2012

In summary

NATIONAL INVENTORY of Radioactive Materials and Waste

ANDRA
Mastering radioactive waste

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE

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

"In the early 1990s, the French government created the National Radioactive Waste Management Agency (Andra) and commissioned it to research and develop safe management solutions for all French nuclear waste.

In accordance with the framework stated above, Andra is responsible for performing an annual inventory of the radioactive materials and waste in the country, comprising information about their type, quantity and whereabouts. Every three years, as part of this general interest mission entrusted to it under the French Planning Act dated 28 June 2006, Andra updates and publishes this information in the *National Inventory*.

The 2012 edition of the *National Inventory* describes the waste that existed on 31 December 2010, on the basis of what was declared by the organisations holding waste, and it forecasts the expected quantities of waste for 2020 and 2030. A longer-term forecast has also been produced for two alternative scenarios regarding the long-term future of France's nuclear facilities and energy policy. It also lists radioactive materials which are stored with a view to reuse.

In the interests of transparency, Andra has set up a steering committee to monitor the production of the *National Inventory*. This committee includes representatives of institutions, environmental protection associations and waste producers.

This inventory is a key resource which is referred to in the management of the current and future radioactive waste in France. It meets the EU's directive that was adopted by member states on the 19th of July 2011 concerning the responsible and safe management of spent fuel and radioactive waste. This directive recommends that each member state should draw up a national programme for the management of spent fuel and waste, based on inventories.

Andra is responsible for informing the public regarding nuclear waste and its management, and wishes to make this summary version of the 2012 edition of the *National Inventory* available to all."

Marie-Claude Dupuis
Chief Executive Officer of Andra

François-Michel Gonnot
Chairman of the Board of Andra

The complete inventory 2012

This summary of the *National Inventory* is intented for the general public. The complete *National Inventory* also includes technical documents that provide a comprehensive set of data on radioactive materials and waste in France:

Synthesis report

A detailed description of all existing and future French radioactive materials and waste, listed under categories such as management solution, economic sector and owner.

Catalogue of families

A presentation of all radioactive waste grouped by family, each family covering waste with similar characteristics (available only in french).

Geographical inventory

The locations of radioactive waste in France (available only in french).

Both the synthesis report and summary versions are available in multimedia format on a USB key and all the documents related to the *National Inventory* can be found on Andra's website (www.andra.fr). Suggestions can also be registered by users directly on the site.

Contents

Radioactive waste

Many industries make use of the properties of natural or artificial radioactivity. These uses produce waste, some of which is radioactive. The vast majority is similar to conventional waste, such as tools, clothing, plastics, scrap metal and rubble. However, its radioactivity presents a health risk and special management methods must be used.

Radioactivity is used in five main industries:

Cruas nuclear power plant

1 **Nuclear power industry:**
nuclear power plants and fuel-fabrication and reprocessing facilities (activities such as extracting and processing uranium ore, manufacturing fuels and reprocessing spent fuels).

French submarine, Le Redoutable

2 **Defence industry:**
activities associated with the nuclear deterrent and the nuclear propulsion systems of certain ships and submarines, along with associated research.

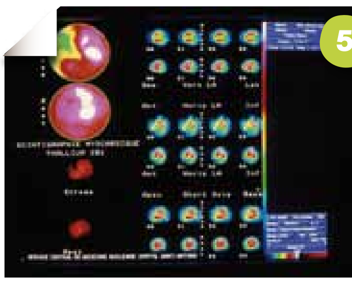
Pharmaceutical laboratory

3 **Research:**
research centres in various fields such as nuclear power, particle physics, agronomics, chemistry and biology.

4 **Conventional industry (excluding nuclear power):**
extraction of rare earths, manufacture of radioactive sources and various other applications (such as weld inspection, sterilisation of medical equipment, food sterilisation and preservation).

Smoke detector

5 **Medical field:**
medical research, diagnostics and treatment.



Cardiac scintigraphy

Very-short-lived waste

Some waste, mainly hospital waste, contains very-short-lived radionuclides (with a half-life of less than 100 days), which are used for diagnostic or therapeutic purposes.

Because of its very short half-life, such waste is stored on site until its radioactivity has decayed away, which takes from a few days to a few months.

It is then disposed of as conventional waste.

Radioactivity

Radioactivity is a natural phenomena discovered at the end of the 19th century, which involves certain unstable isotopes that decay by emitting radiation. The radioactivity of a substance reduces naturally over time, at a rate that will depend on which radionuclides are present.

The half-life is the time taken for half of the initial quantity of a given radionuclide to decay: 8 days for iodine-131, 13 years for tritium, 31 years for caesium-137, 1,600 years for radium-226 and 5,700 years for carbon 14. For example, from a sample of 1 gram of caesium-137 only 0.5 grams would remain after 31 years. This sample would therefore be half as radioactive.

Highly varied waste

Radioactive waste consists of substances for which no later use is envisaged. It contains a mixture of radionuclides (such as caesium, uranium, iodine, cobalt, radium and tritium).

Depending on the nature of these radionuclides, the waste has higher or lower levels of radioactivity which is shorter or longer lived. For management purposes, nuclear waste is classified on the basis of a series of criteria, in particular:

- **its radioactivity** expressed in becquerels (Bq) per gram. The radioactivity (or simply "activity") of waste can be very-low, low, intermediate or high level.
- **its lifetime,** which depends on the half-life of each radionuclide it contains. For the sake of simplicity, waste whose radioactivity mainly comes from short-lived radionuclides (with a half-life of less than or equal to 31 years) is referred to as short-lived waste, while waste with a significant quantity of long-lived radionuclides (with a half-life of more than 31 years) is referred to as long-lived waste.

There are five categories of radioactive waste:

- **very-low-level waste (VLLW)**
- **short-lived low and intermediate-level waste (LILW-SL)**
- **long-lived low-level waste (LLW-LL)**
- **long-lived intermediate-level waste (ILW-LL)**
- **high-level waste (HLW)**

Materials or waste?

The uses of radioactivity also produce radioactive materials. These are substances for which a later use is envisaged, sometimes after reprocessing. Only radioactive waste is due for disposal by Andra. Nevertheless, radioactive materials are included in the *National Inventory* because they could become waste if, ultimately, they are not reused.

Waste classification

Waste is classified when it is produced and when it is placed in temporary storage. Before disposal, waste is subject to detailed analysis and may also be treated. This may change its category and management solution.

Very-low-level waste (VLLW)

At the end of 2010, there was **360,000 m³** of VLLW in France, representing:

- **27% of the total volume** of existing radioactive waste*;
- **less than 0.01% of the total radioactivity** of existing radioactive waste.

Origin of VLLW

Very-low-level waste mainly originates from **the operation and decommissioning of nuclear facilities. It also comes from conventional industries that use naturally-occurring radioactive materials** (such as the chemical, metallurgy and power-generation industries, etc.). Certain types of VLLW are produced by the clean-up and remediation of legacy sites polluted by radioactivity. Such VLLW is generally in the form of inert waste (such as concrete, rubble and soils, etc.) or metallic waste.
Over the coming years, a large fraction of VLLW will come from the decommissioning of current nuclear power plants and nuclear fuel-cycle facilities.
The radioactivity of such waste is generally less than 100 becquerels per gram and it may contain both short-lived and long-lived radionuclides.

Industrial VLLW (such as scrap metal and plastics) before conditioning

Conditioned VLLW in bulk bags

* Waste produced in France that is to be managed by Andra.

By the end of 2010, approximately **175,000 m³ of VLLW** already disposed of

Current and forecast volumes of VLLW

(m³ equivalent after conditioning)

Stocks 2010	2020	2030
360,000	762,000	1,300,000

Management

Since 2003, VLLW has been disposed of in a dedicated repository, operated by Andra in Aube (Eastern France), which is the world's first facility for this type of waste. Between 20,000 and 30,000 m³ of VLLW are disposed of each year *(see page 29)*.

Depending on its type, VLLW is either packed into bulk bags, mainly to facilitate handling, or into metal crates.

Certain waste items may be subject to specific treatment:

- **compaction** of plastic and metallic waste to reduce its volume;
- **solidification and stabilisation** of liquid waste, such as polluted water or sludge.

Compacted VLLW

VLLW disposal cell

A different approach in France and Spain

Due to the very low radioactivity of this waste, most countries treat it as 'conventional' waste.

France, followed by Spain, has decided to manage it in a dedicated facility.

Short-lived low-and intermediate-level waste (LILW-SL)

At the end of 2010, there was **830,000 m³** of LILW-SL in France, representing:

- **63% of the total volume** of existing radioactive waste*;
- **0.02% of the total radioactivity** of existing radioactive waste.

Origin of LILW-SL

Short-lived low and intermediate-level waste is mainly **waste associated with the operation and maintenance of nuclear facilities** (liquid or gaseous effluents from operation; clothing, tools, gloves and filters from maintenance).

Such waste also comes from hospitals universities and research centres, etc. or from **clean-up and decommissioning operations.**

LILW-SL mainly contains short-lived radionuclides (such as cobalt-60 and caesium-137). It could also contain a limited quantity of long-lived radionuclides. The radioactivity of such waste is generally between a few hundred and one million becquerels per gram.

LILW-SL before conditioning

* *Waste produced in France that is to be managed by Andra.*

By the end of 2010, approximately **771,000 m^3 of LILW-SL** already disposed of

Current and forecast volumes of LILW-SL

(m^3 equivalent after conditioning)

Stocks 2010	2020	2030
830,000	1,000,000	1,200,000

Management

LILW-SL was formerly disposed of at the 'Centre de Stockage de la Manche' disposal facility, which has now closed and is monitored by Andra. Since 1992, it has been managed at Andra's Aube facility in Eastern France *(see page 29)* and over 10,000 m^3 are disposed of there each year.

Prior to disposal, LILW-SL is solidified if liquid and solid waste may be compacted to reduce its volume. It is generally placed in a metal or concrete container and then embedded in concrete.

LILW-SL packages comprise 15-20% radioactive waste and 80-85% of embedding matrix.

Compacting a drum of LILW-SL

LILW-SL package

LILW-SL package disposal at the Aube facility

A system that has been operating for 40 years

LILW-SL represents over 60% of radioactive waste currently produced in France (excluding legacy waste). It was the first category to have a dedicated repository, over 40 years ago.

Long-lived low-level waste (LLW-LL)

At the end of 2010, there was **87,000 m³** of LLW-LL in France, representing:

- **7% of the total volume** of existing radioactive waste*;
- **0.01% of the total radioactivity** of existing radioactive waste.

The LLW-LL category covers three main types of waste:

- **'graphite' waste** from first-generation French nuclear power plants that used gas-cooled reactors (GCR). Graphite, a very pure form of carbon, was used in large quantities in these first-generation reactors. This waste comes from operation of these power stations (from fuel sleeves) and from their decommissioning (such as graphite piles from reactor cores and bio-shielding).

It also comes from the operation and decommissioning of experimental reactors which have now shut down.

This waste contains long-lived radionuclides such as carbon-14 (with a half-life of 5,700 years).

Its radioactivity is between 10,000 and 100,000 becquerels per gram.

- **radium-bearing waste** which contains natural long-lived radionuclides, in particular radium and/or thorium.

This mainly comes from the former industry that used radium and its derivatives, and from the chemical treatment of ores by the nuclear and chemical industries.

Graphite sleeve

Radium-bearing waste

* *Waste produced in France that is to be managed by Andra.*

Small quantities of such waste also comes from the clean-up of former industrial sites polluted by radioactivity.

Its radioactivity is generally between a few tens and a few hundreds of becquerels per gram.

- **other types of LLW-LL** like certain spent sealed sources (such as lightning conductors and smoke detectors, etc.) and certain old radioactive objects that are found in private hands (such as radioluminescent watches and medical radium needles, etc.).

Radium lightning conductor

Current and forecast volumes of LLW-LL

(m^3 equivalent after conditioning)

Stocks 2010	2020	2030
87,000	89,000	133,000

Management

Solutions for managing LLW-LL are currently being studied *(see page 30)*. Most LLW-LL is legacy waste which is no longer being produced.

While waiting for Andra to create a suitable repository, such waste is stored, usually on the sites where it was produced.

Radium-bearing waste conditioned in drums

A storage facility for non-nuclear-power waste

While a disposal solution is being developed for LLW-LL, packages are stored in various facilities. Main producers have their own storage facilities.

Non-nuclear-power waste from small producers, which Andra manages, has been stored in various facilities belonging to the main nuclear operators. Some of these facilities can no longer accept such waste, which therefore must be removed.

Andra has therefore proposed the construction of a new storage facility on the site of its Aube low-level-waste repository in Eastern France. This facility should be commissioned during 2012.

Long-lived intermediate-level waste (ILW-LL)

At the end of 2010, there was **40,000 m³** of ILW-LL in France, representing:

- **3% of the total volume** of existing radioactive waste*;
- **4% of the total radioactivity** of existing radioactive waste.

Origin of ILW-LL

Nuclear power plants operate using fuels that are mainly composed of uranium.

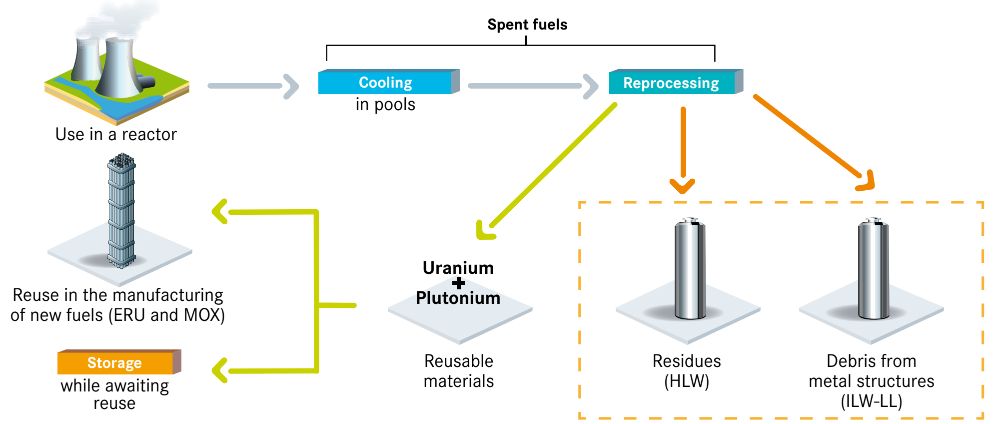
After several years in the reactor core, these fuels become less efficient. They are then reprocessed at the AREVA NC facility at La Hague.

The metal structures surrounding the fuel are sliced into small sections to separate them from the material and residues that they contain. A major fraction of ILW-LL is composed of this metal debris (cladding, hulls and end caps) but some may also come from the reprocessing operations of the spent-fuel itself. ILW-LL can also be components (other than fuel) from the inside of nuclear reactors or waste from maintenance and decommissioning operations on nuclear facilities, workshops or laboratories, etc.

ILW-LL contains significant quantities of long-lived radionuclides.

The radioactivity of such waste is generally between one million and one billion becquerels per gram.

The nuclear fuel cycle



* *Waste produced in France that is to be managed by Andra.*

Current and forecast volumes of ILW-LL

(m³ equivalent after conditioning)

Stocks 2010	2020	2030
40,000	45,000	49,000

Management

Given its radioactivity and lifetime, **ILW-LL is due for disposal in the Cigéo waste disposal centre, currently being studied by Andra** *(see page 31)*.

To reduce its volume, a significant fraction of ILW-LL is compacted into pucks, which are then inserted into concrete or metal packages. Other conditioning methods could be used depending on the type of waste, such as cement or bitumen encapsulation, or vitrification.

While awaiting the creation of a deep geological repository, it is stored mainly on the sites where packages are produced.

Metallic waste from the structures surrounding spent fuel (hulls and end caps).

Package containing several ILW-LL pucks

High-level waste (HLW)

At the end of 2010, there was **2,700 m^3** of HLW in France, representing:

- **0.2% of the total volume** of existing radioactive waste*;
- **96% of the total radioactivity** of existing radioactive waste.

Origin of HLW

HLW mainly comes from the **reprocessing of spent fuel** from nuclear power plants.

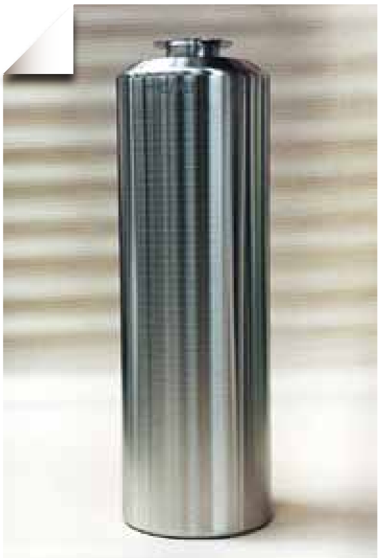
During this reprocessing, spent fuels are dissolved in a chemical solution to separate the uranium and plutonium from the non-reusable residues.

These highly-radioactive residues constitute HLW. They represent approximately 4% of spent fuel. They comprise fission products (such as caesium-134, caesium-137 and strontium-90), activation products (such as cobalt-60) and minor actinides (such as curium-244 and americium-241).

Such waste accounts for most of the radioactivity of the radioactive waste produced in France. Its radioactivity is between a few billion and several tens of billions of becquerels per gram.

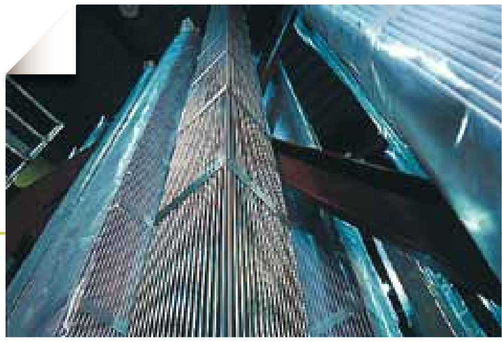
It contains various short-lived and long-lived radionuclides, some of which are very long-lived (such as neptunium-237 with a half-life of approximately 2 million years).

Because of its high radioactivity, this waste gives off heat.



Vitrified HLW package

* *Waste produced in France that is to be managed by Andra.*



Composition of spent fuel*

* Spent UOX fuel

Current and forecast volumes of HLW

(m^3 equivalent after conditioning)

Stocks 2010	2020	2030
2,700	4,000	5,300

Management

Given its radioactivity and lifetime, **HLW is destined for disposal in the Cigéo facility (geological industrial disposal centre), currently being designed by Andra** *(see page 31)*.

The waste is vitrified in an insoluble glass matrix with a particularly high and long-term containment capacity.

It is then poured into a stainless-steel package. HLW packages contain approximately 400 kg of glass and 70 kg of waste. While the deep geological repository is being developed, HLW is stored on the sites where packages are produced.

Is spent fuel waste?

In some countries, spent fuel from nuclear power plants is considered as waste and directly disposed of. In France, it has been decided that it be reprocessed to recover the reusable materials contained in these fuels and only to dispose of the small non-reusable part (waste).

Nevertheless, all spent fuel is included in the *National Inventory* in order to plan its management, would its reprocessing not be any longer considered. Andra is also conducting studies regarding the possibility of spent fuel disposal in the Cigéo repository.

Radium-bearing waste

When radioactivity was first discovered, the risks it presented were not well understood. A very keen interest in this phenomenon developed and gave rise to a 'radium industry' during the interwar years. Radium was used to manufacture numerous everyday objects. Currently, many of these objects are in private hands and Andra collects them so that they can be safely managed. Sometimes, these activities polluted the sites on which they were performed. An inventory of such sites is being produced so that they can be cleaned up.

Radioactive objects in the home

After its discovery, radium was used for the manufacturing of numerous everyday objects, medical equipment and health and beauty products such as lipstick, skin creams, radioluminescent alarm clocks, radium-water dispensers and medical radium needles, etc.

Currently, these objects may be found in private hands, in collections or forgotten in attics, mostly without their owners being aware of the risks they present. Andra accepts such items for disposal free of charge. They are then processed in the same way as other radioactive waste.

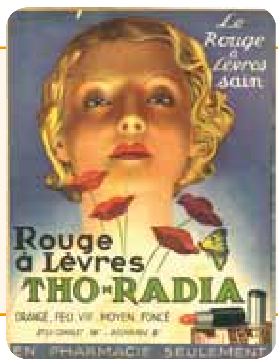
If you possess such an object please contract Andra:
+33(0)1 46 11 83 27
collecte-dechets@andra.fr

Radium-water dispenser

Box for radium needles

Radioluminescent watch

Eye cream



Each year around a hundred objects are collected and approximately 2,500 m^3 of radioactive waste is produced by Andra's clean-up of polluted sites.

This is mainly VLLW and LLW-LL.

Sites polluted by radioactivity

A site polluted by radioactivity is a site on which radioactive substances have been handled or stored in an uncontrolled manner, leading to the dispersal of these substances and presenting a potential risk for health and the environment depending on the later usage of this site.

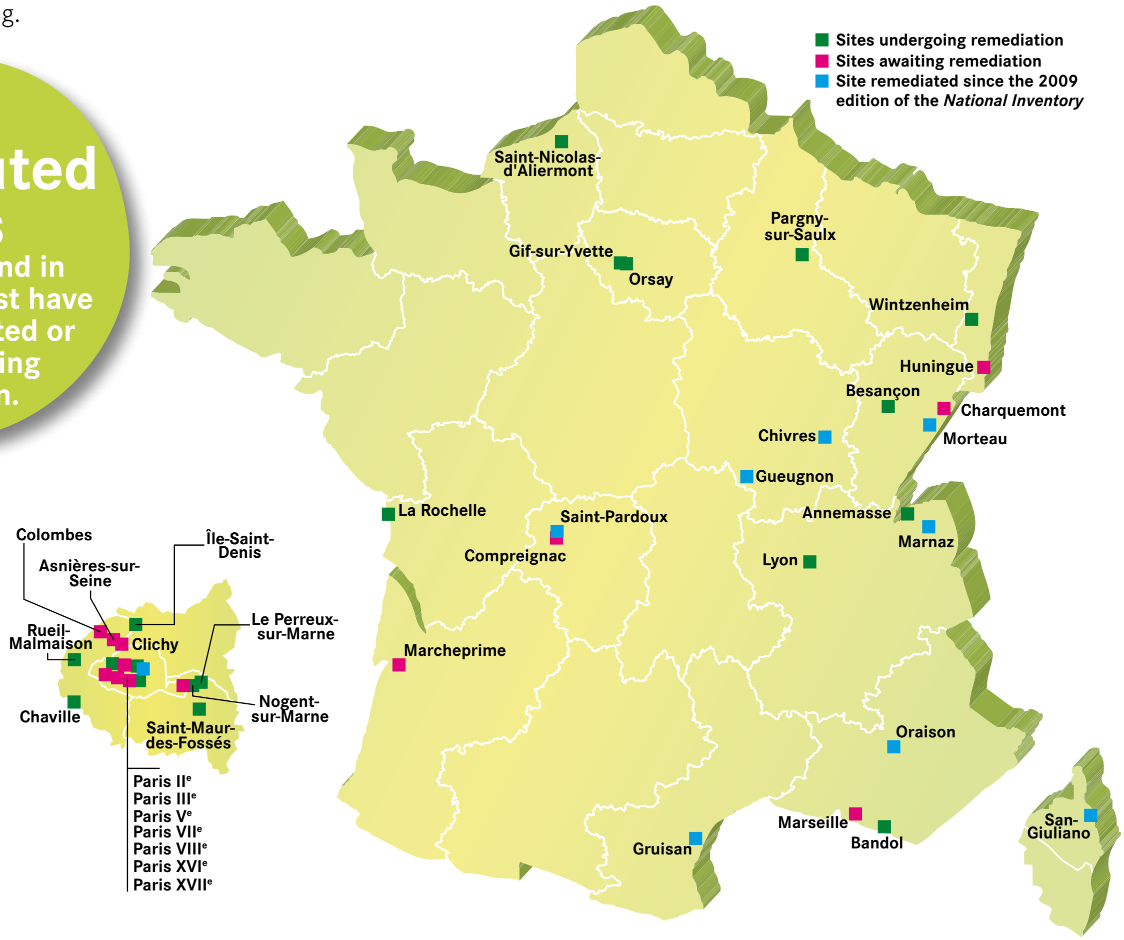
Most polluted sites in France are associated with past activities such as the extraction of radium for medical or health-and-beauty purposes, the manufacturing and application of radioluminescent paints, or the processing of ores, etc.

After the Second World War, many of these sites were forgotten and some were redeveloped for other activities or housing.

Some polluted sites are associated with more recent activities. They have been secured and left as waste ground.

The French government has launched a process for identifying such sites and their remediation. In case of a defaulting site-owner, Andra ensures it remediation. Funding is provided by State subsidy following a position issued by the French National Commission for Radioactivity Assistance (CNAR) on the use of this subsidy and on the need (or otherwise) for site clean-up.

At the end of 2010,
43 polluted sites
had been found in France and most have been remediated or are undergoing remediation.



Operation 'radium diagnosis'

Historical surveys on former industrial or commercial activities that used radioactivity have provided a list of 134 sites that should be checked.

Operation 'radium diagnosis', launched by the French authorities in 2010, consists of inspection of these sites by IRSN specialists, with the current owner's agreement, followed by state-funded clean-up by Andra where necessary.

Waste managed according to former management methods

Certain radioactive waste products were managed in accordance with the methods available at the time of their production and will not be handled in the Andra disposal facilities. For this reason, they are not included in reports presenting volumes of waste, but are nonetheless listed in the National Inventory.

There are three types of 'former' management methods:

Sea dumping

Sea dumping of radioactive waste was implemented by many countries over a period of approximately thirty years from the end of the 1940s. Sea dumping was initially carried out in shallow water, usually within the territorial waters of the concerned countries. It was subsequently carried out in deep water under the coordination of international bodies.

France participated in two campaigns, in 1967 and 1969, during which it dumped 14,200 tonnes of radioactive waste.

A total of 3,200 tonnes of waste from the French nuclear testing programme in the Pacific were also dumped between 1967 and 1982.

The dumped radioactive waste came in a variety of different forms:

- liquid waste, directly discharged into the sea or placed in containers;
- unconditioned solid waste or, in most cases, solid waste packaged in metal drums after incorporation in concrete or bitumen.

Sea dumping of radioactive waste

Sea dumping was considered to be the most appropriate management solution at the time in view of the considerable dilution provided by the volume of the ocean.

France abandoned this practice in 1982.

Disposal of uranium ore processing residues on former mining sites

Between 1948 and 2001, uranium mining operations (uranium exploration, extraction and processing) were carried out on 210 sites in France.

The ore processing operations to recover the uranium generated radioactive residues. These residues, in the form of blocks, sand or sludge are long-lived waste products with a comparable level of radioactivity to that of very-low-level waste (VLLW).

When uranium mining ended in France, an estimated 50 million tonnes of residues were disposed of on twenty of these sites. They are monitored by AREVA, under the supervision of the relevant authorities.

All the plants at which these processing operations were carried out have now ceased operation and been dismantled.

The uranium mine at Bellezane (Haute Vienne) during its working life

Bellezane uranium mine following site reclamation

Other legacy situations

Fifty million tonnes of other waste have been disposed of in repositories that fall outside Andra's scope of responsibility.

80% of this waste can be defined as 'Technologically-Enhanced Naturally-Occurring Radioactive Material' i.e. waste generated by the processing of raw materials containing naturally-occurring radionuclides that are not used for their radioactive properties. This is very-low-level waste, but it contains long-lived substances.

There are about fifty recorded legacy waste repositories in France:

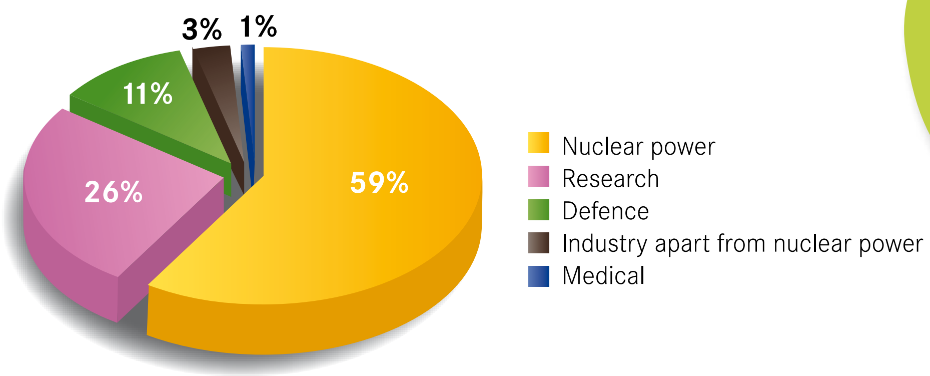
- *in situ* repositories (repositories adjacent to nuclear facilities or plants, in most cases taking the form of mounds, backfill or lagoons);
- conventional waste disposal facilities.

Port de La Pallice, La Rochelle (Charente-Maritime)

Waste already produced

At the end of 2010, there were approximately 1,320,000 m³ of radioactive waste in France. Legacy waste having been managed according to 'former' methods (see pages 20-21) is not included in the records presented here, as it is not planned to be taken over by Andra.

Breakdown of radioactive waste by economic sector at the end of 2010



The production of radioactive waste in France represents the equivalent of **2 kg per year and per inhabitant**

Waste volumes existing at the end of 2010

These volumes correspond to the waste after conditioning in 'primary packages' to be stored in readiness for transport to waste disposal facilities.

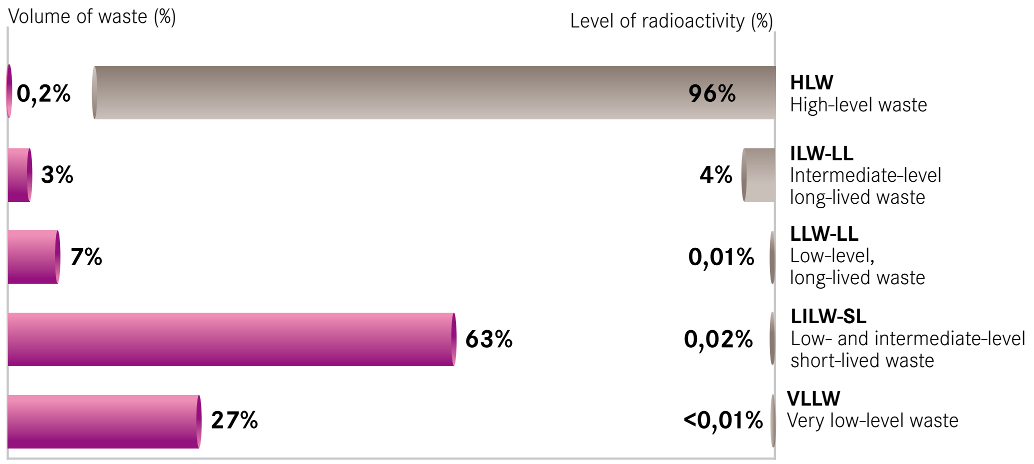
In some specific cases, such as deep disposal, for example, additional conditioning may be required before the waste can be placed into the repository.

Category	Volume at end 2010 (m³ equivalent conditioned)
HLW	2,700
ILW-LL	40,000
LLW-LL	87,000
LILW-SL	830,000
VLLW	360,000
DSF*	3,600
Grand total	**~ 1,320,000**

** Waste identified as belonging to the DSF category (déchets sans filière), is that for which no management solution exists or is being studied, due in particular to its chemical and physical characteristics. The management of this waste is currently under examination.*

Since the 1970s, the AREVA-COMURHEX plant at Malvési (Aude) has been converting uranium concentrates that are then used in the manufacturing of nuclear fuel. This industrial activity has generated 600,000 m³ of radioactive residues in sludge form. Several thousand m³ of this type of waste are produced each year. Studies are currently being conducted to define the characteristics of this waste and its long term management. In the previous edition of the *National Inventory*, these residues were counted as mining residues. This type of waste is not included in the records.

Breakdown of volume and radioactivity level of radioactive waste existing at the end of 2010



Changes in volumes

The volumes of radioactive waste presented in the 2012 edition have changed relative to those presented in 2009. This change is due to the regular production of waste during the three years between the two editions of the *National Inventory*, as well as to:

- optimised conditioning of certain types of ILW-LL, leading to a reduction in volume;
- additional characterisation of certain ILW-LL products, allowing them to be reclassified as LLW-LL, with a resulting reduction in volume of ILW-LL and an increase in the volume of LLW-LL;
- a tightening of the requirements concerning the cleanup targets for the civil works of the facilities to be dismantled, leading to an increase in VLLW.

Table of differences per category 2010/2007
(m^3 equivalent after conditioning)

Category	Difference 2010/2007 (m^3 conditioned equivalent)
HLW	400
ILW-LL	-2,000
LLW-LL	4,500
LILW-SL	37,000
VLLW	130,000
DSF*	2,100
Grand total	**~ 170,000**

** Waste identified as belonging to the DSF (déchets sans filière) category, is that for which no management solution exists or is being studied, due in particular to its chemical and physical characteristics. The management of this waste is currently under examination.*

Tomorrow's waste

In addition to the survey of existing stocks, forecasts are also made to anticipate the volumes and types of waste that will be produced between now and 2020 and 2030. Longer term forecasts are also made according to two contrasting scenarios regarding the future of the nuclear facilities and French energy policy.

Waste volume forecasts for 2020 and 2030*

	For 2020	For 2030
HLW	4,000	5,300
ILW-LL	45,000	49,000
LLW-LL	89,000	133,000
LILW-SL	1,000,000	1,200,000
VLLW	762,000	1,300,000
Grand total	**~ 1,900,000**	**~ 2,700,000**

** As far as the nuclear power industry is concerned, the forecasts are based on the assumption that the operating life of the power plants will be extended to 50 years and that all spent fuel will be processed. The* National Inventory *takes account of the 58 current reactors and the Flamanville EPR under construction.*

The anticipated waste volumes forecast for 2020 and 2030 have changed compared to those given in the 2009 edition.

This is due essentially to:

- an increase in the spent nuclear fuel treated each year;
- a longer assumed plant operating life (50 years instead of 40) in accordance with EDF's strategic orientations. This assumption does not pre-judge the decision of the public authorities;
- better identification of the waste that will result from the dismantling of the facilities;
- the postponement of the start of the nuclear power plant dismantling process, that delays the production of the associated waste;
- an increase in the volume of VLLW due in particular to the tightening of requirements concerning the cleanup targets for the civil works of the facilities to be dismantled.

Dismantling of facilities

The dismantling of a nuclear power plant produces 80% 'conventional' waste and 20% radioactive waste, the great majority of which is VLLW. The remainder is essentially LILW-SL.

What happens after 2030?

Outlook beyond 2030

The *National Inventory* also presents a forecast beyond 2030, i.e. up until the end-of-life and deconstruction of the nuclear facilities of the current fleet.

In order to anticipate the effect of possible political changes on the future of the nuclear industry, various scenarios have been examined to estimate the consequences on the type and the volume of waste that would be produced up to the dismantling of the facilities.

The volumes below are presented for illustrative purposes with two intentionally contrasting scenarios: the continuation or discontinuation of nuclear power production. These quantities also take account of the waste produced by other economic sectors.

In both cases, the *National Inventory* covers only the waste produced by those facilities which have been licenced by the end of 2010 (existing facilities plus the Flamanville EPR currently under construction).

1 If nuclear power production continues

This scenario envisages the continuation of the nuclear power industry and of the current French strategy of reprocessing spent nuclear fuel. It is based on various assumptions, including:

- a fifty-year plant operating life;
- the reprocessing of all nuclear fuels to extract the recoverable materials they contain, and that are used to produce new fuel (uranium: 650 to 950 tonnes per annum; plutonium: 10 to 13 tonnes per annum assuming a constant annual reprocessing rate).

HLW (m^3)	10,000
ILW-LL (m^3)	70,000
LLW-LL (m^3)	165,000
LILW-SL (m^3)	1,600,000
VLLW (m^3)	2,000,000

2 If nuclear power production is not renewed

This scenario assumes the non-renewal of the current nuclear fleet, leading to the discontinuation of spent fuel processing. It is based on:

- a forty-year plant operating life;
- the discontinuation of spent fuel processing in 2019 in order to avoid recovering plutonium that can no longer be recycled in the form of MOX fuels due to the reactors able to operate with this type of fuel having been shut down.

HLW	CU UOX*	~ 50,000 assemblies
	CU RNR*	~ 1,000 assemblies
	CU MOX*	~ 6,000 assemblies
	Vitrified Waste (m^3)	3,500
ILW-LL (m^3)		59,000
LLW-LL (m^3)		165,000
LILW-SL (m^3)		1,500,000
VLLW (m^3)		1,900,000

* *Types of spent fuel: UOX (uranium oxide), FNR and MOX (mixture of uranium oxide and plutonium oxide).*

What happens to the radioactive waste?

The management of radioactive waste has developed over time. For over forty years, France has opted for industrial repositories as a safe and sustainable waste management solution. Andra is responsible for managing all French radioactive waste and for designing the centres for isolating them from humans and the environment until such time as their radioactivity has reduced sufficiently to no longer present a hazard.

Why dispose of waste in a repository?

In France, **disposal facilities already exist for 90 % of the radioactive waste** produced each year.
Disposal centres for other waste are currently under study.

The danger of radioactive waste diminishes over time through natural decay of the radioactivity contained. According to the type of waste, this decay can take a few days to several hundred thousand years.

The principle of disposal consists in isolating the waste for a sufficiently long period of time to ensure that the radioactivity in contact with humans presents no health hazard.

This solution was chosen to avoid passing the burden for managing the waste produced today onto future generations. Surface disposal facilities already exist in France, operated and monitored by Andra, in the Manche and the Aube districts.

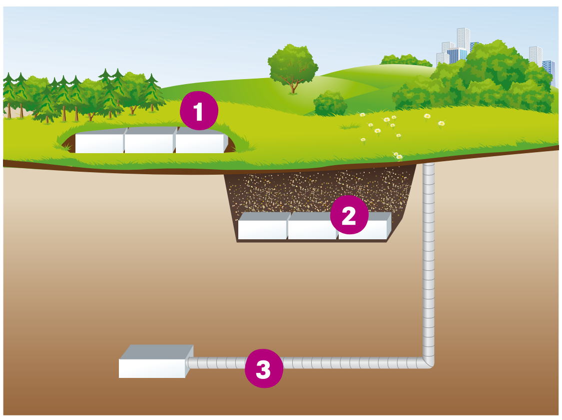
These can accommodate 90% of the radioactive waste produced each year, consisting of very-low-level or short-lived waste (VLLW and LILW-SL).

In addition, Andra is studying underground disposal facilities for high-level or long-lived radioactive waste. In the meantime, the waste concerned is temporarily stored in dedicated facilities.

Three types of repository

are envisaged in France to take over all French nuclear waste regardless of the level of radioactivity or the lifetime:

1. **Surface repositories**
2. **Shallow repositories** (under design)
3. **Deep repositories** (under design)



The journey of radioactive waste

1

Conditioning

After having been sorted according to its characteristics, the waste is treated (compaction, incineration, solidification, etc.) then conditioned by the producer in packages designed to prevent the dispersion of the radioactivity they contain.

Compacted VLLW packages

Vitrification of HLW

2

Storage

Prior to disposal, or while awaiting the creation of a suitable disposal facility, the waste is temporarily stored in dedicated buildings, usually at their site of production.

Storage of HLW

Storage of ILW-LL

3

Disposal

After checking their conformity, the waste packages are disposed of by Andra in facilities compatible with the hazard they present and the evolution of this hazard over time.

The role of these facilities is to isolate the radioactive waste for as long as it presents a hazard for humans and the environment.

The safety of industrial repositories relies on a series of artificial or natural barriers to isolate the substances contained in the waste: the packages, the repository structures and the geological medium that constitutes a very effective natural barrier over very long periods of time.

Very low-level waste (VLLW) disposal facility

Low- and intermediate-level waste (LILW) disposal facility

Radioactive waste transport

The transport of radioactive waste is governed by **strict international regulations**. In the majority of cases, waste is transported by road or rail, in sealed canisters, designed and certified to withstand extreme conditions such as high speed collision, fire and immersion in water without damage.

Disposal facilities

Andra operates and monitors three surface disposal facilities in France that accommodate the vast majority of waste produced in France each year, covering very-low-level waste (VLLW) and low-and intermediate-level, short-lived waste (LILW-SL).

The waste disposal facility in the Manche district (CSM)

First disposal facility in France, the CSM was commisioned in 1969.

After 25 years of operation it was closed down and covered with several layers of material to protect the structures, in particular against rain water.

Since its closure, the facility has been regularly monitored by Andra, to keep track of changes and monitor its environmental impact.

Andra is currently undertaking the works necessary to ensure the durability of the cap. This monitoring will be performed for a minimum of 300 years.

527,225 m³ of waste has been disposed of in the waste disposal facility in the Manche district (CSM).

As at 31 December 2010, **72% of the volume of radioactive waste produced has been definitively disposed of.** The remaining waste is temporarily stored:

- awaiting disposal in existing disposal facilities;
- awaiting the creation of a suitable disposal facility.

Facilities under surveillance

Because of their activity, the disposal facilities release radioactivity. Everything is done to limit these releases as much as possible. Whether they are closed or in operation, the facilities are **regularly monitored** to check that their impact on the environment and neighbouring populations remains well below that of the naturally-occurring radioactivity.

The low-and intermediate-level, short-lived waste disposal facility in the Aube district

Taking stock of the lessons learnt over a quarter of a century at the CSM waste disposal facility, the Andra waste disposal facility in the Aube has been receiving LILW-SL since 1992.

Its footprint is 95 hectares, of which 30 are reserved for the repository. The waste is disposed of on the surface in reinforced concrete structures 25 metres square and 8 metres high.

Once they are filled, these structures are closed with a concrete slab and then sealed with an impermeable coat. At the end of operation, a cap formed mainly of clay will be placed over the structures to ensure the long-term containment of the waste.

The LILW-SL disposal facility is designed to house one million m³ of waste. At the end of 2011, 255,140 m³ of waste had already been disposed of in this facility.

The very-low-level radioactive waste disposal facility in the Aube district

Because of the very low level of radioactivity of VLLW, the majority of foreign countries decided to manage it as 'conventional' waste. France decided to treat it as radioactive waste, and designed a dedicated disposal facility in 2003.

Located in the Aube district, this Andra facility covers 45 hectares of which 28.5 hectares are reserved for the repository. Once conditioned, the batches of waste are identified and disposed of at the surface in cells 176 metres long by 25 metres wide, excavated in a clay layer to a depth of several metres.

Once filled, these cells are closed, then covered with a cap consisting mainly of sand, an impervious membrane and clay.

The VLLW disposal facility is designed to house 650,000 m³ of waste. At the end of 2011, 203,435 m³ of waste had already been disposed of in this facility.

Will the existing disposal facilities be sufficient for future volumes?

No, but before considering the creation of new disposal facilities, efforts will be made to reduce the volumes of waste to be disposed of at source (treatment, compacting, recycling, etc.).

The possibility of extending the capacity of the existing repositories could also be examined.

Studies for long-lived or high-level waste

Less than 10% of radioactive waste produced in France has a level of radioactivity or a life span that prevents it being disposed of in surface repositories. Studies are currently being undertaken to design facilities to receive this waste and isolate it for very long periods. According to the type of waste concerned, these repositories will be located at a depth of several tens or even hundreds of metres, within impermeable rock that will serve as a very long-term natural barrier.

Waste concerned

The studies relate to three categories of waste:

- **high-level waste (HLW) and long-lived intermediate-level waste (ILW-LL)** for which a 500 m deep disposal facility, Cigéo, is currently being studied;
- **long-lived low-level waste (LLW-LL)** for which a number of solutions are currently being studied.

While awaiting the creation of dedicated disposal facilities, this waste is stored in specific buildings, usually at their site of production.

30 %
of HLW
and
60 %
of ILW-LL
intended for disposal in the Cigéo facility have already been **produced at the end of 2010**

LLW-LL waste

In 2008, Andra began to look for a suitable site to house a LLW-LL disposal facility. Applications were received from forty municipalities. In June 2009, based on analysis carried out by Andra, the Government shortlisted two locations for further geological and environmental investigation. Under pressure from opponents to the project, these two municipalities withdrew from the project in August 2009.

In June 2010, the State redirected the project strategy. It requested Andra to continue the studies into low-level, long-lived waste and its possible management methods, and to submit to the Government, no later than the end of 2012, a report presenting the different management scenarios available for this waste. At the same time, the French high committee for transparency and information on nuclear safety (HCTISN) issued recommendations for resuming the site-search process (report published in July 2011).

Clay

In France, studies have examined the disposal of radioactive waste in **argillaceous rocks**, which have the particular property of **delaying and limiting the movement of the radionuclides** contained in the waste over very long periods.

Deep HLW and ILW-LL disposal

Since the beginning of the 1990s, studies have been undertaken for a reversible deep disposal facility for high-level and intermediate-level, long-lived waste (HLW and ILW-LL) produced by all existing nuclear facilities* and for processing the spent fuels used in French NPPs. If approved, the Cigéo waste disposal centre will be sited at the boundary between the Meuse and the Haute-Marne districts, becoming operational in 2025, as required by law.

A reversible, flexible project

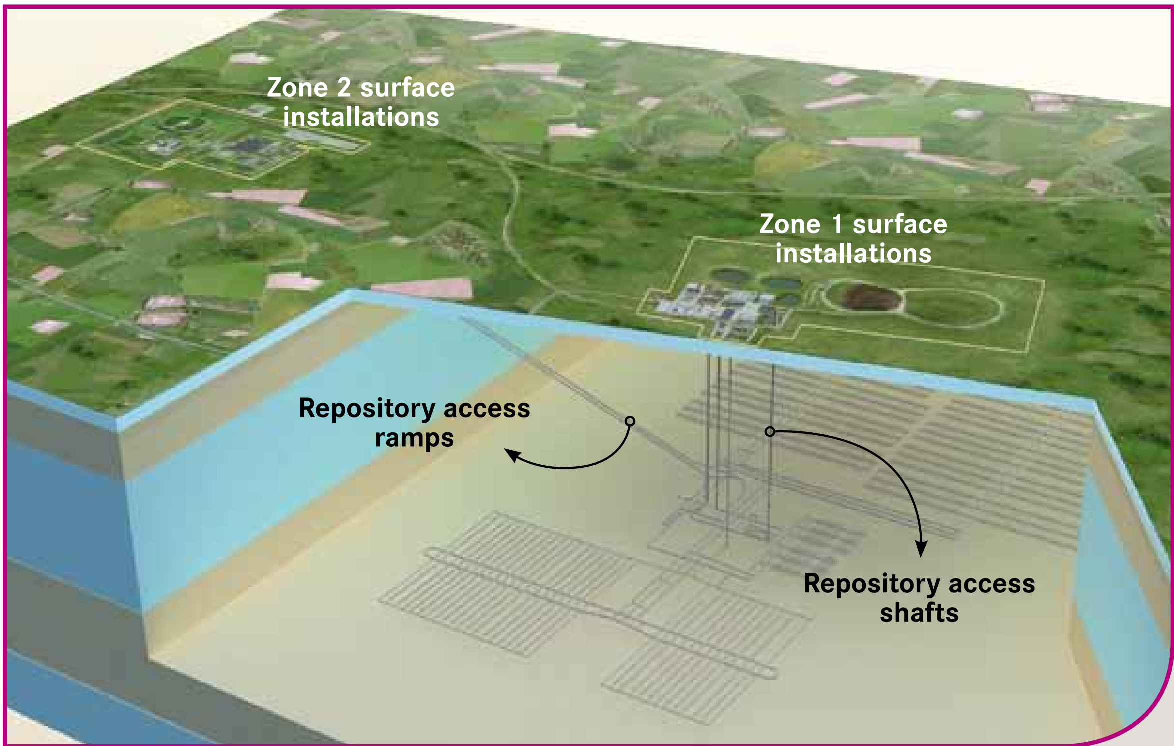
The inventory of waste to be sent to Cigéo is based on current political choices. Nevertheless, Cigéo is designed to take account of all possible waste disposal requirements in the event of changes affecting the nuclear power industry (operating life of power plants, new facilities, discontinuation of fuel processing, etc.) or to take account of advances in research into waste treatment.

Cigéo is designed to be reversible throughout its operating life, i.e. a minimum of 100 years. This reversibility will enable future generations to be involved in decisions regarding the future of the repository and, for example, to remove the waste packages already emplaced if another method of management were to be considered.

** Existing facilities, to which are added the Flamanville EPR currently under construction and the International Thermonuclear Experimental Reactor (ITER) project in the south of France.*

Why deep repository disposal?

A number of options for managing HLW and ILW-LL waste were studied since 1991. In 2006, after 15 years' research, the French law has opted for deep disposal, studied by Andra, as the only safe solution in the long term that prevents the burden for the management of this waste to be passed onto future generations. The European directive on radioactive waste of 2011 considers deep disposal to be the best option for this type of waste.



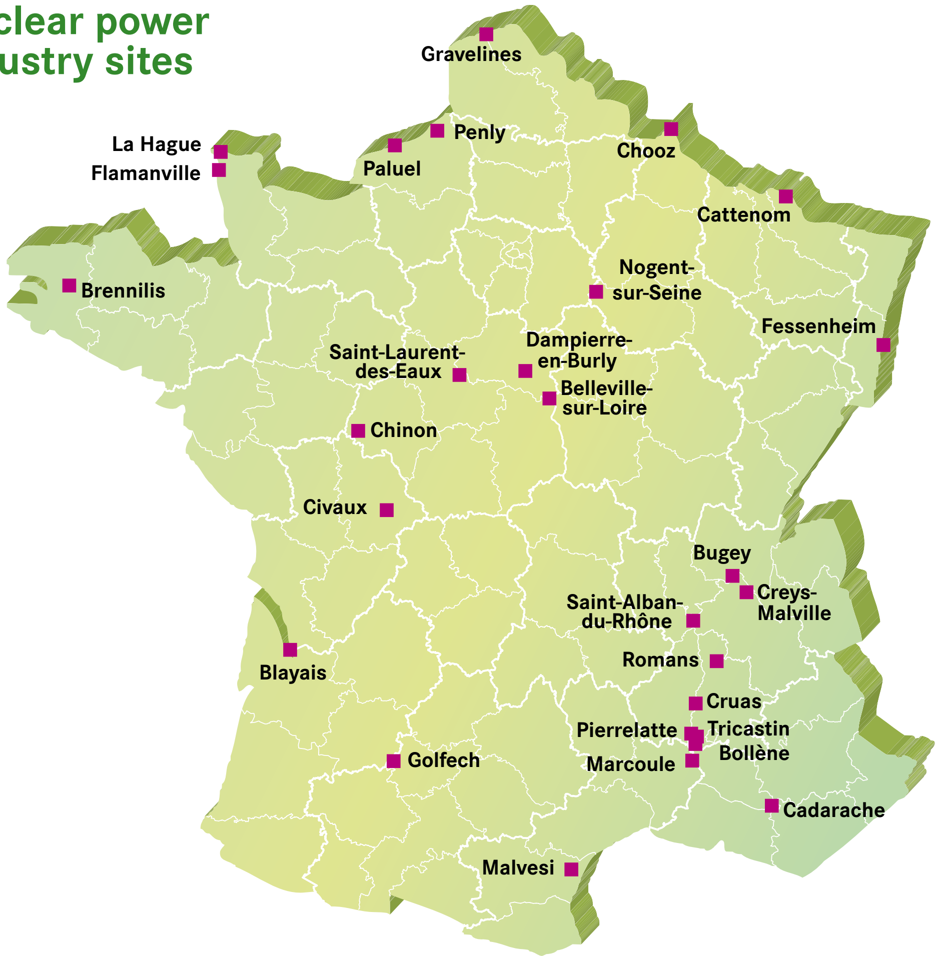
Schematic lay-out of the deep repository

Location of the waste

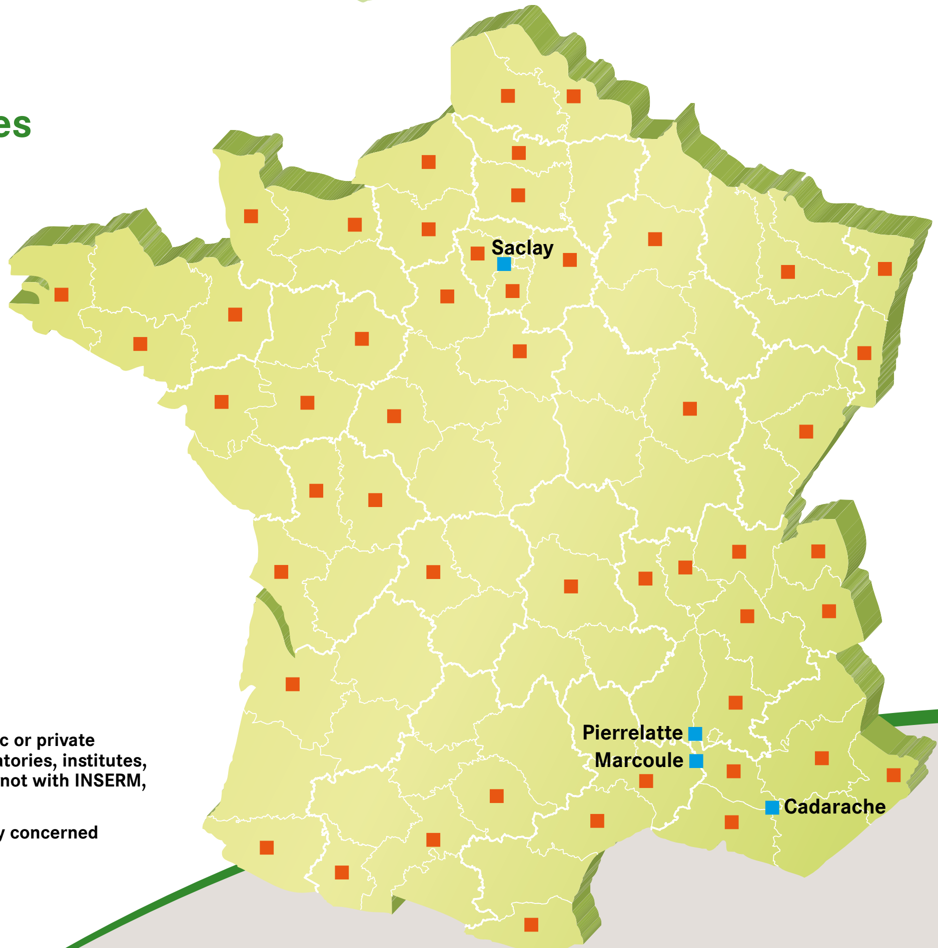
In France, there are more than one thousand holders of radioactive waste across all sectors (nuclear power industry, research, national defence, medicine and conventional industry), spread over as many sites throughout the country. The maps show the main locations.

Main storage and disposal sites

Nuclear power industry sites



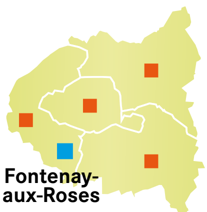
Research sites



DOM / TOM

Guadeloupe Islands (x4)
French Guina
Reunion Island
Tahiti Island

PARIS and neighboring districts
(Petite couronne)

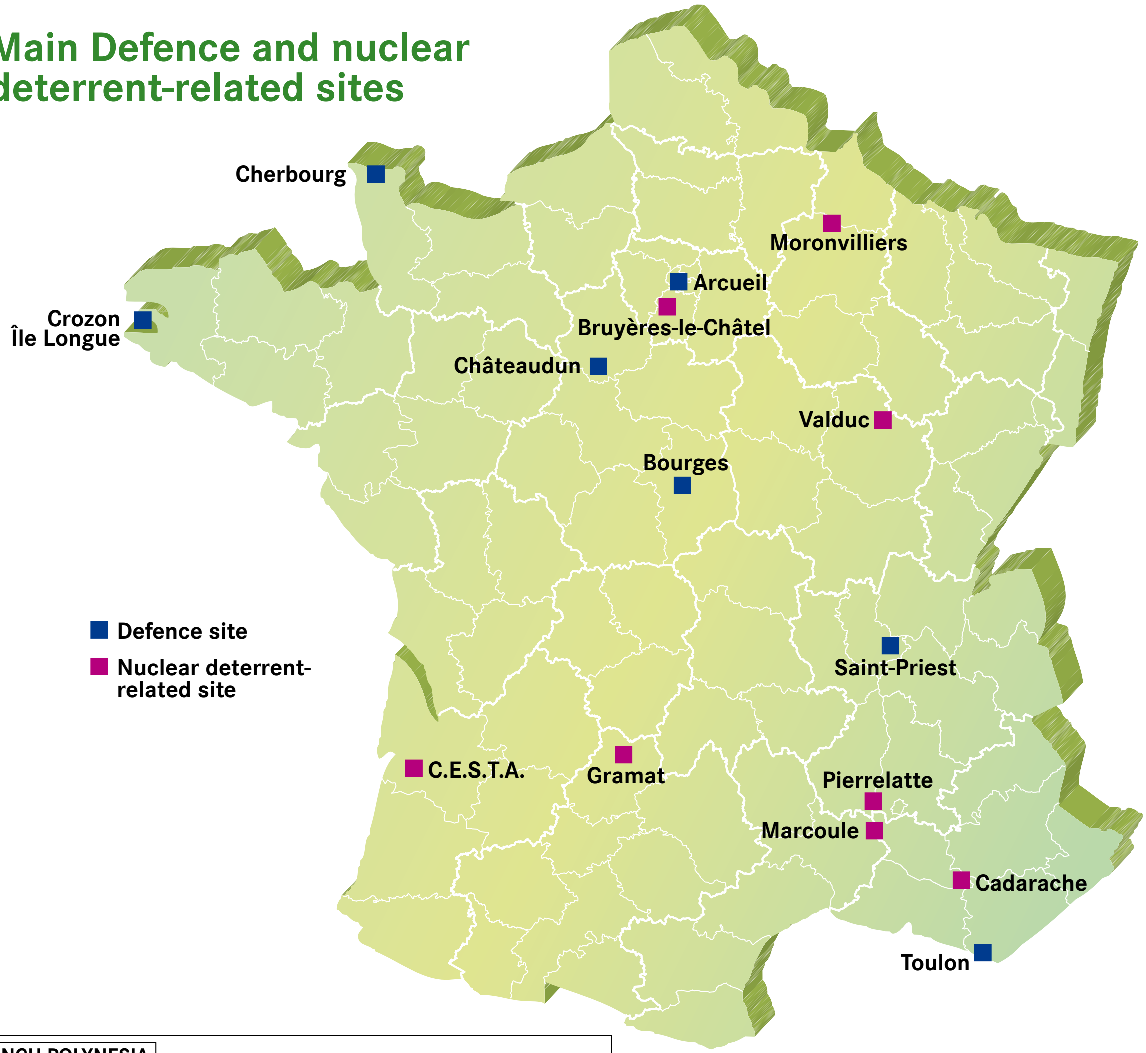


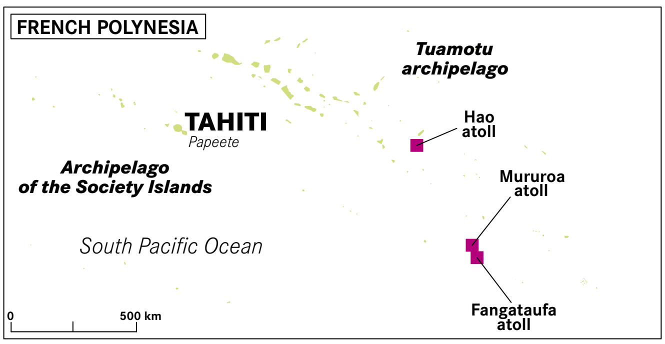
Districts with one or more public or private research sites (university laboratories, institutes, schools, whether associated or not with INSERM, CNRS or INRA)

Research establishments mainly concerned with civilian nuclear research

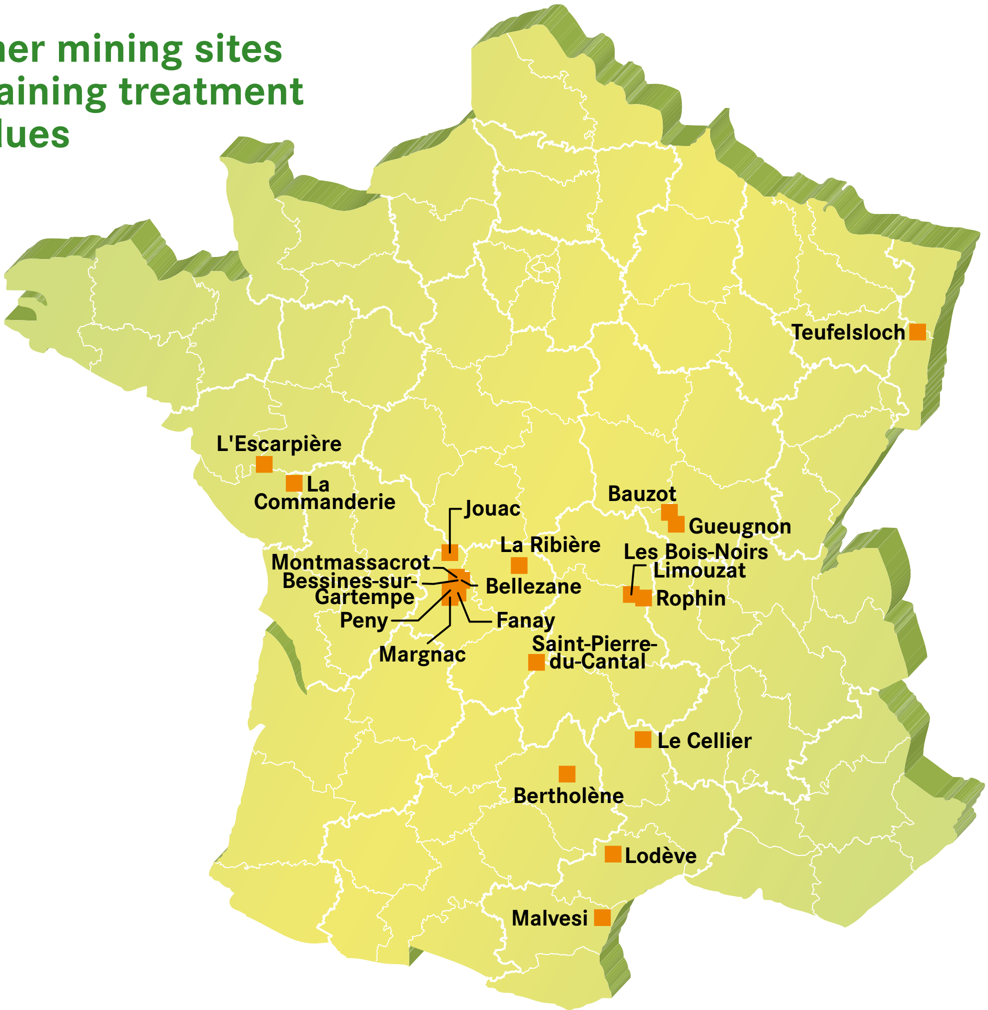
Location of the waste

Main Defence and nuclear deterrent-related sites





Former mining sites containing treatment residues



‘Technologically enhanced natural radioactivity’ waste repositories and legacy waste repositories

Recoverable materials

Radioactive materials are substances for which subsequent use is planned or intended, if need be following treatment. Some, such as plutonium, are already reused. Others are stored awaiting possible future use. These materials are listed in the National inventory *as their reuse could produce radioactive waste. They could also, in the long term, fall within the radioactive waste category if their recovery was not envisaged.*

Yellow cake

Natural uranium extracted from mines

Termed yellow cake, this yellow powder is a uranium concentrate. Uranium is a naturally-occurring radioactive metal found in rock and extracted from ore. Today, all of the French mines have been shut down and natural uranium is imported directly from abroad.

Enriched uranium

Enriched uranium is produced from natural uranium, by increasing its concentration of uranium-235 in order to be used in fuel manufacturing for nuclear power plants.

Depleted uranium

Uranium which is depleted in uranium-235 is a residue obtained during the natural-uranium enrichment process. It is transformed into a chemically stable, noncombustible, insoluble and non-corrosive solid that appears as a black powder.

Recycled uranium (from spent fuel following processing)

Recycled uranium is recovered during spent fuel processing at the AREVA plant at La Hague. It can be used to manufacture new fuel.

Storage of spent fuel in fuel cooling pool

Fuel in use at nuclear power plants and in research reactors

At any time, there are stocks of fuel being used in nuclear power plants and research reactors.

What if these materials were not reused?
The holders of these materials are now obliged to study how they would be managed if they were to be considered as waste in the future.

Spent fuel awaiting processing

Spent fuel must be stored in cooling pools before it can be processed in order to recover the uranium and plutonium it contains. Some spent fuels are not processed and are stored pending future recovery.

Recycled plutonium (from spent fuel following processing)

Plutonium is a radioactive element, artificially generated in nuclear reactors. It is recovered during spent fuel processing, on the same basis as uranium, to be reused in the manufacturing of new MOX type fuels.

Materials associated with the processing of rare earths

The rare earths, metals found naturally in the Earth's crust, are extracted from ores such as monazite and used in numerous applications (electronic equipment, automotive catalytic convertors, etc.).

- The processing of these rare earths gives rise to a by-product, thorium, a radioactive metal which is currently stored pending a possible future use.
- The treatment of these rare earths also produces chemical waste that is then treated in order to be neutralised. Suspended materials, composed of 25% rare earth residues, are recovered and can be reused.

Table: Quantities of recoverable radioactive materials (stocks and predicted)

Material	2010	2020	2030
Natural uranium (tHM)*	15,913	25,013	28,013
Enriched uranium (tHM)	2,954	2,344	2,764
Depleted uranium (tHM)	271,481	345,275	454,275
Recycled uranium (tHM)	24,100	40,020	40,020
Fuel in use (tHM)	4,932	5,120	4,320
Spent fuel (tHM)	13,929	15,251	18,362
Plutonium	80	55	53
Thorium (t)	9,407	9,334	9,224
SS (t)	23,454	0	0

**tHM tonne of heavy metal: tonne of uranium and plutonium contained in fuel before irradiation.*

Glossary

B **Becquerel**	Unit of measurement for radioactivity. One becquerel (Bq) corresponds to one nuclear decay per second.
C **Conditioning**	The immobilisation of waste in a container, using a matrix material where necessary.
D **Disposal**	The placement of radioactive waste in a specially designed facility without intention to retrieve it.
E **ERU fuels**	Enriched reprocessed uranium fuels.
F **FNR fuels**	Fuels for the Phénix and Superphénix fast neutron reactors (FNR). These fuels may be UOX or MOX fuels.
H **(Radioactive) half-life**	The time it takes for half of the quantity of a single radionuclide to undergo natural decay. The radioactivity of a pure sample of a single isotope would then be halved. After 10 such periods, the radioactivity would be divided by a factor of 1,000.
L **Long-lived waste**	Waste containing a significant quantity of long-lived radionuclides, i.e. those with a half-life of more than 31 years.
M **MOX fuels**	Mixed uranium oxide and plutonium oxide fuels.
P **Package**	Conditioned and packaged radioactive waste.
R **Radioactive source**	A device, radioactive substance or facility that emits ionising radiation or radioactive substances.
Radionuclides	Unstable isotopes that undergo radioactive decay and emit radiation, which is the origin of the phenomenon of radioactivity.
S **Short-lived waste**	Radioactive waste whose radioactivity mainly comes from short-lived radionuclides, i.e. those with a half-life of less than or equal to 31 years. It could also contain a limited quantity of long-lived radionuclides.
SS	Suspended solids, residues from the processing of rare earths containing thorium.
Storage	The temporary placement of radioactive matter or waste in a specially designed facility, pending subsequent retrieval.
T **Tonne of heavy metal (tHM)**	A tonne of uranium or plutonium contained in fuel before irradiation.
Treatment	All mechanical, physical or chemical operations that aim at modifying the characteristics of waste.
U **UOX fuels**	Uranium oxide fuels.

Photo taken by: Andra, M. Aubert, P. Bourguignon, M. Bultzer, H. Cazin/Médiathèque EDF, F. Dano, D. Delaporte, P. Demail, V. Duterme, N. Guillaumey, Les Films Roger Leenhardt, P. Maurein, S. Muzerelle, C. Pauquet/Médiathèque EDF, P. Lesage/AREVA, F. Roux, E. Sutre, D. Vogel, G. Wallet.

2012

NATIONAL INVENTORY
of Radioactive Materials and Waste

- Synthesis report
- Geographical inventory
- Catalogue of families
- Edition summary

Both the synthesis report and summary versions are available in multimedia format on a USB key and all the documents related to the *National Inventory* can be found on Andra's website **(www.andra.fr)**. Suggestions can also be registered by users directly on the site.

ANDRA
Mastering radioactive waste

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