended for further use, after treatment if need be.

MILESTONE

The long-term management of radioactive materials consists in implementing reusage methods.

The Plan's recommendation

Comurhex has been asked to submit by the end of 2011 a study proposing long-term management routes for this sludge, as well as management modalities for new waste produced by the operation of the facilities.

A storage capacity to be extended

The adequacy between the capacity of the recent storage centres and the estimated volumes of waste must be verified. To this end, The national inventory of radioactive materials and waste published in 2009 evaluates the cumulative quantities of waste following various timetables. For waste necessitating an interim storage (notably pending the long-term management route), the national inventory compares these stocks to the capacity of temporary storage.

For high or intermediate level and long lived (HL/IL-LL) waste, the evaluation shows that the storage facilities on the production sites should allow satisfying the estimated needs until the deep repository enters operation (scheduled for 2025), provided the extensions scheduled today by Areva, CEA and EDF are achieved, notably on La Hague, Marcoule, Cadarache and Bugey sites.

The Plan's recommendation

Several studies were requested from Andra, EDF, CEA and Areva in order to analyse how to best integrate these new storage facilities in the global scheme for the long-term management of HL/IL Long-lived waste after the opening of the reversible deep disposal centre around 2025.

Regarding the low level and long lived (LL-LL) waste from the diffuse nuclear sector, Andra will be creating a storage facility scheduled to go into industrial operation in 2012. This waste originates notably from historical activities, such as the handling and utilisation of radium during the 1st half of the 20th century. In addition, a more detailed comparison between the global LL-LL waste capacity and the estimated inventory of all the LL-LL waste should be completed on a date to be determined, which is consistent with the global evolution of the shallow depth disposal project.

Long-term management of reusable materials

Radioactive materials may be used inside and outside of France; for the sake of transparency, the French National Plan presents an assessment of the various flows of reusable materials at the borders (imports, exports, net flow).

The Plan's recommendation

Before the end of 2010, all French owners of reusable radioactive materials must conduct, as a conservatory measure, studies on possible management routes in case these materials would be qualified as waste in the future.

Spent fuels

The majority of spent fuels present in France is intended for reprocessing, which is currently accomplished in the Areva plant at La Hague. The extracted (reprocessed) uranium and plutonium can be reused as explained hereafter. However, small quantities of spent fuels from research reactors are likened to "high level" waste (for example, the fuels of the Brennilis EL4 reactor) and managed as such.

Uranium

Uranium comes in different forms: natural, enriched, depleted, and reprocessed.

Natural uranium
Starting from natural uranium, the enrichment plants produce two substance flows: on the one hand, uranium enriched in isotope U235, used in the fabrication of fuels, and, on the other hand, uranium depleted in U235 (content on the order of 0.4%).

Enriched uranium
Enriched uranium is used to fabricate fuel for the nuclear production of electricity and is, therefore, already reused today.

Depleted uranium
Depleted uranium may be used for three purposes:
- it has been entering for several years in the composition of the MOX fuel, which feeds some EDF reactors;
- it may be re-enriched to higher contents, which may be economically interesting if natural uranium prices rise, or if enrichment engineering techniques evolve;
- in the longer term, it will be reusable on a large scale in 4th generation fast neutron reactors, which could be deployed by the mid 21st century.

Reprocessed uranium
Reprocessed uranium (URT) extracted from spent fuels always contains a significant part of isotope U235, on the order of 0.8%. At the request of the customer EDF, this reprocessed uranium can be sent to an enrichment plant in order to produce enriched recycled uranium (URE) used for the fabrication of fuels. Today, of the 800 tonnes of reprocessed uranium obtained annually from the processing of spent fuels, approximately 300 tons are re-enriched. The four reactors on the Cruas site will thus be fed in the future with URE. As of 2010, due to the increase in spent fuel reprocessing (climbing to 1,050 tonnes of spent fuels reprocessed), the reprocessed uranium which will originate each year from the processing of spent fuels will be on the order of 1,000 tonnes.

After their utilisation in the reactor, the spent fuels are stored in water-filled pools to cool them off. The height of the water ensures a protection against the radiation they emit.

Concentrated uranium resulting from ore processing. This is the material which is transported and then enriched.

MILESTONE

4th generation reactors
4th generation reactors will be fast neutron reactors. Unlike current pressurised water reactors, they should allow using all the energy potential of uranium. If this technology is confirmed, the depleted uranium stocks available today in France will allow having resources for several thousand years. The research in France is mainly concentrated on the sodium cooled fast reactor. The objective is to place a technological demonstration prototype in operation around 2020.

Canisters containing plutonium oxide awaiting fabrication of MOX fuel.

DEFINITION

MOX fuel
The MOX fuel (mix of oxides) is a nuclear fuel based on depleted uranium oxide and plutonium oxide. The plutonium used is extracted from the spent fuel during reprocessing operations at La Hague. The MOX is elaborated in France in the Melox plant located at Marcoule in the Gard. Today, 20 EDF nuclear reactors use this fuel.

KEY FIGURES

95% of the spent fuel after irradiation in nuclear reactors consists of uranium which can be extracted in the form of reprocessed uranium, which can be reused.

In France, the MOX fuel used by EDF contributes to the nuclear production of electricity up to **10%** approximately.

Thus, on the order of **10 tonnes** of plutonium are annually recycled, that is, the entire flow recovered from the EDF fuels processed by Areva in the plant of La Hague.

Plutonium

Like uranium, the plutonium contained in the spent fuel assemblies is extracted during their processing. A spent uranium fuel of the light water reactor type contains today approximately 1% plutonium per mass. The mono-recycling of plutonium is practiced today in the MOX fuel.

In the longer term, plutonium may be used to start fourth generation reactors. The quantity of plutonium available around 2040 could allow starting approximately 25 fourth generation fast neutron reactors of the type studied by CEA.

Thorium

Thorium has neutronic properties favouring its utilisation in reactors. A "thorium cycle" for producing electricity by using thorium as the fuel may possibly materialize, but not before several decades considering the research and development work still to be done.

The Plan's recommendation

Given the strong reservations about the potential for thorium reuse in the short and medium term, the opportunity and feasibility of a mechanism to financially secure long-term management of thorium will be studied in the upcoming years in case this material would be eventually qualified as waste.

Long-term management of radioactive waste

The method used for the long-term management of a radioactive waste depends on its nature and its dangerousness. For some substances, such as mining residues and waste rock or some waste with enhanced natural radioactivity, an on-site disposal or the disposal in conventional disposal centres was deemed adequate. For others, such as very low level (VLL) waste, or low or intermediate level short lived (LL/IL-SL) waste, dedicated disposal centres were constructed.

On-site management or management in conventional disposal centres

On-site management concerns mining residues and waste rock, as well as a part of the waste with enhanced natural radioactivity. Management in conventional disposal centres concerns essentially waste with enhanced natural radioactivity. Other types of radioactive waste could also be disposed of in the past in conventional disposal centres (11 sites identified). Such waste consists of mainly sludge, earth, industrial residues, rubbish and scrap iron. Considering the nature of these disposals and the waste concerned, risks in terms of radiological protection appear limited.

The Plan's recommendation

The exhaustiveness of the inventory of the sites having accommodated low level waste in the past will be verified and the necessity of reinforcing the radiological monitoring measures on these sites will be studied.

Mining residues and waste rock

In France, uranium mines were exploited between 1948 and 2001. Exploration, extraction and processing activities concerned approximately 210 sites in France distributed over 25 "départements". Ore processing was carried out in eight plants. The exploration and exploitation of uranium mines generated mining residues and waste rock.

Today, the management of these products is an in-situ management considering the large quantities of waste produced, with arrangements being made to reduce the risk over the long term.

Mining residues, whose volume is evaluated at 50 million tonnes, are disposed of over 17 sites installed in the proximity of uranium ore processing facilities.
With the progressive closing of mining works, the disposal sites of mining residues were re-engineered by installing a solid covering on the residues to build up a protection barrier to limit the risks of intrusion, erosion, dispersion of disposed products and to reduce the radiological exposure of the surrounding populations. Studies conducted by Areva provide a first indication of the long-term impacts on health and on the environment of these disposals of mining residues. Additional analyses are, however, necessary to make the demonstration of the long-term safety of these disposals more robust.

The Plan's recommendation

Areva will study, in particular, methods to reinforce the quality of the coverings, which seems to be an efficient solution, in order to evaluate the feasibility and relevance of these methods on all the disposals of mining residues.

At the beginning of the exploitation of uranium mines, the waste rocks were made available to neighbours who needed materials for backfilling. In 1982, a transfer register was created to ensure a better traceability; subsequently, in 1990, the mining code was changed to regulate more strictly the management of materials derived from mining. Thus, the waste rocks are present in regions where rocks naturally rich in natural radioactivity are found and, therefore, where analogous conditions already naturally exist (notably during infrastructure construction work). The issue of the waste rock, therefore, is partially linked to that ofthe protection of the population in regions with natural radioactivity above the average. However, the reuse of these waste rocks in the environment can lead over the years to the result that the usage of the soil is not compatible with the presence of such waste rocks (for example, in the case of residential constructions right above such backfills).

DEFINITIONS

Mining residues
The mining residues are very low level or low level waste generated during ore processing operations.

Waste rock
Waste rocks correspond to material (soils, rocks, etc.) excavated to access the uranium lode to be mined. They were not subjected to any special mechanical or chemical processing.

KEY FIGURE

17 sites for the disposal of mining residues in the proximity of the uranium ore processing facilities.

Old mining site of Bellezane in the Haute-Vienne before its remediation.

Old mining site of Bellezane in the Haute-Vienne after its remediation.

FOCUS

The four key objectives of the circular of 22 July 2009

As an extension of the actions already taken and to resolutely pursue the management of old uranium mines, the Ministry of Sustainable Development and the ASN defined in the circular of 22 July 2009 an action plan comprising the following work objectives:

- check the old mining sites;
- improve knowledge about the health and environmental impact of the old uranium mines and monitor it;
- manage the waste rocks: get a better understanding on their uses and reduce impacts, if necessary;
- reinforce information and consultation.

DEFINITION

Waste with enhanced natural radioactivity

This waste is the waste generated by the transformation of raw materials naturally containing radioactive elements, but used for other reasons than for their radioactive properties.

The Plan's recommendation

Without systematically reconsidering a priori past utilisations, Areva should draw up for the end of 2011 a list of the sites reusing waste rocks and the situations for which incompatibilities between the use of the sites and the presence of these steriles should be identified and managed.

Waste with enhanced natural radioactivity

Waste with enhanced natural radioactivity originates from different sources and can represent significant volumes. This waste, which is long-lived, can be of low level or very low level:

- waste with enhanced natural radioactivity of a very low level of activity is eliminated either in dangerous, non dangerous or inert waste disposal centres, or in the very low level waste disposal centre operated by Andra (cf. p. 15), or in an internal dump. Finally, it can be managed in situ when important volumes of very low level waste are involved. An example of this type of waste generated in the past are the ash and phosphogypsum dumps. Each of these dumps represents at least several hundred thousand tonnes;
- waste with enhanced natural radioactivity, of a low level, is generally stored by the companies because no elimination management route is operational today (cf. p. 18).

Some urban development work has also used, in the past, backfills of materials originating from the conventional industry, but with low radiological levels. This is true for the harbour zones of La Rochelle, whose facilities were backfilled with residues originating from historical production activities of rare earths from ore containing thorium.

The Plan's recommendation

The management of waste with enhanced natural radioactivity could be improved by following four objectives: consolidate the inventories; reinforce traceability; implement adapted monitoring programmes; consolidate the current management solutions of this waste.

In view of this, the following actions should be engaged as a priority:

- *compile an assessment of the application of the circular related to the acceptance of waste with enhanced natural radioactivity in ultimate conventional waste disposal centre(s);*
- *draw up an inventory of the reusage modes for residues containing enhanced natural radioactivity;*
- *provide storage solutions by Andra to companies occasionally producing waste with enhanced natural radioactivity to be disposed of in the future shallow depth disposal centre.*

Management in dedicated radioactive waste disposal centres

Surface disposal centre of very low level (VLL) waste

The policy to manage very low level waste originating from nuclear facilities in France is not based on unconditional clearance levels, but rather on the origin of the waste within the facility. All the substances originating from a "nuclear waste zone" of a nuclear facility are, therefore, considered to be radioactive waste of at least the VLL level, even when this waste represents only an extremely low risk of containing radioactive elements.

To accommodate VLL waste, Andra has been operating since August 2003 a dedicated surface disposal centre in the commune of Morvilliers in the Aube.

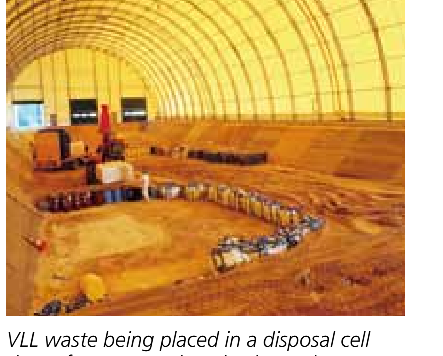
At the end of 2008, the total volume of waste disposed at the VLL waste centre was approximately 115,700 m^3, representing approximately 18 % of the authorised regulatory capacity (650,000 m^3). In order to avoid saturating the centre before the date scheduled during its design and to preserve the rare resource that the disposal volume constitutes, new optimisation pathways for the management of this waste must be studied. Thus, the reutilisation in the nuclear sector of metals and concrete originating from the dismantling of the nuclear facilities must be encouraged.

Surface disposal centre for very low level (VLL) waste at Morvilliers in the Aube.

The Plan's recommendation

Areva, CEA, EDF and Andra should join forces and increase their efforts to set up reutilisation management routes in the nuclear sector. It is also necessary for the main waste producers to examine the technical possibilities and the economic opportunity of densifying the waste delivered to the VLL waste disposal centre.

Today, the industrial management of large-scale waste in the VLL waste surface disposal centre necessitates a preliminary breakdown for waste weighing more than 30 tonnes. Andra will examine the interest of developing an industrial management route to take care of this waste in dedicated disposal cells.



VLL waste being placed in a disposal cell dug a few metres deep in clay rock.

The VLL waste surface disposal centre cannot take care of some of the chemically toxic VLL waste, even though it would be acceptable in ultimate waste disposal centres (technical burial centres) if it were not radioactive; therefore, there is no management route today for this waste. Andra will conduct a comparative study of the safety approaches of the conventional ultimate waste centres and the VLL waste surface disposal centre (located in Morvilliers) in order to define the management modalities to be adopted for this type of waste.

Aerial view of the Manche disposal centre (CSM) at Digulleville.

Surface disposal centre for low or intermediate level- Short lived waste located at Soulaines-Dhuys in the Aube.

Waste packages stacked in a disposal cell. This cell will then be closed by a concrete slab.

The low or intermediate level and short lived (LL/IL-SL) waste disposal management route for LL/IL Short lived waste is being managed in a dedicated management route, historically via the Manche surface disposal centre, and currently via the waste surface disposal centre at Soulaines-Dhuys in the Aube.

The Manche surface disposal centre (CSM)

Since its entry in operation in 1969 and until 1994, 527,000 m³ of waste packages have been disposed of in the Manche surface disposal centre (CSM) at Digulleville. The CSM has been in the monitoring phase since 2003. The centre was made leak tight by the installation of a covering. In 2009, Andra submitted to ASN a report on the evolution of this covering proposing solutions to improve the long-term stability of the slopes of the cover, which are too steep due to the current ground surface footprint limitations of the centre.

The Plan's recommendation

IIt is likely that eventually the ground surface footprint of the covering will necessitate extending the centre, which implicates that Andra already has to watch today for the real estate availability of lands contiguous to the centre.

The Aube surface disposal centre

The Aube surface disposal centre with a capacity of a million cubic metres located at Soulaines-Dhuys took over from the CSM in 1992. It benefitted from the CSM feedback and the safety rules which were established there during the 1980s. At the end of 2008, 220,000 m³ of waste packages were disposed of representing approximately 22% of its authorised capacity. Concerted efforts to reduce the production of low or intermediate level and short lived waste at the source in nuclear facilities allowed significantly extending the lifetime of the centre up to 2040-2050. However, it is important to remain vigilant and monitor in the upcoming years the evolution of the waste volume still to be stored, as well as the estimated timetable for its conditioning and disposal.

The Plan's recommendation

This management route is being covered by two main study topics:

- *the disposal of large-dimensioned waste (reactor vessel heads): these types of operations, which are already performed after maintenance operations, are planned or being studied for waste coming from dismantling operations. This disposal option versus conditioning in a standard package deserves to be assessed. Based on international approaches, Andra and the concerned waste producers will study the criteria in order to evaluate the relevance of the disposal for large-dimensioned (LL/IL-SL) waste in their current state;*
- *the limitation of the quantity of tritium liable to be accepted: experience acquired at the Manche surface disposal centre led Andra to limit the quantities of tritium liable to be accepted in the Aube surface disposal center in order to avoid contaminating soils and ground water by tritium. A reflection on new acceptance criteria at the Aube surface disposal center for waste containing significant quantities of tritium will be made.*

Developing new long-term management routes

This part presents the long-term management routes being developed for some categories of waste still not being disposed of, particularly waste containing tritium, sealed radioactive sources, low level and long lived (LL-LL) waste and high or intermediate level and long lived (HL/IL-LL) waste. It also treats the case of very low quantities of waste which cannot be connected today to a long-term management route project under development; the French National Plan asks for studies to define management routes for this waste.

Waste containing tritium

Today, waste containing tritium (called tritium-bearing waste) originates to a great extent from activities linked to national defence. Tritium is also used in research activities, the pharmaceutical sector or in hospitals, which is generically called the diffuse nuclear sector. In the future, significant quantities of tritium-bearing waste will also be produced by the operation and dismantling of the ITER facility (for research on nuclear fusion).

Today's operational management routes for the evacuation of tritium-bearing waste apply only to the least active waste. For other waste, considering the high mobility of tritium through the media which contain it, it does not seem possible to accommodate it immediately in the Andra surface disposal centre; this practice would have for an effect the tagging of the ground water around the disposal by tritium. Consequently, tritium-bearing waste with a high tritium concentration does not have for the time being a long-term management route.

The French National Plan published in 2007 had requested CEA, which currently holds most of the waste without a management route, to study storage solutions pending a sufficient drop in the tritium's activity.

The new storage concepts proposed by CEA provide today a concrete solution ensuring the short -and medium- term safety for the management of tritium-bearing waste pending the implementation of definitive elimination management routes.

The Plan's recommendation

As a result, CEA must construct new storage centres for its waste, following the principles defined in its orientation file.Moreover, operational solutions for the management of tritium-bearing waste that have no management route, and that do not belong to CEA but originate from the diffuse nuclear sector, must be determined by Andra in conjunction with CEA. Andra should also consolidate in conjunction with the concerned waste holders the inventory of this tritium-bearing waste from the diffuse nuclear sector, taking into account notably the radioactive objects and sealed sources present in the civil equipment (aeronautics, railways, etc.) and those in the defence sector.

DEFINITIONS

Diffuse nuclear sector

Some hospitals, research centres and industries use radioactivity for activities other than the production of electricity, national defence or nuclear research. The radioactive waste which they produce results in particular from medical examinations by scintigraphy, experiments for the refining of medications or industrial welding tests. Even though there are a large number of producers of this type of waste, the generated volume remains low.

Tritium

Tritium is a radioactive element. It is a hydrogen isotope with one proton and two neutrons. Due to its dilution with hydrogen, present in large quantities, and having the same physical and chemical properties, the tritium concentration is always very low.

DEFINITION

Sealed radioactive sources
Sealed radioactive sources are small objects used for their radioactive properties in many different applications (medical, scientific or industrial). They concentrate the radioactivity in small volumes and are mostly composed of stainless metals with a high longevity.

Sample of sealed radioactive sources.

Sealed radioactive sources

Sealed radioactive sources are numerous (tens of thousands and even millions of them), but their volume is very small (less than 1% of the total volume of radioactive waste).

Once the authorised service life has been reached (10 years in France unless extended under certain conditions), the sealed sources must be returned to their supplier, who in turn returns them to the manufacturer or has them eliminated in authorised facilities. Concretely speaking, there are three possibilities:

- return of the source to the supplier, and then exportation to a supplier or a foreign manufacturer;
- return to the supplier, and then to the manufacturer located in France;
- no supplier identified; a system must be set up to allow the recovery of the source.

In France, most spent sealed sources are currently stored temporarily pending a final management solution. Andra is, in fact, only authorised to dispose of a part of the inventory of spent sources at the Aube surface disposal centre. To remedy this situation, Andra submitted in 2008 a study of processes for disposing of spent sealed radioactive sources in existing centres or centres to be constructed.

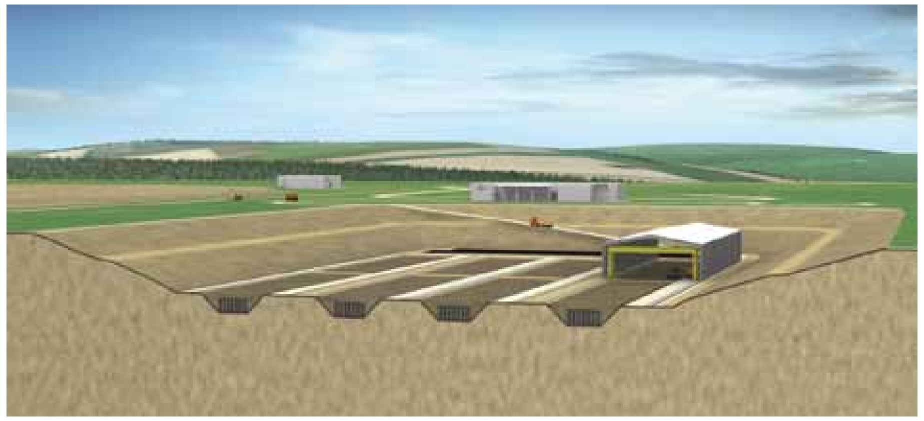
The Plan's recommendation

This scheme for the orientation of sources should be specified and completed in the upcoming years in view of its operational implementation.

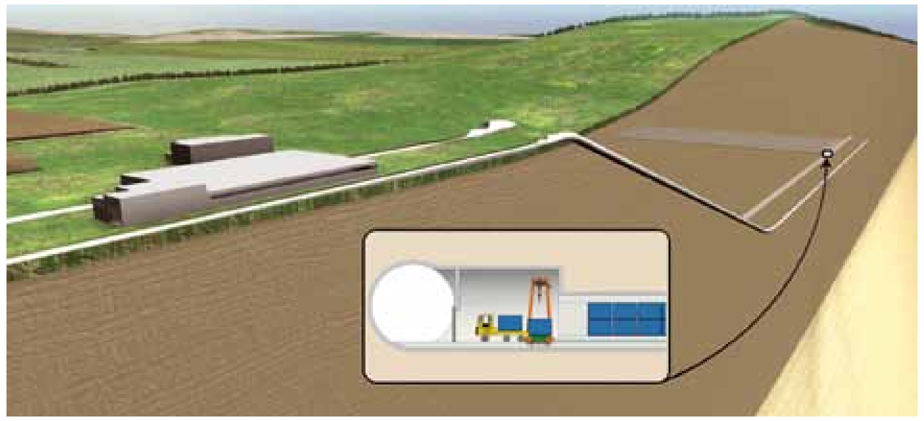
Low level and long lived (LL-LL) waste

Low level and long lived radioactive waste must be handled by a special management method adapted to their long lifetime, which does not allow it to be disposed of in the Andra centres in the Aube department. Its low radioactivity does not justify, however, it being disposed of in a deep geological layer. This waste includes notably graphite waste originating from the operation and future dismantling of EDF gas cooled reactors and radium-bearing waste, originating mainly from the processing of ores containing rare earths.

The management solution being studied is a sub-surface disposal (between 15 and 200 m) in a geological layer of low permeability (essentially of the clayey or marly type) of sufficient thickness (at least 50 m). The volume to be disposed of is on the order of 200,000 m³ of conditioned waste.



Shallow depth LL-LL waste disposal with a reworked cover. *Rock is excavated into the open air. After the waste is disposed of, the zone is backfilled with natural materials extracted from the site.*



Shallow depth LL-LL waste disposal with an intact cover. *The disposal is dug into the subsoil; the access drifts are backfilled once the waste is disposed of.*

In 2008, on request by the Government, Andra initiated a search for sites favourable for the disposal of such waste in order to undertake in-depth investigations on these sites. Thus, Andra received forty-some candidatures from localities interested in the project and located in a priori favourable zones. After a technical evaluation of the candidatures and consultations with the Nuclear Safety Authority (ASN), the National Evaluation Committee (CNE) and the elected officials of the concerned territories, two sites of the Aube department were identified. Since the concerned localities had withdrawn their candidatures, the search process for a disposal site is continuing to be pursued.

The Plan's recommendation

The site search process will be pursued with the objective of exemplarity not only in terms of nuclear safety, but also in terms of consultation and transparency, following the principle of free choice by the territories. A public debate is already anticipated to take place prior to the selection of the site.

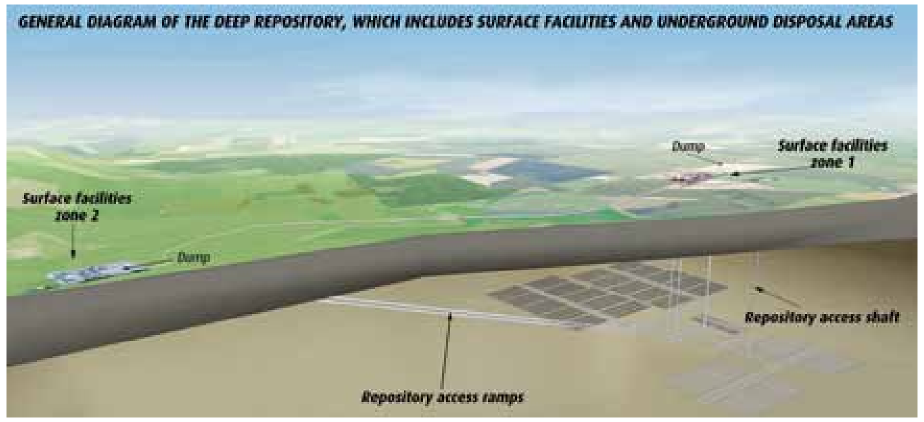
In parallel with the search for sites, studies will be conducted regarding the knowledge, processing and conditioning of the LL-LL waste. The work involving the quantitative inventory and characterisation of the waste shall also be studied in more depth so that Andra can propose a dimensioning inventory model to size the disposal.

High or intermediate level and long lived (HL/IL-LL) waste

Research related to the long-term management of high or intermediate level and long lived (HL/IL-LL) radioactive waste is being pursued, mainly around the three research objectives defined by the act of 2006: reversible deep disposal (reference option), the separation-transmutation of long lived radioactive elements, and storage. In addition, complementary research is also being conducted on the processing and conditioning of the waste. The objective is to have by 2015 sufficient elements to file an authorisation for implementation for a deep disposal centre.

Reversible deep disposal

Reversible deep disposal at a depth on the order of 500 m is the reference management option for HL/IL-LL waste.



General Diagram of the Deep Repository, *which includes surface facilities and underground disposal areas.*

The law stipulates that the reversible deep repository is the reference option for ultimate radioactive waste that cannot be disposed of on the surface or at a sub-surface for reasons of nuclear safety or radiological protection. It sets an objective to place the repository in operation by 2025, provided authorisations are granted as of 2015. It imposes, in addition, that the disposal be reversible for a period of at least 100 years; the reversibility conditions should be determined by the Parliament and enacted in a new act around 2015.

Since 2005, the feasibility of such a repository has been acquired. Recent research by Andra, notably in the Meuse/Haute-Marne underground research laboratory, allowed specifying the repository design, refining the geological model of the studied sector, and defining a zone of a smaller size to select the site. So, Andra proposed to the Government at the end of 2009 a so-called zone of interest for in-depth exploration (ZIRA) in which more in-depth research will be conducted for the subsequent underground installation of the repository. Based on a dialogue with local bodies, Andra also proposed scenarios for the layout of the disposal's surface facilities. The Government turned to ASN and CNE for a technical opinion and also consulted the Local Information and Oversight Committee (CLIS) set up with the Meuse/Haute- Marne underground research laboratory. CNE and ASN rendered a positive technical opinion. The Government will take a stance in early 2010 as soon as the CLIS responds. Studies will then be pursued in and around this ZIRA notably to refine the geological knowledge of the zone.

Separation and transmutation of long lived radioactive elements

This is one of the two other objectives studied in addition to the reversible deep disposal. Research assessment concluded that separation is feasible and that transmutation may be envisioned in fourth generation fast neutron reactors (which could be placed in operation at an industrial scale by the mid century). However, considering the results obtained, it is clear that this process may be applied only to a part of the elements contained in the future HL/IL-LL waste and that it is not realistic to envision it for vitrified waste produced up to now. The technical/economic performances of the various transmutation scenarios are currently being evaluated.

Storage

It is the last objective studied in addition to the reversible deep disposal. Since 2006, the so-called long-term storage is no longer studied as a long-term management solution because it raises the problem of overburdening the future generations. Long-term storage would entail, in fact, an active control by the society – present and future – throughout the storage period, as well as, eventually, the recovery and a new management of the waste.From now on, the work on storage will consist of applied studies whose purpose will be to accompany by 2015 the extension of existing facilities or the creation of new facilities. The studies conducted by Andra are aimed at, in particular, designing storage facilities which will complement as much as possible disposal in order to optimise the overall management of the HL/IL-LL waste, while taking into account the principle of disposal reversibility legally imposed.

DEFINITION

Separation-transmutation
Designates the transformation, subsequent to a nuclear reaction, of one element into another element. The transmutation can take place in the reactor or with a particle accelerator. This is a way that is being studied to eliminate some radioelements contained in spent fuels and currently found in ultimate radioactive waste. The objective is to diminish its harmfulness by transforming it into shorter lived radio-elements. To this end, it is necessary to separate before-hand the various radio-elements and expose them to special neutron fluxes; the entire process is called separation-transmutation.

Processing and conditioning

Finally, the three previous research objectives for long-term waste management are completed by other more specific studies on the processing and conditioning of HL/IL-LL waste. Today HL waste is conditioned at the industrial scale thanks to vitrification; the IL-LL waste has been or is currently being conditioned by compaction, cementation or bitumisation.

The Plan's recommendation

Today's research, which is to be pursued and increased in the upcoming years is aimed notably at implementing conditioning modes adapted to IL-LL waste containing organic substances and at specifying the conditioning modes for all the historicalIL-LL waste still not conditioned (for which the law stipulates that it must be conditioned before 2030).

Additional steps for the definition of the HL/IL-LL waste management route will be to have a number of response elements available for 2012:

- **on the deep repository:** *Andra will pursue its research and studies in order to submit by the end of 2012 a support file for the organisation of a public debate on waste scheduled for 2013, consisting of notably a site proposal for the location of the disposal centre. Thereafter, Andra will file an authorisation application to create the repository by the end of 2014, in conformity with the legally fixed objective;*
- **on separation-transmutation:** *the research assessment conducted by CEA will be completed and updated in 2012; it will include notably industrial perspectives and the advantages of this process with respect to direct deep disposal. In parallel, a feasibility review on fourth generation nuclear reactors will be carried out in 2012 to assist in making a selection between the studied reactor types;*
- **on storage:** *Andra is to submit by the end of 2012 an assessment of all the research and studies which it will have driven and coordinated.*

Waste currently without management route

Almost all waste can be managed today in an existing or planned long-term management route. Even though progress has been made since the previous French National Plan (definition of the management routes for spent sealed radioactive sources or for waste containing tritium), there still exists a small volume (less than 0.1% of the total) of waste which cannot be assigned, mainly for reasons of chemical composition, to an existing long-term management route (for example, some radioactive waste with asbestos).

The Plan's recommendation

Studies have been requested from Andra and waste producers to develop decontamination or processing processes of this waste, which would then allow attaching it to an existing or planned long-term management route.

In France, almost 90% of the radioactive waste volume already has long-term management routes, the other waste being temporarily stored pending the development of such management routes. Even though the set-up management framework is solid, progress must still be made, particularly to define long-term management routes for all the waste.

Since the publication of the first French National Plan in 2007, significant advancements have been made, particularly to define management routes for certain waste categories for which no management route was available (for example, for sealed radioactive sources and waste containing tritium). An important milestone was achieved at the end of 2009 for the reversible deep disposal project: Andra submitted four studies notably on the repository design and on the choice of a zone of small size for in-depth exploration.

The new French National Plan edition is the occasion to define an action plan in new fields: program the recovery of waste from some old storage sites, study the impact of the historical reutilisation of waste rock, or improve the global consistency of the management of radioactive materials and waste.

The French National Plan also defines a consistent work programme for the upcoming years in order to pursue and intensify the actions already engaged within the framework of the previous French National Plan:

- reversible deep disposal project (Andra will make a site proposal in 2012 in view of a public debate);
- sub-surface disposal project;
- historical waste to be conditioned;
- long-term impact of the disposals of mining residues to be reduced;
- new management routes to be industrially implemented for waste for which no such route was available.

The publication of a new French National Plan 2013-2015 in transparency and consultation will allow strengthening the advancements in terms of the management of radioactive materials and waste in France.

The main stakeholders in the management of radioactive materials and waste

In France, the main players are:

- the producers of radioactive materials and waste, particularly Areva, CEA and EDF;

- Andra (National Agency for Radioactive Waste Management), the radioactive waste manager, whose missions include notably the design and operation of disposal centres, the performing of research and studies on storage and the deep repository, the collection of radioactive waste for which the people in charge are defaulting and information to the public;

- French research institutions other than Andra: the Atomic Energy Commission (CEA) and the National Centre for Scientific Research (CNRS);

- the French ministries responsible for energy, the environment and research. In particular, within the Ministry of Ecology, Energy, Sustainable Development and Sea (MEEDDM), the General Directorate for Energy and Climate (DGEC) elaborates the policy and implements the Government's decisions related to the civil nuclear sector, except for those dealing with nuclear safety and radiological protection;

- the Nuclear Safety Authority (ASN), an independent administrative authority, which ensures the control of nuclear safety and radiological protection for civil nuclear facilities and activities. The delegate for the nuclear safety and radiological protection of facilities and activities pertaining to defence (DSND) performs the same mission in the defence field;

- the Institute for Radioprotection and Nuclear Safety (IRSN) provides technical support to nuclear safety authorities;

- the Parliamentary Office for the Evaluation of Scientific and Technological Choices (OPECST);

- the National Evaluation Committee (CNE), which is responsible for an annual evaluation of the research conducted in the field of the management of radioactive materials and waste, submits its report to Parliament;

- the representatives of the civilian society, the environmental protection associations and the representatives of elected officials, who participate in exchanges organised to promote transparency and consultation. In this field, the key role played by the High Committee for Transparency and Information on Nuclear Security (HCTISN) and the Local Information and Oversight Committee (CLIS) created with the Meuse - Haute-Marne underground research laboratory should be noted, as well as by local information committees (CLI) installed nearby the basic nuclear facilities (INB) and united in a National Association of CLIs (ANCLI).

For more information

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Ministère de l'Écologie, de l'Énergie, du Développement durable et de la Mer
en charge des Technologies vertes et des Négociations sur le climat

Direction générale de l'énergie et du climat (DGEC)

Arche Nord – 92055 La Défense Cedex

Tél. : 33 (0)1 40 81 21 22

www.developpement-durable.gouv.fr

Autorité de sûreté nucléaire

6 place du Colonel Bourgoin – 75572 Paris cedex 12

Tél. : 33 (0)1 40 19 86 00

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