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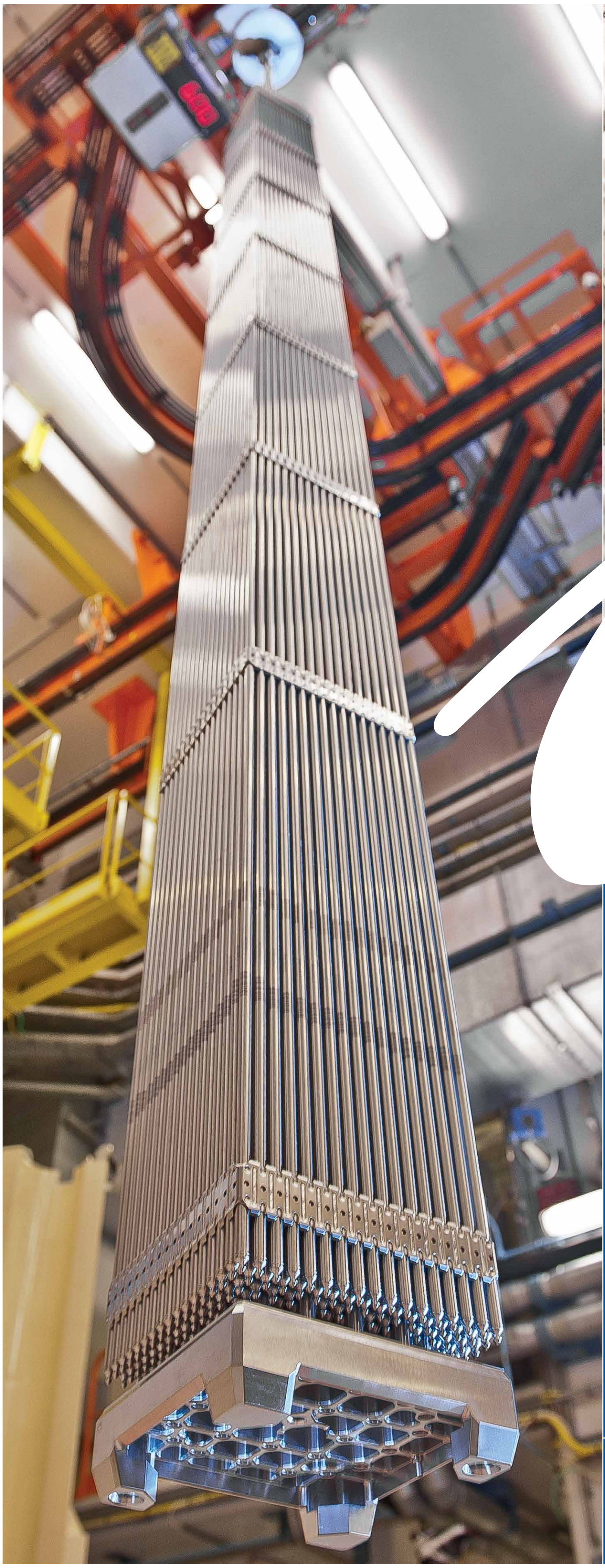

National Inventory of Radioactive Materials and Waste

2025 ESSENTIALS

As a government agency, Andra is mandated with the task of drafting and publishing the ***National inventory of radioactive materials and waste*** every 5 years. The ***National inventory*** provides a precious baseline for managing the radioactive materials and waste policy by identifying and publishing information on sources, locations and volumes. Andra also provides forecast quantities based on several wide-ranging scenarios focusing on the future of nuclear facilities and France's long-term energy policy. The most recent edition was published in December 2023*.

The publication of the ***National Inventory*** is completed each year with a document called ***Essentials***. This 2025 edition includes an update to the inventory of materials and waste in France on 31 December 2023. ***Essentials*** also includes a summary of forecast quantities.

All of the data in the ***National Inventory*** is freely available

from the dedicated website
inventaire.andra.fr

in open data format from
data.gouv.fr

* On the basis of available data on 31 December 2021.

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Forecast inventories from the 2023 edition of the *National Inventory*

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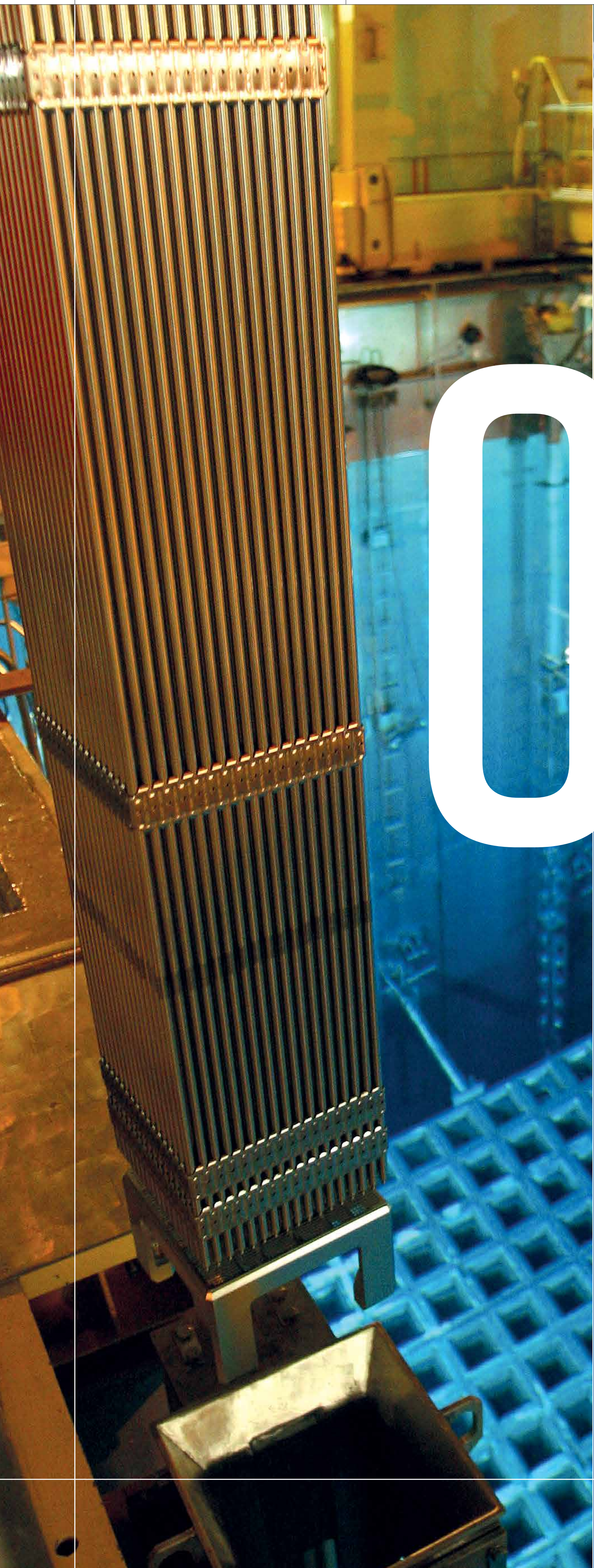
Current news in the radioactive waste and materials sector

Figures given in this document have been rounded. They are based on declarations made by holders of radioactive materials and waste and reflect the situation on 31 December 2023.



01

Radioactive materials and waste and their management methods

SECTORS USING RADIOACTIVITY

Various business segments use radioactive materials and produce radioactive waste. Since this radioactivity can present a risk to health and environment, radioactive materials and waste are subject to special management procedures.

In France, radioactive materials and waste management principles are governed by a strict regulatory framework, established at national level (Act no. 2006-739 of 28 June 2006, giving rise to the National Radioactive Materials and Waste Management Plan (PNGMDR) in particular, and at European level (see European Council Directive 2011/70/Euratom of 19 July 2011).

Radioactivity

Radioactivity is a natural phenomenon that has existed since the dawn of the universe when atoms were formed. A phenomenon whereby certain atoms – known as radionuclides – release energy as they decay, in the form of radiation and/or particles. Radioactivity can also be created artificially by human activity.

NUCLEAR POWER INDUSTRY

Nuclear power plants, but also facilities dedicated to producing nuclear fuel (via uranium ore mining and processing, chemical conversion and enrichment of uranium concentrate), reprocessing spent fuel and recycling a portion of the materials recovered from it.

NON-NUCLEAR POWER INDUSTRY

Rare earth mining and the fabrication of sealed sources, as well as various other applications such as weld inspection, medical equipment sterilisation, food sterilisation and preservation, etc.

DEFENCE

Mainly deterrence activities, including nuclear propulsion for certain ships - including submarines - as well as associated research and the activities of the armed forces.

RESEARCH

Research activities for civil nuclear applications, medical science, nuclear and particle physics, agronomics, chemistry and biology, among others.

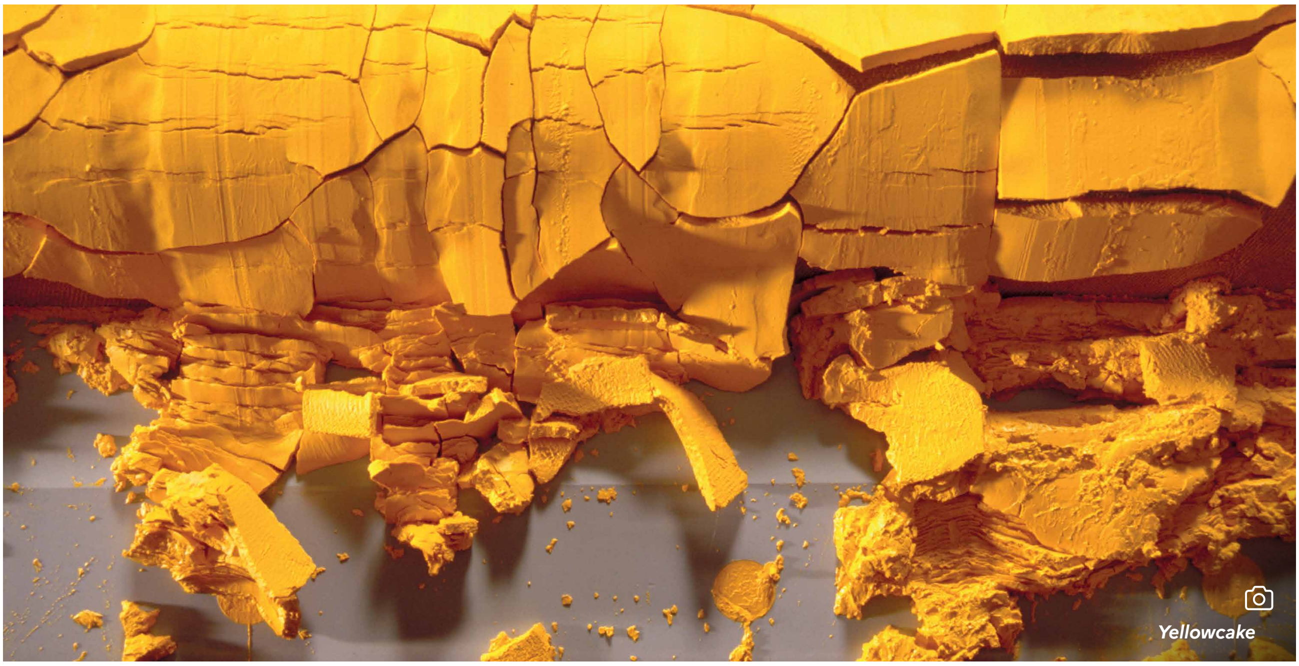
HEALTHCARE

Diagnostic and therapeutic activities (scintigraphy and radiotherapy, among others).

RADIOACTIVE MATERIALS AND RELATED MANAGEMENT METHODS

RADIOACTIVE MATERIALS

A radioactive material is a radioactive substance for which subsequent use is planned or intended, after processing if necessary (cf. Article L. 542-1-1 of the French Environmental Code).



Yellowcake

NATURAL URANIUM

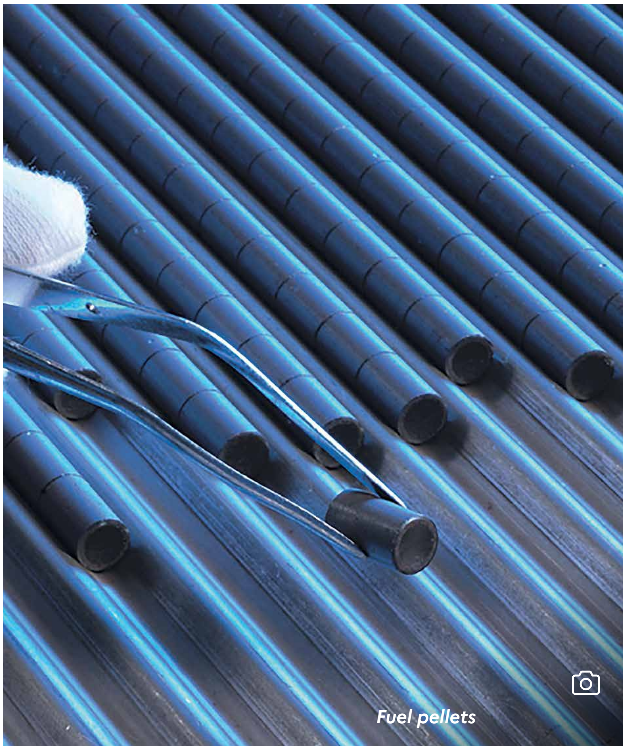
Mined natural uranium: uranium is a naturally-occurring radioactive metal found as an ore in certain rocks. It is mined, processed and formed into a solid uranium concentrate known as *Yellow Cake*. There are no longer any open uranium mines in France; all uranium is sourced from abroad.

Enriched natural uranium: obtained by increasing the uranium-235 concentration of natural uranium, is used to manufacture fuel for nuclear reactors.

Depleted uranium: obtained during the natural uranium enrichment process and transformed into a solid, chemically stable:-combustible, insoluble and non-corrosive material in the form of a black powder. This material is used to manufacture uranium and plutonium mixed oxide fuel (MOX).

URANIUM FROM SPENT FUEL REPROCESSING

Reprocessed uranium (RepU): obtained by reprocessing spent fuel. This material can be used to produce enriched fuel (ERU) after re-enrichment.


Fuel pellets

NUCLEAR FUEL

Nuclear fuel is mainly used in nuclear power plants to generate electricity.

Fuel types:

- **Enriched natural uranium fuel (ENU)** made from uranium oxide;
- **Enriched reprocessed uranium fuel (ERU)** made from uranium oxide produced by the enrichment of reprocessed uranium;
- **MOX fuel, made from mixed uranium and plutonium oxide**, used in certain nuclear plants.

It may also refer to:

- **fuel used in research reactors;**
- **fuel for defence purposes**, used for deterrence activities and in nuclear propulsion reactors in ships and submarines;
- **fast neutron reactor (FNR) fuel made from mixed uranium and plutonium oxide**, for the Phénix and Superphénix reactors, now permanently decommissioned and no longer used.

This fuel may be new, in use, spent and awaiting reprocessing, or take the form of scrap.

PLUTONIUM

Plutonium is an artificial radioactive element generated by the operation of nuclear reactors. Like uranium, it is recovered when spent fuel is reprocessed. It is then used to manufacture uranium and plutonium mixed oxide fuel (MOX).

MATERIALS PRODUCED BY RARE EARTH MINING

Rare-earth metals (which occur naturally in the Earth's crust) are extracted from ores such as monazite and used in numerous applications (e.g. electronic equipment, automotive catalytic converters, etc.).

When processed, these metals produce the following materials:

- **thorium**, a by-product of concentration, which is stored pending possible future use;
- **materials in suspension**, obtained by processing and neutralising chemical effluents, comprising traces of rare-earth residue that will be reused.


Madagascar monazite

RADIOACTIVE MATERIAL MANAGEMENT METHODS

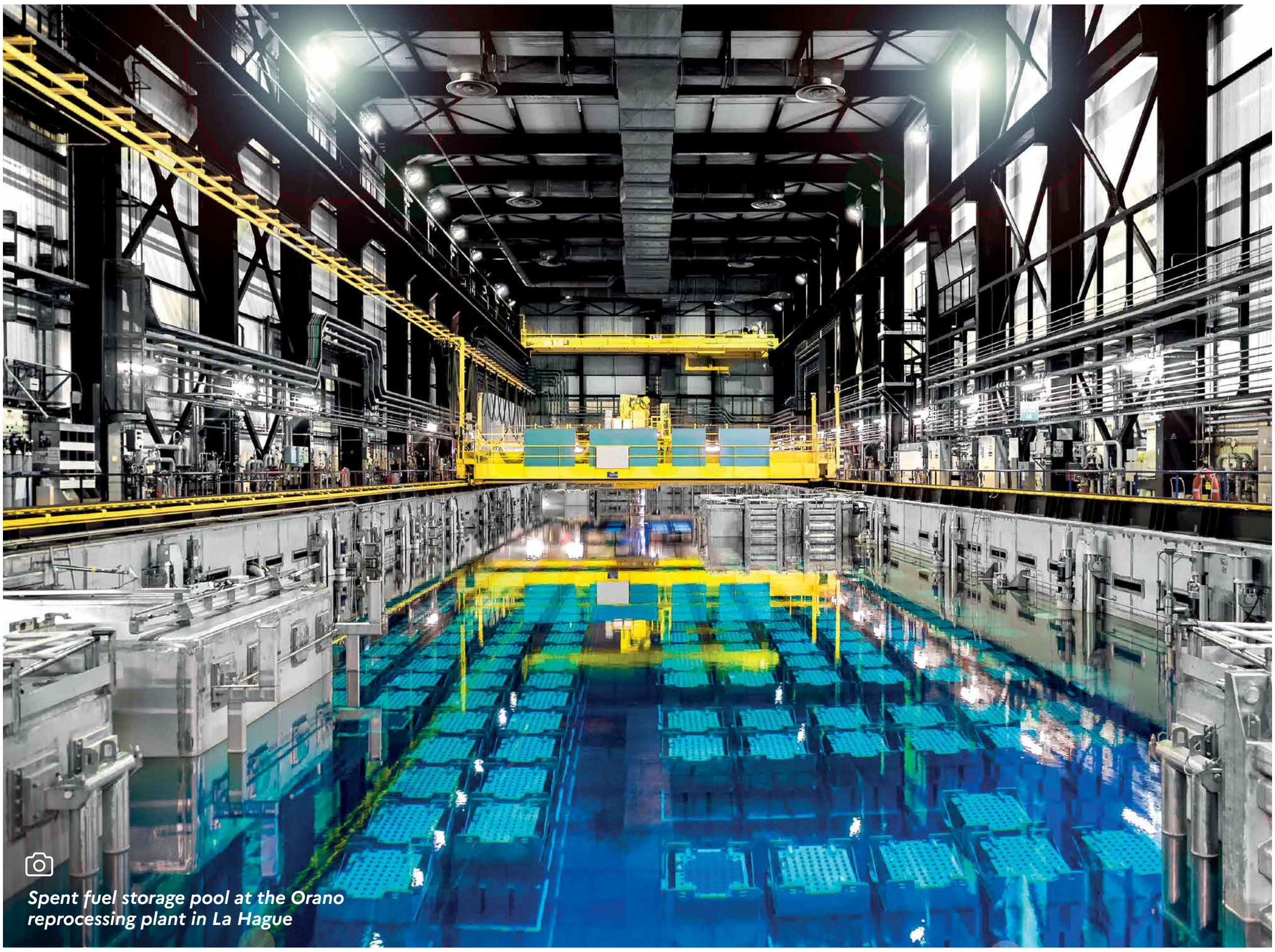
Radioactive materials are stored in facilities suited to their characteristics until they can be used or reused. Some of these materials are already reused, such as plutonium, which has been used to produce MOX fuel for over thirty years, and reprocessed uranium (RepU), which has been used to produce ERU fuel once again since 2023.

Recovery plans were prepared by the owners of radioactive materials as part of the National Radioactive Materials and Waste Management Plan (PNGMDR) 2022-2026. The PNGMDR also emphasises the need to support research into this recovery process.

Storage

The storage of radioactive materials or waste involves temporarily placing these substances in a specifically-designed facility in view of future retrieval.

Article L. 542-1-1 of the French Environmental Code.



Spent fuel storage pool at the Orano reprocessing plant in La Hague

RADIOACTIVE WASTE AND RELATED MANAGEMENT METHODS

Radioactive waste consists of radioactive substances for which no subsequent use is planned or intended (Article L. 542-1-1 of the French Environmental Code).

In general, radioactive waste contains a mix of radionuclides (i.e. radioactive isotopes: caesium, cobalt, strontium, etc.). Depending on the composition of the waste, radioactivity levels may vary in intensity and persist for different periods of time. Waste is classified into six categories.

The origin of radioactive waste

Radioactive waste is produced during the operation of facilities using radioactive substances, and also when these facilities are dismantled.

CATEGORIES OF RADIOACTIVE WASTE AND RELATED MANAGEMENT METHODS

Radioactive half-life / Activity**	Very short-lived (VSL) (half-life < 100 days)	Mainly short-lived (SL) (half-life ≤ 31 years)	Mainly long-lived (LL) (half-life > 31 years)
Very low-level waste (VLLW) < 100 Bq/g		**VLLW** Surface disposal (Industrial facility for grouping, storage and disposal)	
Low-level waste (LLW) between a few hundred Bq/g and one million Bq/g	**VSLW** Management through radioactive decay	**LILW-SL** Surface disposal (Aube and Manche disposal facilities)	**LLW-LL** Management methods under study
Intermediate-level waste (ILW) in the range of one million to one billion Bq/g			**ILW-LL** Deep geological disposal facility under study (Cigéo Project)
High-level waste (HLW) several billion Bq/g	Not applicable***	**HLW** Deep geological disposal facility under study (Cigéo Project)	

*Half-life of the radioactive elements (radionuclides) contained in the waste.
**Level of radioactive waste activity.
*** No VSLW with an activity level of several billion Bq/g exists.

Waste may sometimes be classified in a particular category but managed using an alternative management solution due to other characteristics, such as its chemical composition or physical properties.

RADIOACTIVE HALF-LIFE

The "Radioactive half-life" expresses the time it takes for the initial radioactivity of a given radionuclide to be halved. A distinction is drawn between:

- short-lived waste, which contains radionuclides with a half-life less than 100 days. This waste can only be sent to a conventional waste management solution after a period of more than ten times the radionuclide half-life, i.e. around 3 years;
- short-lived waste, whose radioactivity is mainly due to radionuclides with a half-life less than or equal to 31 years;
- long-lived waste, which contains a significant quantity of radionuclides with a half-life exceeding 31 years.

ACTIVITY LEVEL

The "activity" reflects the number of disintegrations of nuclei produced per second (and hence the radiation per second). It is expressed in becquerels: 1 becquerel corresponds to one decay per second.

Radioactive waste is therefore considered as:

- very low-level, if the activity level is less than 100 becquerels per gram;
- low-level, if the activity level is between a few hundred becquerels per gram and one million becquerels per gram;
- intermediate-level, if the activity level is between one million and one billion becquerels per gram;
- high-level, if the activity level is several billion becquerels per gram.

DESCRIPTION OF RADIOACTIVE WASTE CATEGORIES

HLW HIGH-LEVEL WASTE

- High: several billion Bq/g
- Long to very long (up to several hundreds of thousands of years)
- Disposal in deep geological formations under development[1]

This waste mainly comes from the reprocessing of spent fuel[2] (after use in a nuclear reactor). It is made up of highly radioactive residue from the chemical dissolution of spent fuel. This waste is encapsulated in glass, then conditioned in stainless steel containers.

HLW waste package

ILW-LL INTERMEDIATE-LEVEL LONG-LIVED WASTE

- Intermediate: one million to one billion Bq/g
- Long to very long (up to several hundreds of thousands of years)
- Disposal in deep geological formations under development[1]

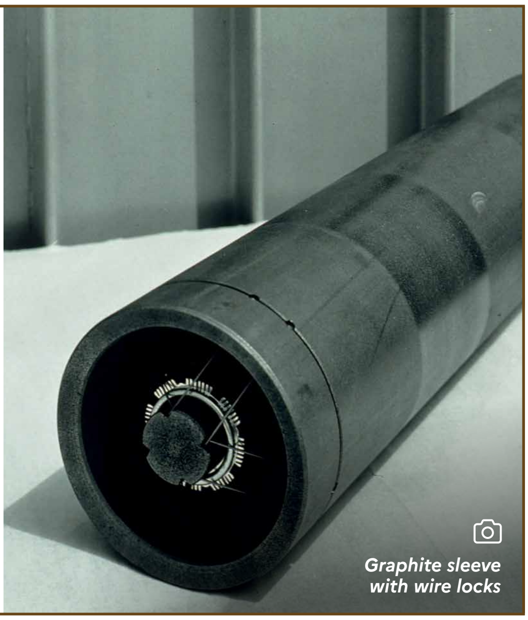
This primarily comprises waste from the metal structures surrounding the fuel (hulls and end fittings), which comes from the reprocessing of spent fuel[2] and, to a lesser extent, technological waste from the use and maintenance of nuclear facilities, the treatment of liquid effluents (bituminised sludge) and activated waste having spent time in nuclear reactors.

Hulls from the zirconium alloy cladding covering fuel pellets

LLW-LL LOW-LEVEL LONG-LIVED WASTE

- Low: a few tens to several thousand Bq/g
- Disposal under development
- Long to very long (up to several hundreds of thousands of years)

This includes:
- graphite waste from the operation and decommissioning of the first nuclear plants;
- radium-bearing waste, mainly from non-nuclear-power industrial activities, such as the extraction of rare earths;
- other types of waste, such as certain legacy waste packages conditioned in bitumen, uranium conversion residues from the Orano Malvési plant (see page 19), and operating waste from the La Hague reprocessing plant.



Graphite sleeve with wire locks

Activity level.
Time required for the radioactivity to decay (to a level that presents no risks to human health or the environment). This time depends on the half-life.
Final waste management method.

LILW-SL LOW- AND INTERMEDIATE-LEVEL SHORT-LIVED WASTE

- Low to intermediate: a few hundred to one million Bq/g
- Existing surface disposal[3]
- Short (up to around 300 years)

This waste mainly comes from the operation (processing liquid effluents or filtering gaseous effluents, etc.), maintenance (clothing, tools, gloves, filters, etc.) and dismantling of nuclear plants, fuel cycle facilities and research centres. A small portion may also come from medical research activities.

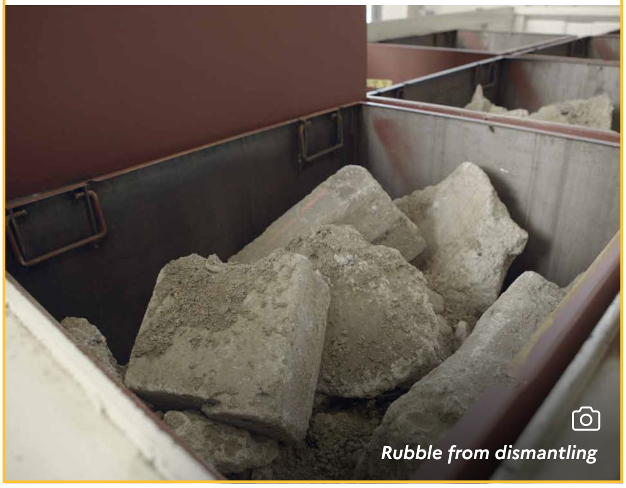
Waste generated by the use of radioactive products in a laboratory

VLLW VERY LOW LEVEL WASTE

- Very low: less than 100 Bq/g
- Not a determining factor[4]
- Existing surface disposal[5]

This waste mainly comes from the operation, maintenance and dismantling of nuclear plants, fuel cycle facilities and research centres.

VLLW usually consists of inert waste (concrete, rubble, earth, etc.) or metal and plastic waste.



Rubble from dismantling

VSLW VERY SHORT-LIVED WASTE

- Very low to intermediate
- Management through decay
- Very short (up to around three years)

This waste mostly comes from the medical and research sectors.

Medical waste may comprise liquid or gaseous effluents, or contaminated solid or liquid waste generated by the use of radionuclides in this field.

Decay tanks

1. Cigéo project, for which the construction licence application was filed in January 2023.
2. Recoverable materials (plutonium and uranium) can be separated from the final waste comprising HLW and ILW-LL by reprocessing spent fuel. These materials can be recycled to produce new fuel. The waste is stored at reprocessing sites pending disposal.
3. Aube (CSA) and Manche (CSM) disposal facilities.
4. Time is not taken into account when classifying this waste category due to its very low activity level.
5. Industrial facility for grouping, storage and disposal in the Aube department (Cires).

RADIOACTIVE WASTE MANAGEMENT METHODS

In order to adequately confine the waste and isolate it from humans and the environment, French authorities decided to manage this waste in dedicated disposal facilities compatible with the inherent radioactivity and lifetime, potentially after a storage period.

- surface disposal facilities: two facilities operated by Andra in the Aube department have been used since 2003 for the disposal of very low-level waste (VLLW) and since 1992 for the disposal of low- and intermediate-level waste, mainly short-lived (LILW-SL). There is also the Manche disposal facility, which was in operation from 1969 to 1994 and is currently in the closure phase;
- the deep geological disposal facility, the Cigéo project, for the disposal of high-level (HLW) and intermediate-level long-lived waste (ILW-LL).

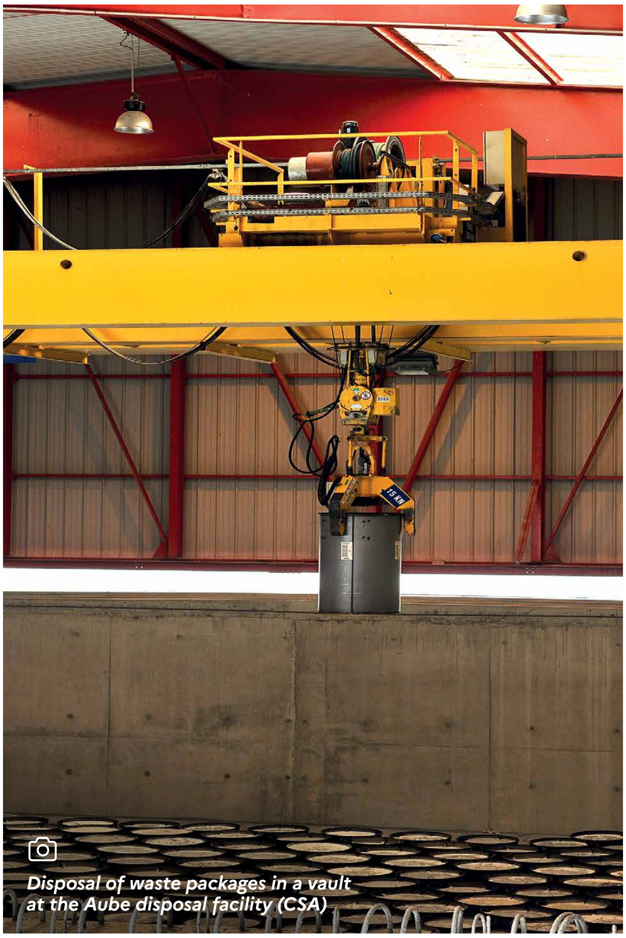
Disposal facilities designed to host low-level long-lived waste (LLW-LL) are also under development.

The initial management solution selected will depend on waste characterisation studies and processing and conditioning methods. The final decision will be based on the characteristics of the package produced.

Disposal

The disposal of radioactive waste involves placing these substances in a facility especially designed to hold them on a potentially permanent basis [...], without any intention of subsequent retrieval.

Article L. 542-1-1 of the French Environmental Code.



Disposal of waste packages in a vault at the Aube disposal facility (CSA)

The radioactivity of very short-lived waste (VSLW) decreases significantly within a few months, or even a few days or hours. Such waste is therefore stored on-site during radioactive decay, before being disposed of via the most appropriate conventional waste management for its physical, chemical and biological characteristics.

Finally, some types of radioactive waste cannot yet be processed and conditioned in a way which is compatible with a given management solution, generally due to their specific physical or chemical characteristics. Such waste is conventionally referred to as 'waste without a specific disposal solution' (DSF). After being processed, conditioned or characterised, where appropriate, DSF is subjected to the appropriate management process.

FOCUS

THE PRODUCTION OF RADIOACTIVE MATERIALS AND WASTE BY THE NUCLEAR POWER SECTOR IN FRANCE

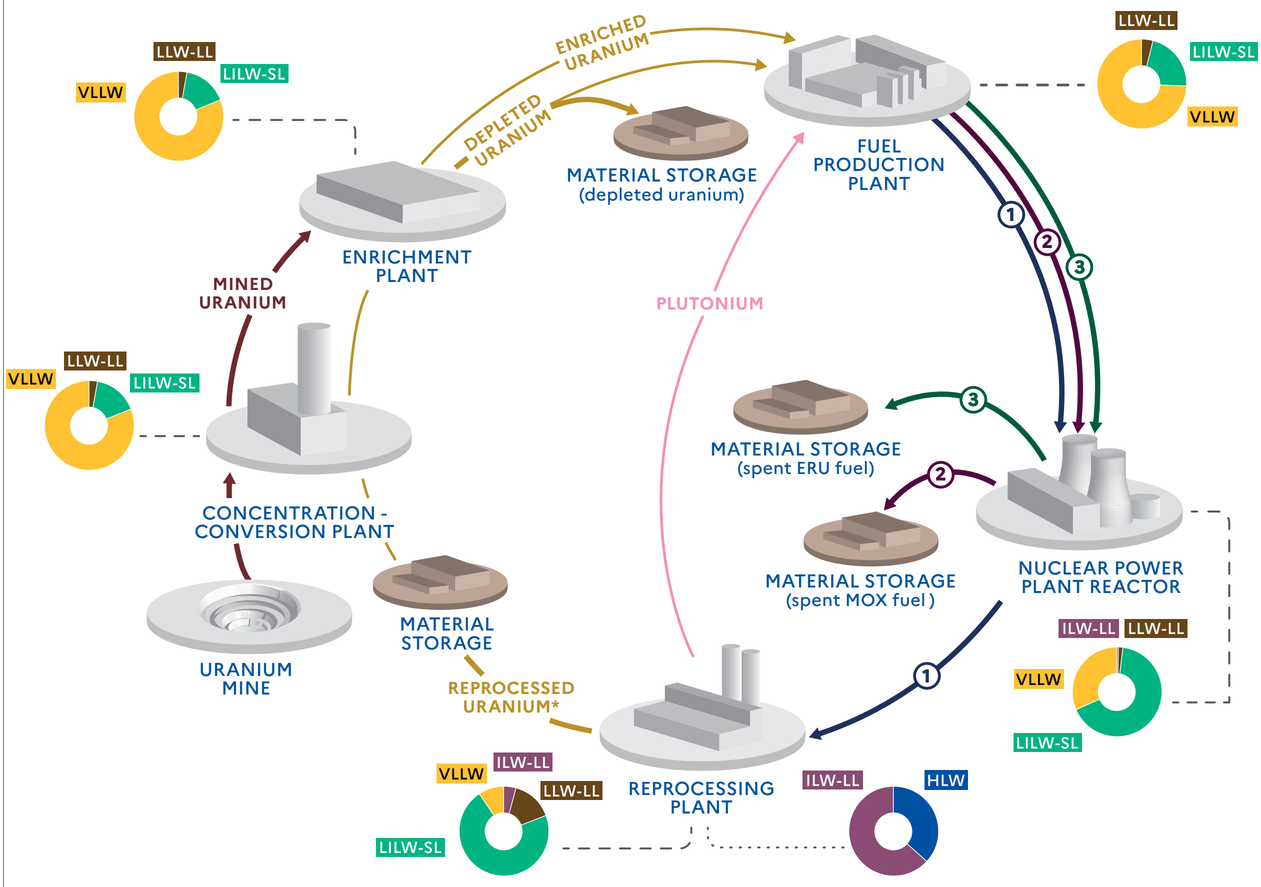
Most radioactive materials and waste produced by the nuclear power sector result from the operation of the facilities that manufacture, use and then reprocess nuclear fuel.

This includes both the operation and dismantling of the facility.

Most of the waste produced by the operation of these plants is taken to Andra's industrial facilities in the Aube (Cires and CSA). Intermediate-level long-lived waste (ILW-LL) and high-level waste (HLW) are also produced and stored at the production sites, pending the creation of a disposal facility designed for this purpose: Cigéo. The nuclear power sector generates a small amount of low-level long-lived waste (LLW-LL), for which a repository is also under development.

Dismantling nuclear installations also produces waste, the vast majority of which is very low-level waste (VLLW).

Radioactive materials are currently either recovered or stored pending future reuse. For example, reprocessed uranium (RepU) can be used in nuclear power reactors in the form of Enriched Reprocessed Uranium (ERU). Research is under way into the potential recovery of the materials contained in spent MOX and ERU fuel assemblies in Pressurised Water Reactors (PWR) and, ultimately, in Fast Neutron Reactors (FNR) in order to improve material recycling.



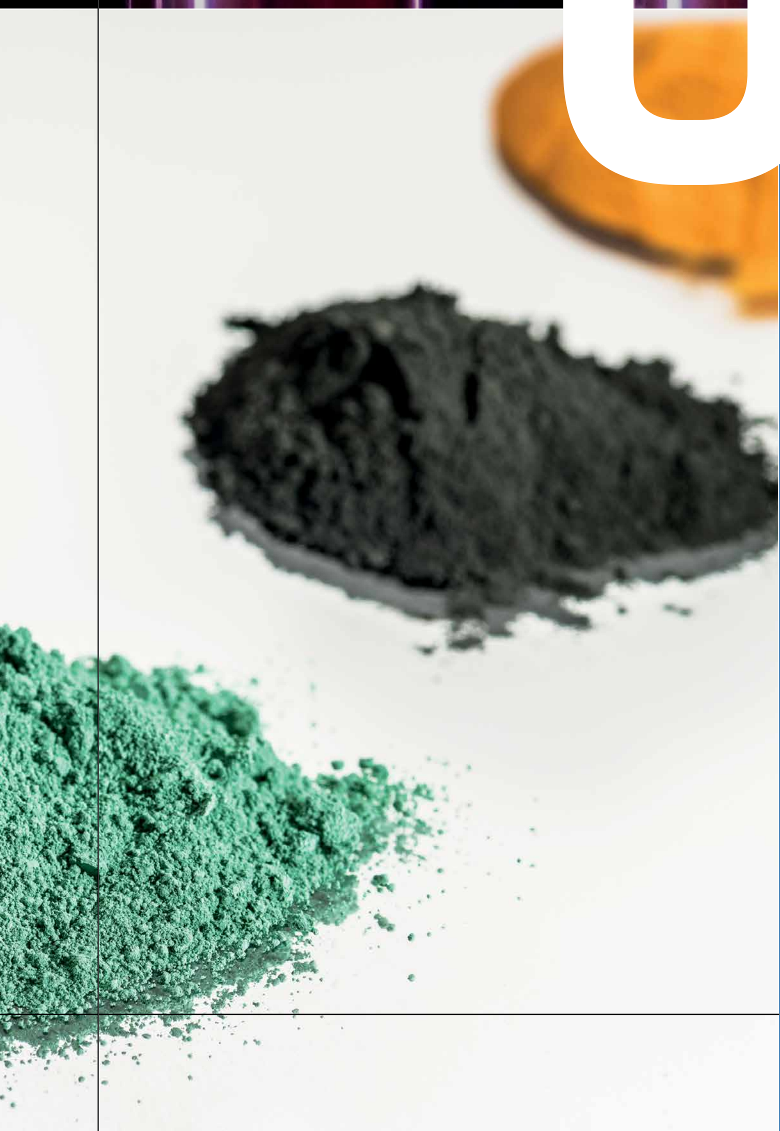
1. Enriched natural uranium oxide fuel (ENU)
2. Uranium and plutonium mixed oxide fuel (MOX)
3. Enriched recycled uranium oxide fuel (ERU)

– – – Operating and dismantling waste - Inventory at the end of 2023

······ Residual waste after reprocessing spent fuel - Inventory at the end of 2023

* *Restart for the RepU sector*

02



Inventory of radioactive materials at the end of 2023

MATERIALS RECORDED

Andra performs an annual inventory of all radioactive materials present on French territory on 31 December every year, based on information provided by the holders of those materials. These are substances for which later use is planned or envisaged, if necessary after reprocessing, with the exception of sealed sources, which are registered by the French nuclear safety and radiation protection authority (ASNR) in accordance with Article R. 1333-154 of the French Public Health Code.

Holders of fissile materials primarily include organisations involved in the nuclear fuel cycle, all nuclear reactor operators (nuclear power, defence and research facilities) and chemical industry stakeholders holding radioactive materials for use in their activities (e.g. mining rare-earth metals).

The foreign materials in France referred to under Article L. 542-2-1 of the French Environmental Code are also considered in overviews. These foreign materials are to be sent back to their country of origin.

Measuring unit

Quantities of radioactive materials are indicated is tonnes of heavy metal (tHM). This unit represents the quantity of uranium, plutonium or thorium contained in the materials, except fuel used for defence purposes, which is expressed as tonnes of assemblies (t).

In accordance with the PNGMDR, Andra initiated *"discussions aimed at improving the comparison of inventories of radioactive materials and waste".* The first step in this approach aimed to indicate the equivalence of the quantities of materials as “conditioned equivalent volumes” (this unit expresses the quantity of waste), as part of the forecast inventories (see chapter 4).

Uranium hexafluoride crystals

INVENTORY OF RADIOACTIVE MATERIALS

The following table shows the inventory of radioactive materials at the end of 2023, the difference with the previous year and the percentage of materials owned by foreign countries (foreign materials are intended to be returned to the original owners).

OVERVIEW OF INVENTORIES OF RADIOACTIVE MATERIALS (in tHM, except for spent fuel from French defence sources which is indicated in tonnes of assemblies)

No.	Material category	End of 2023	2023/2022 trend	Foreign share
1	ENU fuels before use	784	– 90	-
2	ENU fuels in use in nuclear power plants	4,120	+ 630	-
3	Spent ENU fuels pending reprocessing	11,000	– 500	0.2%
4	ERU fuels before use	19	+ 19	-
5	ERU fuels in use in nuclear power plants	-	-	-
6	Spent ERU fuels pending reprocessing	625	– 3	-
7	Mixed uranium-plutonium fuels before use or under manufacture	32	+ 7	-
8	Mixed uranium-plutonium fuels in use in nuclear power plants	185	– 5	-
9	Spent mixed uranium-plutonium fuels pending reprocessing[1]	2,510	+ 50	-
10	Non-irradiated mixed uranium-plutonium fuel scrap pending reprocessing	375	+ 16	-
11	Non-irradiated uranium fuel scrap pending reprocessing	-	-	-
12	Spent FNR fuels pending reprocessing	131	+ 6	-
13	Research reactor fuels before use	0.03	– 0.03	-
14	Fuel in use in research reactors	1	-	-
15	Other civil spent fuel	62	+ 1	2%
16	Spent fuel for defence purposes	217 tonnes	+ 14 tonnes	-
17	Non-irradiated separated plutonium, in all its physical-chemical forms	72	+ 2	19%
18	Mined natural uranium, in all its physical-chemical forms	33,200	– 2,700	-
19	Enriched natural uranium, in all its physical-chemical forms	3,350	– 190	-
20	Enriched uranium from spent fuel reprocessing, in all its physical-chemical forms[2]	22	-	-
21	Uranium from spent fuel reprocessing, in all its physical-chemical forms[2]	34,600	-	7%
22	Depleted uranium, in all its physical-chemical forms	341,000	+ 10,000	-
23	Thorium, in the form of nitrates and hydroxides	8,510	-	-
24	Suspended particulate matter (by-products from processing of rare earth ore)	4	– 1	-
25	Other materials[3]	70	-	-

1. The residue from non-irradiated mixed uranium-plutonium fuel awaiting reprocessing will eventually be reprocessed and recycled in nuclear power reactors.
2. Uranium from spent fuel reprocessing will be enriched to form enriched uranium from spent fuel reprocessing, which will then be used to make enriched reprocessed uranium oxide fuel (ERU).
3. The second Superphénix core, which was not and will not be irradiated, was classified in the "Other materials" category as it does not correspond to either "fuel before use" or "spent fuel".

The published inventory consists of rounded values. The differences were calculated on the basis of the rounded inventory values.

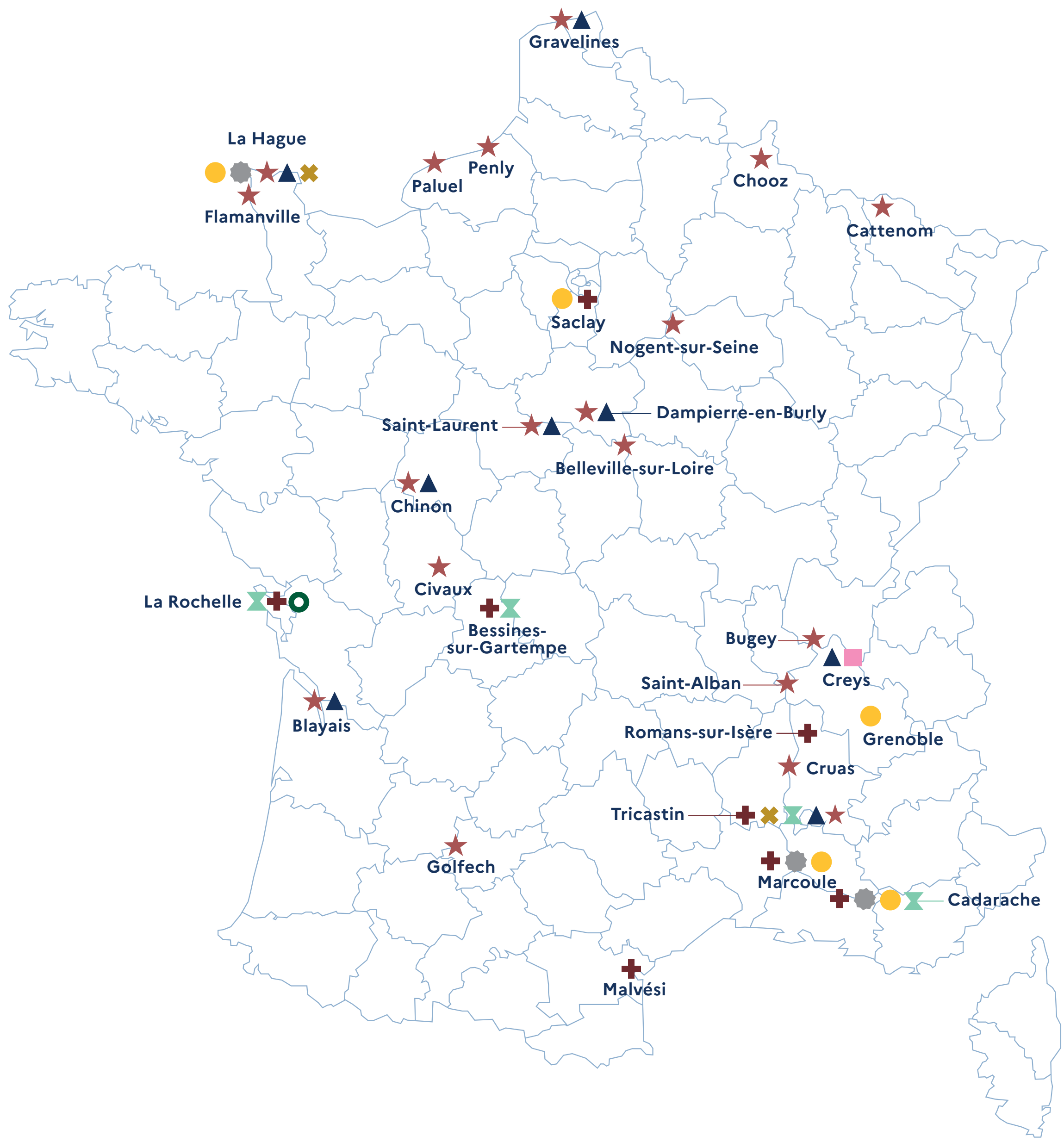
The differences, consistent with those observed since 2022, can be explained by:

- one year of operation of nuclear power plants, in line with the recorded production capacities of the fuel cycle plants;
- restarting the RepU sector, with the production of ERU type fuel in 2023.

In the current framework of nuclear power generation, some processed radioactive materials are intended to be used as fuel, while others are stored pending reuse.

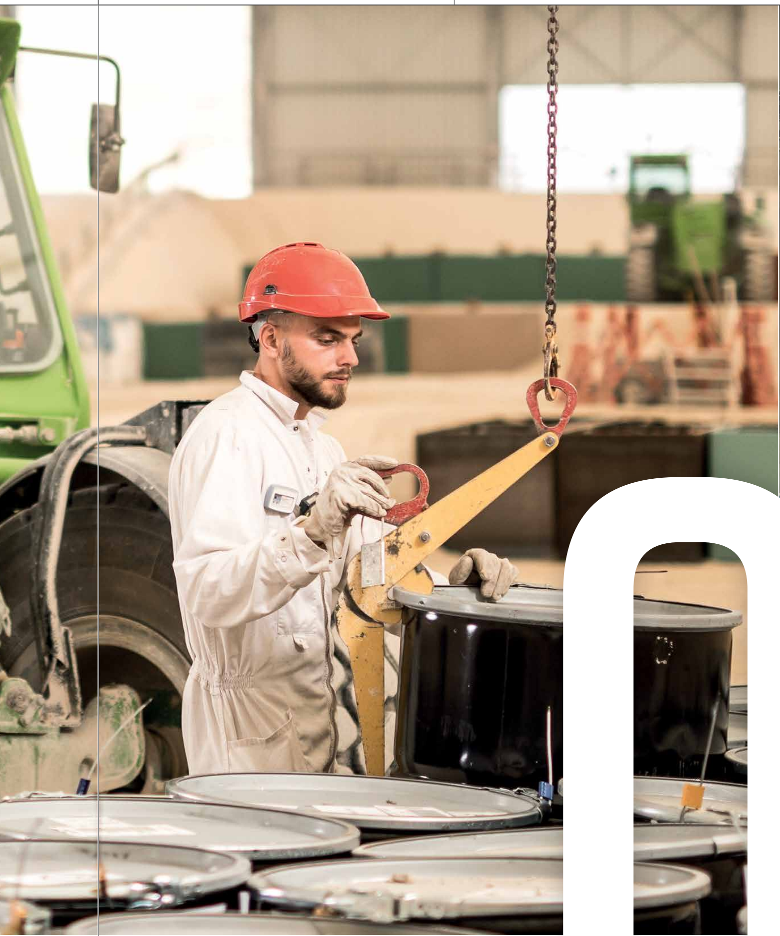
FOCUS

LOCATIONS OF RADIOACTIVE MATERIALS IN FRANCE ON 31/12/2023



- Natural uranium
- Uranium from spent fuel reprocessing
- Uranium oxide fuel (ENU, ERU)
- Mixed oxide fuel (MOX, FNR)
- Research reactor fuel
- Thorium
- Materials in suspension
- Plutonium
- Other materials

National defence fuels are not shown on this map. In order to protect information that if disclosed may harm the interests identified in Article L. 124-4 of the French Environment Code, the corresponding material locations cannot be communicated.



03

Inventory of radioactive waste at the end of 2023

Andra runs an annual inventory of France-wide radioactive waste on 31 December every year, based on the information provided by waste holders. There are more than 1,000 waste holders across all business segments, and a small number of these holders control most radioactive waste.

Foreign waste referred to in Article L. 542-2-1 of the French Environmental Code, which is to be returned to foreign customers, is included in these overviews if present in France on the reference date.

WASTE ALREADY DISPOSED OF OR DUE TO BE MANAGED BY ANDRA

Stated waste volumes refer to conditioned waste, i.e. waste that the producers do not intend to process further before disposal. This conditioned waste constitutes primary packages.

A standard unit was adopted for overview purposes: the "conditioned equivalent volume".

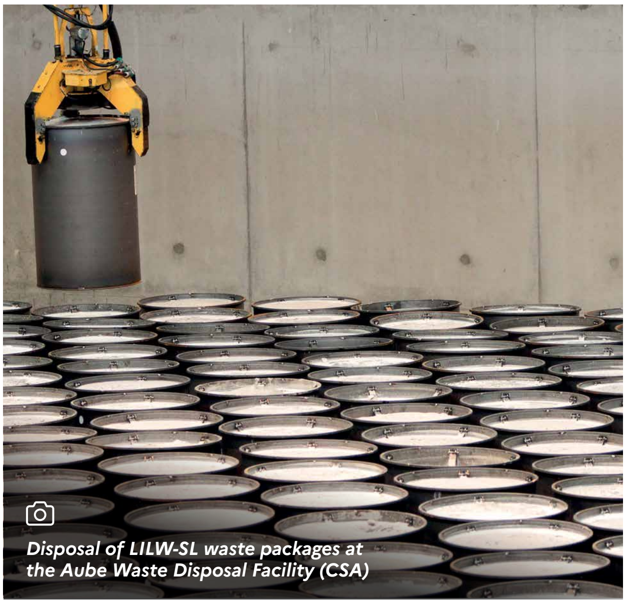
The conditioned equivalent volume is estimated for waste that has not yet been conditioned.

In the specific case of the Cigéo geological disposal project (which is designed to receive high-level waste (HLW) and intermediate level long-lived waste (ILW-LL)), additional conditioning, in the form of disposal packages, may be necessary, particularly for handling or retrievability purposes. Only the volume of primary packages is taken into account in this document.

The data below corresponds to radioactive waste already disposed of at Andra facilities, or due to be managed by the Agency.

Conditioning

Conditioning involves placing waste in a container compatible with its radioactivity and half-life, then immobilising it, if necessary, with immobilisation or embedding material.



Disposal of LILW-SL waste packages at the Aube Waste Disposal Facility (CSA)

OVERVIEW AND DIFFERENCE IN VOLUMES (in m³) OF WASTE ALREADY DISPOSED OF OR DUE TO BE MANAGED BY ANDRA (rounded totals and variation)

Category	Inventory at the end of 2023	2023/2022 trend
HLW	4,550	+ 130
ILW-LL	34,800	– 4,800
LLW-LL	122,000	+ 18,000
LILW-SL	994,000	+ 5,000
VLLW	693,000	+ 39,000
DSF	372	+ 28
Total	1,850,000	+ 60,000

The published inventory consists of rounded values. The differences were calculated on the basis of the rounded inventory values.

The differences between the quantities of waste at the end of 2022 and at the end of 2023 can be accounted for by ongoing waste generation for most categories and by switching some types of ILW-LL waste to LLW-LL.

INVENTORY OF VOLUMES (m^3) OF WASTE AT PRODUCER/HOLDER SITES AND DISPOSED OF AT ANDRA FACILITIES AT THE END OF 2023

Category	Total	At producer/holder sites	Disposed of at Andra facilities	Capacities of existing Andra disposal facilities.
HLW	4,550	4,550	-*	-
ILW-LL	34,800	34,800	-*	-
LLW-LL	122,000	122,000	-*	-
LILW-SL	994,000	95,100	906,000	1,530,000
VLLW	693,000	233,000	469,000	650,000
DSF	372	372	-*	-
Total	**1,850,000**	**490,000**	**1,380,000**	**2,180,000**
		26%	75%	

* This waste has not yet been disposed of: the disposal solution for HLW and ILW-LL (Cigéo) is currently under development. The LLW-LL waste disposal solution is also under development. Waste without a specific disposal solution (DSF) will be directed to a management solution after any necessary treatment or characterisation.

LILW-SL and VLLW waste is stored at the production site for retrieval, conditioning or removal to Andra disposal facilities.

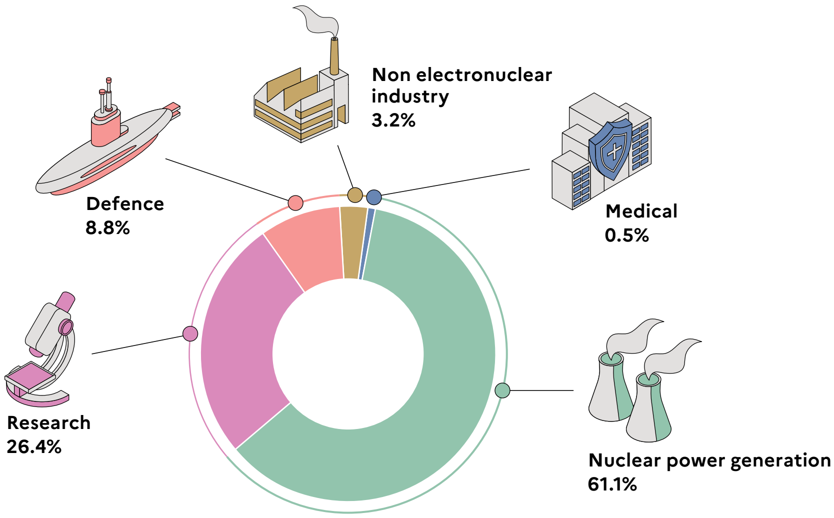
VLLW at Cires

VLLW is disposed of at the Cires facility. By the end of 2023, this facility had filled approximately 72.2% of its total licensed disposal capacity of 650,000 m^3. In its current configuration, Cires will not be sufficient to dispose of the VLLW volumes produced by dismantling in the coming years. Complementary management solutions are therefore currently being studied, including the recovery of some types of VLLW and finding a new disposal site.

The medium-term solution involves increasing the licensed disposal capacity of Cires to approximately 950,000 m^3, without changing the current footprint of the disposal zone and while maintaining its safety level (Acaci project).

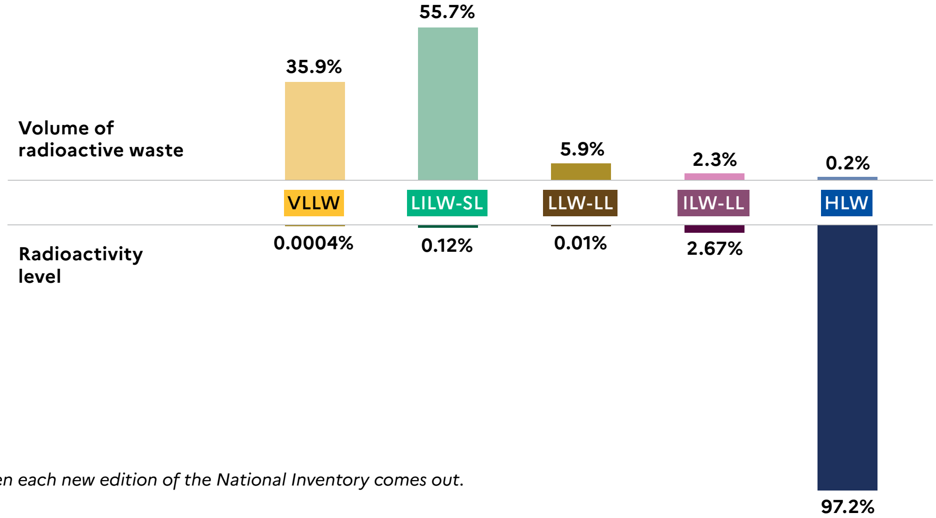
This increase in capacity was licensed with a prefectoral order in July 2024, and will allow Cires to operate for an extra ten years or so, i.e. up to around 2040.

END-2023 BREAKDOWN BY ECONOMIC SECTOR OF WASTE VOLUME (conditioned equivalent) ALREADY DISPOSED OF OR DUE TO BE MANAGED BY ANDRA



Percentages were calculated based on the exact figures, then rounded.

THE BREAKDOWN OF VOLUMES AND RADIOACTIVITY LEVELS PRESENTED BELOW IS TAKEN FROM THE 2023 EDITION OF THE *NATIONAL INVENTORY*.



Data are updated when each new edition of the National Inventory comes out.

WASTE NOT INTENDED TO BE MANAGED BY ANDRA

VERY SHORT-LIVED WASTE

INVENTORY AND DIFFERENCE IN VOLUMES (m³) OF VERY-SHORT-LIVED WASTE MANAGED THROUGH DECAY

Category	Inventory at the end of 2023	2023/2022 trend
VSLW	2,318	– 158

These volumes are not included in the overviews.

THE SPECIFIC CASE OF WASTE FROM ORANO MALVÉSI PRODUCED BEFORE 2019

Some of the uranium conversion treatment residue (RTCU) from the Orano Malvési plant is legacy waste. Work is underway to find a safe, long-term management solution at the Malvési site for legacy RTCU waste, given its specific nature (large volumes, etc.). RTCU waste produced after 1 January 2019 was included in the VLLW and LLW-LL management solutions, in accordance with Article 63 of the Order of 23 February 2017 (Decree No. 2017-231).

INVENTORY AND FORECASTS OF VOLUMES OF URANIUM CONVERSION TREATMENT RESIDUES STORED AT THE MALVÉSI SITE (m³)

	Inventory at the end of 2023	2023/2022 trend
Settling ponds	15,900	+ 6,300
ECRIN facility (legacy RTCU)	309,000	+ 39,000
Evaporation ponds (nitrated effluents)	372,000	-

These volumes are not included in the overviews.

The volumes of settling ponds changed due to the mechanical transfer of residual sludge in pond B6 to the CERS cell from 2022.

The start of the monitoring phase for the ECRIN facility allows legacy RTCU to be safely stored by keeping them in a reversible state in view of a future permanent solution.

FOCUS

MINE WASTE AND TAILINGS WHICH HAVE BEEN SUBJECTED TO SPECIFIC MANAGEMENT METHODS
(this waste is not included in the overviews)

- **Waste disposed of inside of or near the perimeter of nuclear facilities or plants.** The corresponding activity is approximately a few becquerels per gram (several thousands of tonnes).

- **Tailings from processing uranium ores** at former mining sites. These are long-lived tailings with a similar activity level to VLLW (approximately 50 million tonnes).

Former Bellezane mine

- **Waste which is naturally highly radioactive managed through on-site disposal.** This waste is generated by the processing of raw materials containing naturally-occurring radionuclides, but which are not used for their radioactive properties. Much of this waste is comparable to VLLW (around 50 million tonnes).

Tailings from the treatment of very slightly radioactive materials were used as backfill at the La Palice port in La Rochelle

- **Waste disposed of in conventional waste disposal facilities** (excluding waste which is naturally highly radioactive). Some of these facilities have received waste with low activity levels, around a few becquerels per gram. This waste mainly comprises sludge, soil, industrial residues, rubble and scrap from conventional industry or from the civilian or military nuclear industry. This practice has not been permitted since 2004.

- **Defence disposal sites in French Polynesia:** between 1966 and 1996, France carried out nuclear experiments in the South Pacific, in French Polynesia. The waste produced by these experiments and on dismantling the associated facilities was disposed of *in situ* in wells or dumped in French territorial waters.

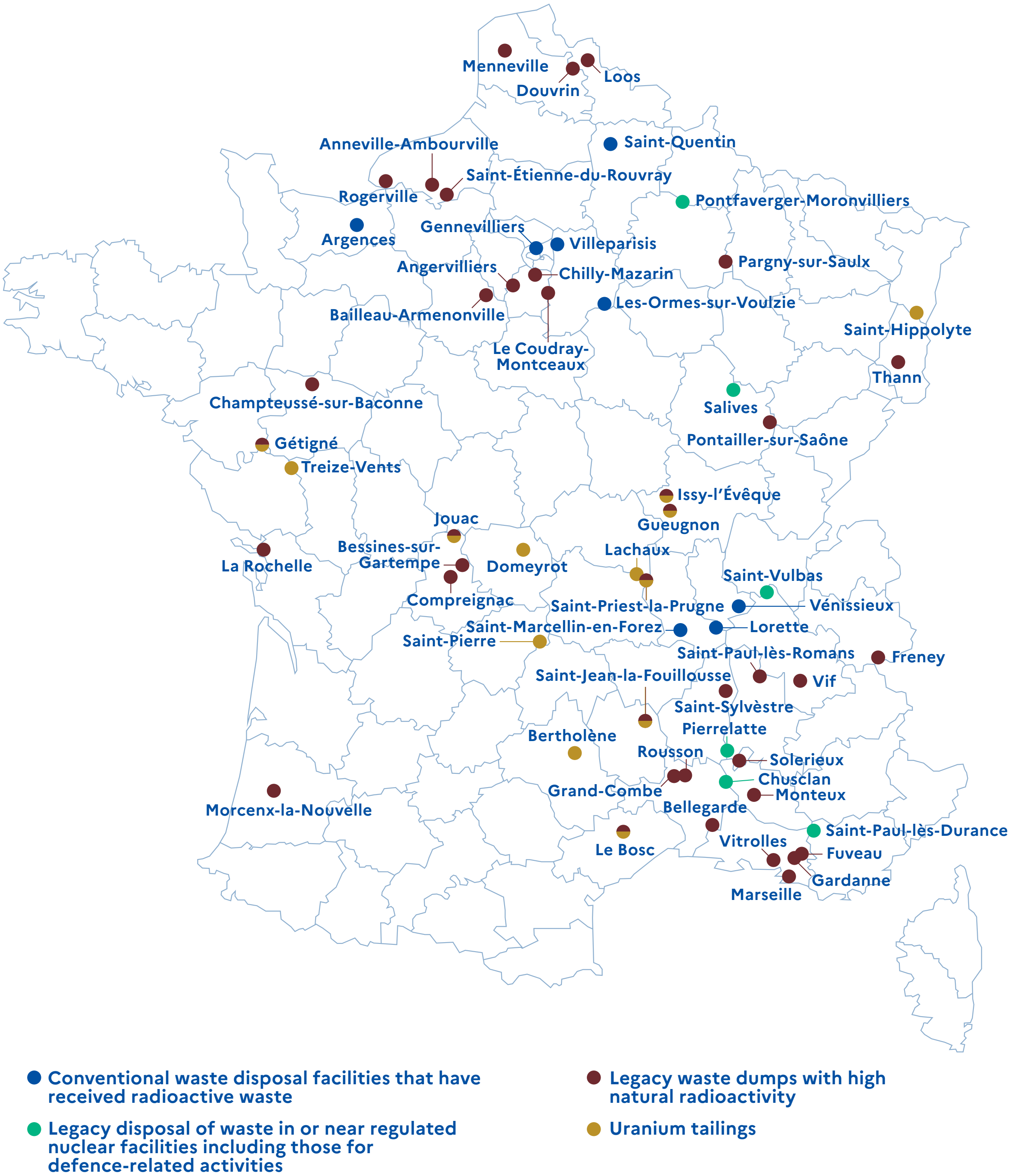
- **Dumped waste:** several countries dumped radioactive waste between 1946 and 1993. This management solution was considered as safe by the international scientific community at the time. In fact, it was assumed that the waste was diluted and rapidly isolated and therefore safe. Several thousands of tonnes of waste were thus dumped in this way by France between 1967 and 1982. A permanent ban on dumping radioactive waste at sea came into effect in 1993.

Dumping radioactive waste packages

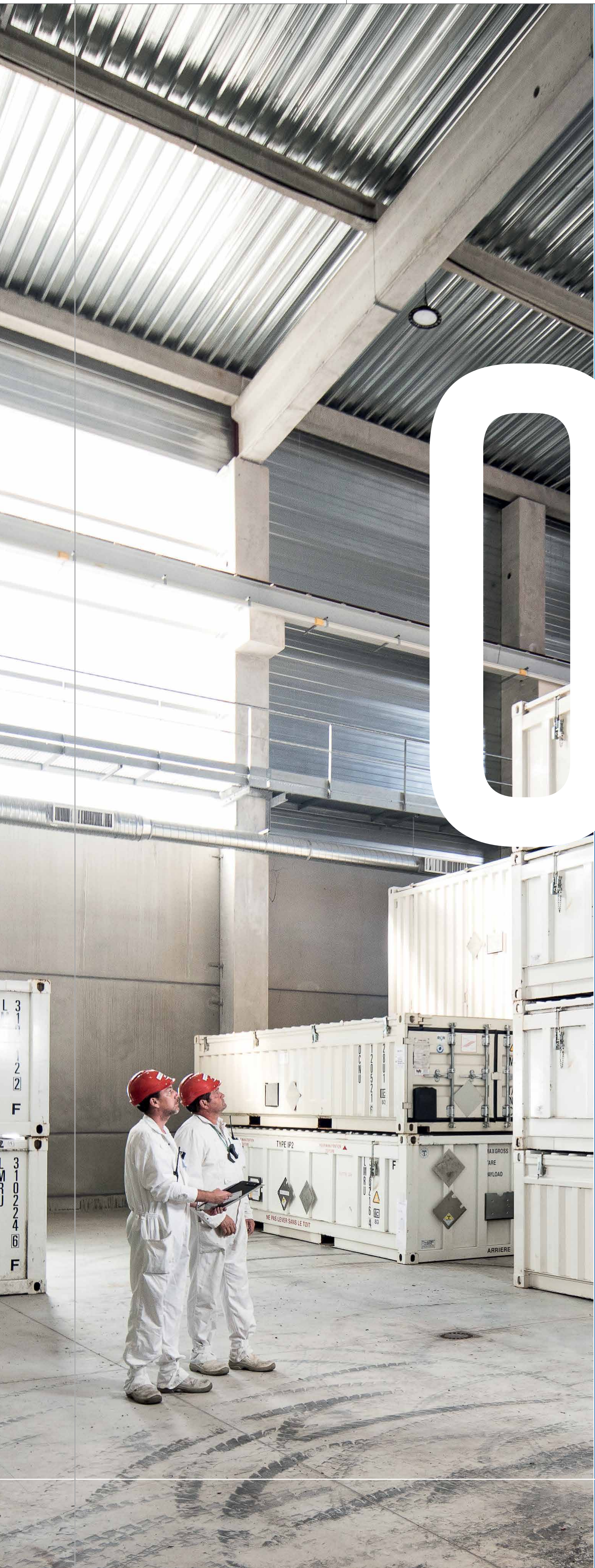
Disposal sites (except those at sea) undergo environmental monitoring, which makes it possible to check that the potential impact of this waste is under control.

FOCUS

LOCATIONS OF MINE WASTE AND TAILINGS SUBJECTED TO SPECIFIC MANAGEMENT METHODS
(mainland France)



The quantities declared by radioactive waste producers/holders can be consulted in the summary report of the National Inventory.



04

Forecast inventories from the 2023 edition of the *National Inventory*

In order to manage radioactive waste and materials, we must establish a clear medium- and long-term vision of future waste volumes for the purpose of planning for and taking suitable action to guarantee the continuous availability of storage and disposal capacities and ultimately protect both people and the environment from the inherent risks of these materials and waste.

Andra prepares assessments and forecast inventories for this purpose, based on reports from the nuclear power industry, issued by waste producers or holders of radioactive materials. The outlook described in the 2023 edition of the National Inventory includes data from different periods.

The National Inventory primarily includes the estimated volumes of radioactive materials and waste for installations with a construction licence at the end of 2021. This period is governed by a number of regulations and takes account of the National Radioactive Materials and Waste Management Plan (PNGMDR). Scenarios based on the applicable Multi-annual Energy Programme 2019-2028 (PPE2) are integrated. These scenarios are prepared in a coordinated manner, within the framework of the PNGMDR, which provides a means of coordinating the management of radioactive materials and waste, and therefore takes account of the main guidelines of the PPE2 in order to ensure that the guidelines defined for the management of radioactive materials and waste are compatible with the French energy strategy. These scenarios cover a range of contrasting energy policy developments: the continued generation of nuclear power using different fuel reprocessing strategies, or the withdrawal of nuclear power generation facilities.

In order to cover the impact of energy policy guidelines on the management of radioactive materials and waste, the 2023 edition of the National Inventory was completed with a chapter on "Prospects" describing:

- information from the analysis of the impact of radioactive waste generated by the potential deployment of six additional EPR2-type nuclear power reactors, studied by Andra at the request of the Directorate General for Energy and Climate (DGEC) as part of the New French Nuclear Power project (NNF);
- a qualitative analysis of the issues relating to the continued operation of reactors for up to 60 years, carried out by Andra specifically for the 2023 edition of the National Inventory.

SUMMARY OF THE OUTCOMES OF FORECAST SCENARIOS

All four scenarios are based on the following common assumptions:

- 57 reactors currently exist;
- reactors operate for 60 years, except for 12 reactors which will be progressively shut down between 2027 and 2035 (in accordance with the current Multi-annual energy programme);
- renewed use of reprocessed uranium (RepU) to manufacture fuel;
- recycling of plutonium extracted when reprocessing spent fuel as mixed uranium-plutonium fuel (MOX).

All four scenarios provide for a common pathway up to 2040. The pathways then diverge according to different hypotheses, with the main ones being as follows:

- the renewal or non-renewal of the current nuclear power plants;
- decision reached in terms of fuel reprocessing: ceasing or continuing (mono-recycling) the recycling of spent enriched natural uranium (ENU) fuel, recycling of enriched processed uranium (ERU) or MOX fuels (multi-recycling);
- the type, pace of deployment and nature of the fuels used (ENU, ERU or MOX fuels) in a potential future fleet of reactors (EPR2 and/or FNR).

Spent fuel reprocessing strategy

The French energy policy provides for the reprocessing of spent fuel after use in a nuclear reactor. During reprocessing, the depleted uranium and plutonium are extracted in view of re-use to produce new fuel.

Potential options:

- **"mono-recycling",** which involves exclusively reprocessing ENU type spent fuel (Enriched Natural Uranium), most of which is used for current reactors. Fuel is reprocessed at an Orano group plant based in La Hague;
- **"multi-recycling",** which involves reprocessing all types of spent fuel from nuclear power plants: the above types, ENU fuels, and fuel produced with reprocessed substances.

Andra also analyses the potential impact of stopping the reprocessing of spent fuel, which would lead to a situation where spent fuel is considered as waste.

SUMMARY OF THE SCENARIOS

		Scenario S1	Scenario S2	Scenario S3	Scenario S4
Total reactor operating life		60 years excluding closure of 12 reactors between 2027 and 2035 (see PPE 2019-2028)			
Nuclear power production sector		Continuation	Continuation	Continuation	No renewal
Types of reactors deployed in the future		EPR2 then FNR	EPR2	EPR2	-
Reprocessing of spent fuel		Multi-recycling All: ENU at term, ERU, MOX, EL4, FNR Phénix and Superphénix, Research	Mono-recycling ENU at term, EL4	Reprocessing phased out ENU by 2040	Reprocessing phased out ENU by 2040
Reclassification of materials as waste		None	Spent fuel: ERU, MOX, FNR Phénix and Superphénix, Research excluding EL4 Depleted uranium, research plutonium	Spent fuel: ENU (after 2040), ERU, MOX, FNR Phénix and Superphénix, Research including EL4 Depleted uranium, research plutonium	Spent fuel: ENU (after 2040), ERU, MOX, FNR Phénix and Superphénix, Research including EL4 Depleted uranium, research plutonium
HLW	**Spent ENU fuel**	-	-	14,500 tHM ≈ 7,000 m³	14,500 tHM ≈ 7,000 m³
	Spent ERU fuel	-	6,110 tHM ≈ 3,000 m³	6,110 tHM ≈ 3,000 m³	6,110 tHM ≈ 3,000 m³
	Spent MOX fuel	-	5,030 tHM ≈ 3,000 m³	5,030 tHM ≈ 3,000 m³	5,030 tHM ≈ 3,000 m³
	MOX scrap	-	386 tHM ≈ 200 m³	386 tHM ≈ 200 m³	386 tHM ≈ 200 m³
	Spent FNR fuel	-	149 tHM ≈ 100 m³	149 tHM ≈ 100 m³	149 tHM ≈ 100 m³
	Spent fuel used in research	-	6.4 tHM ≈ 10 m³	56 tHM ≈ 100 m³	56 tHM ≈ 100 m³
	Non-irradiated separated plutonium	-	2 tHM ≈ 20 m³	2 tHM ≈ 20 m³	2 tHM ≈ 20 m³
	Other materials	-	70 tHM ≈ 90 m³	70 tHM ≈ 90 m³	70 tHM ≈ 90 m³
	Final waste excluding materials reclassified as waste	11,800 m³	8,960 m³	6,890 m³	6,890 m³
	Final total	11,800 m³	≈ 15,000 m³	≈ 20,100 m³	≈ 20,100 m³
ILW-LL	**Final waste**	68,800 m³	67,100 m³	63,200 m³	63,200 m³
LLW-LL	**Depleted uranium**	-	899,000 tHM* ≈ 300,000 m³	899,000 tHM* ≈ 300,000 m³	899,000 tHM* ≈ 300,000 m³
	Final waste excluding materials reclassified as waste	218,000 m³	218,000 m³	218,000 m³	218,000 m³
	Final total	218,000 m³	518,000 m³	518,000 m³	518,000 m³
LILW-SL	**Final waste**	1,870,000 m³	1,870,000 m³	1,850,000 m³	1,850,000 m³
VLLW	**Final waste**	2,430,000 m³	2,410,000 m³	2,400,000 m³	2,400,000 m³

* For depleted uranium owned by Orano, the quantities indicated and "reclassified as waste" status do not take account of the recovery pathways already implemented and envisaged for nuclear power sectors in France or abroad and in innovative non-nuclear pathways. The PNGMDR (National Radioactive Materials and Waste Management Plan) 2022-2026 provides for several actions intended to improve forecasts for the potential future recovery of materials. It also emphasises the need to support research into such recovery.

Tonne of heavy metal (tHM): rounded to three significant figures.
Volume of materials reclassified as waste: rounded to one significant figure.
Conditioned equivalent volume: rounded to three significant figures for radioactive waste.
In this case, "final waste" means after the decommissioning of the nuclear installations licensed at the end of 2021.

According to the different scenarios, the quantity of vitrified waste (FLW) and metal waste from the structures surrounding the fuel (ILW-LL) is not only impacted by the operating lives of the reactors, but also by the spent fuel reprocessing strategy. This reprocessing strategy also affects the type of waste in question: in mono-recycling scenarios and those in which reprocessing is ceased, some spent fuel is reclassified as waste and then classified as HLW based on its properties. On this basis, the total quantity of HLW at the end of the process, including any spent fuel potentially reclassified as waste, is higher in scenarios in which recycling is ceased, including if the volume of vitrified waste alone (HLW) – excluding reclassified materials – and waste from the metal structures surrounding the fuels (ILW-LL) is larger than for recycling scenarios, given that this waste is produced when reprocessing fuel.

For other types of waste (VLLW, LILW-LL and LLW-LL), the different scenarios have little to no impact on the forecast volumes.

It is important to take note that, regarding the three scenarios including the renewal of the nuclear fleet, the forecast estimates only relate to waste produced by current power plants, and do not take account of any waste or materials generated by the possible future replacement reactors mentioned in the assumptions. If new reactors are licensed, the volume of waste from such reactors must be added to the forecast volumes.

OUTLOOK

ESTIMATED VOLUMES OF RADIOACTIVE WASTE PRODUCED BY THE OPERATION OF SIX EPR2S

At the request of the French government in view of the *New Nuclear Works* report published in February 2022, Andra carried out an initial technical assessment of the impact of the potential deployment of 6 new EPR2 reactors on the current or planned radioactive waste disposal facilities.

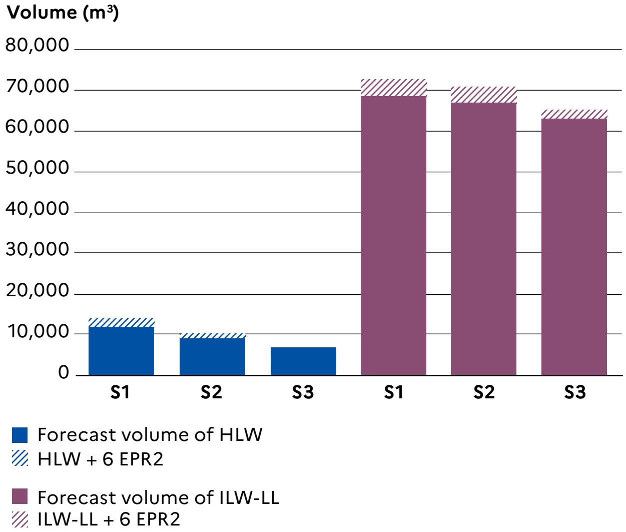
If we compare with the planning scenarios from the *National Inventory,* according to the preliminary study completed by Andra, the increase in volume of radioactive waste produced by six new reactors would represent:

- terms of HLW, depending on the fuel recycling strategy, around 16% (multi-recycling) or 11% (mono-recycling). If reprocessing ceases, the spent fuel would be reclassified as waste;
- in terms of ILW-LL, between 4% and 6% depending on the fuel recycling strategy;
- in terms of VLLW and LILW-SL, around 5% for any fuel recycling strategy.

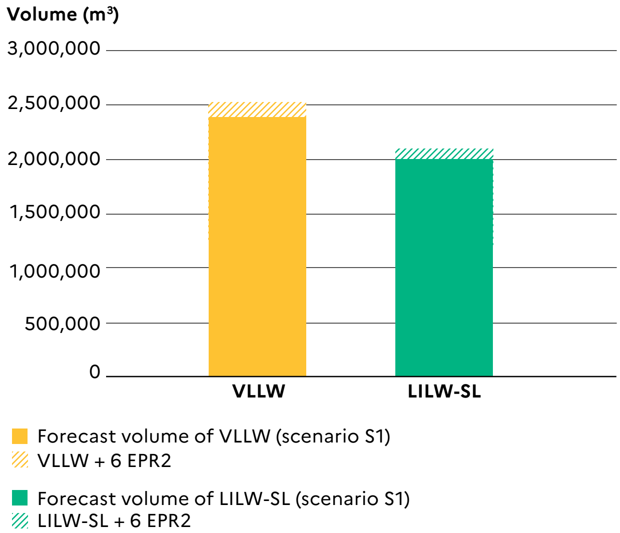
In the same way as for the nuclear power plants currently active in France, no LLW-LL is produced by operational EPR2 reactors.

Scan this QR Code to read the report *New Nuclear Works*

ESTIMATED VOLUMES OF HLW AND ILW-LL GENERATED DURING THE OPERATION OF SIX EPR2S



ESTIMATED VOLUMES OF VLLW AND LILW-SL GENERATED DURING THE OPERATION OF SIX EPR2S



CONTINUED OPERATION OF THE CURRENT REACTORS

The operating lives assumed for the forecast scenarios in the National Inventory were established according to the applicable Multi-annual energy programme (PPE2), which provided for the shutdown of 12 reactors by 2035.

Although we cannot assume ASNR's decision with respect to the continued operation of these installations, Andra analysed the volume of waste to be expected if the operating life for these 12 reactors is extended by 10 years.

VOLUME OF OPERATING WASTE CONDITIONED FROM ONE REACTOR OVER ONE YEAR

Category	
HLW	About 3 m^3
ILW-LL	About 3 m^3
LILW-SL	Between 110 and 150 m^3
VLLW	Between 60 and 80 m^3

IMPACT OF THE QUANTITIES OF WASTE GENERATED BY THE OPERATION OF 12 REACTORS OVER 10 YEARS

Category	
HLW	Between 2% and 5% depending on the scenarios
ILW-LL	Less than 1%
LILW-SL	Less than 1%
VLLW	Less than 1%

Thanks to these estimates, we can assess the effect of extending the 10-year operating life of 12 reactors on waste generation, proving that this impact represents no more than a few percent of the final waste inventory in each category, for all scenarios.

SMR/AMR small reactor projects*

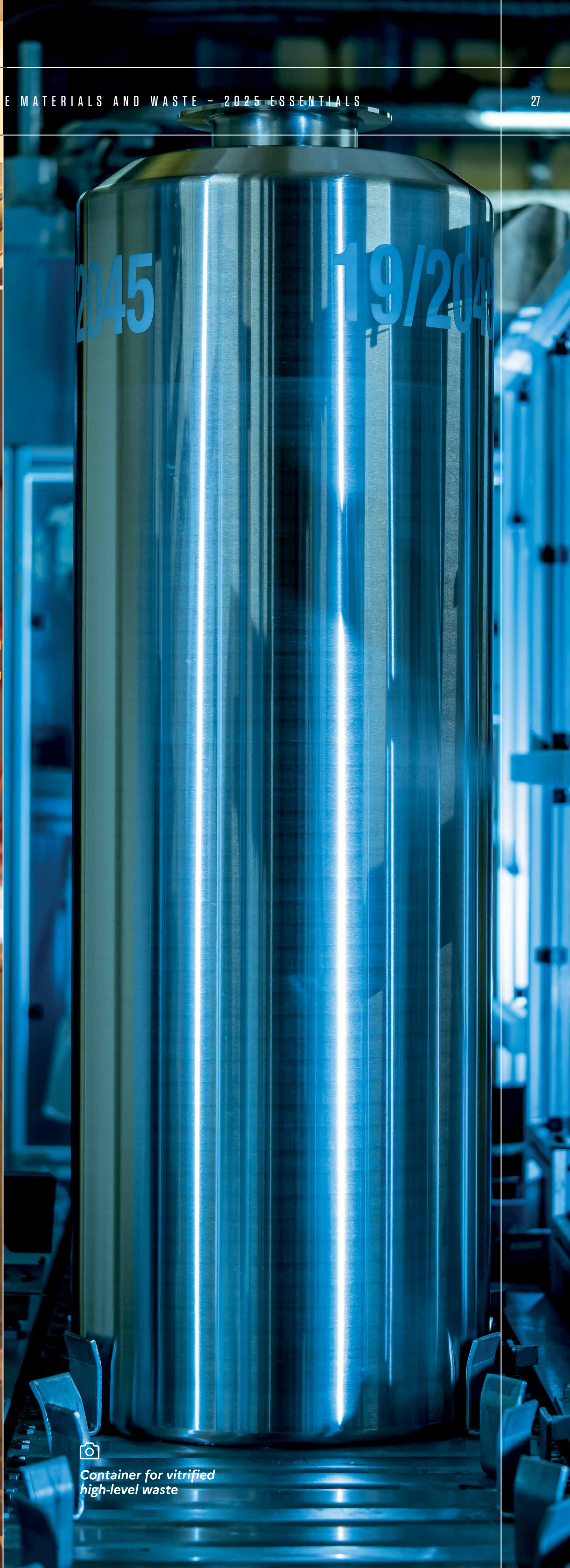
The development of small modular reactors, SMRs or AMRs, is currently under consideration for many projects. This development phase is primarily part of the France 2030 call for projects for "Innovative nuclear reactors".

These reactors are relatively less powerful and smaller than the current reactors in use. Different technologies are used and are at different development stages.

As is the case for any nuclear installation, SMRs and AMRs will produce radioactive waste, and Andra must obtain permission to dispose of this waste in its facilities. Andra is considering this issue carefully, primarily to support the project leaders, so that they can provide the data required to identify management solutions for the waste produced by their installations (properties, volume of waste). While such discussions will allow future waste producers to characterise their waste, they cannot lead to any assumption that Andra will be authorised to manage this waste at its facilities.

** SMR: Small Modular Reactor,*
AMR: Advanced Modular Reactor.

Disposal of intermediate- and low-level waste packages, mainly short-lived, in a vault at the Aube disposal facility



Container for vitrified high-level waste

05

Current news in the radioactive waste and materials sector

LAUNCH OF THE EXTENSION TO THE GEORGES BESSE II URANIUM ENRICHMENT PLANT

Orano started the extension works for its George Besse II uranium enrichment plant at its Tricastin site in October 2024. The first modules are due to be commissioned in 2028. This extension project, which provides for the construction of four new uranium enrichment modules, will increase the production capacity of the site by 30%, reaching the maximum production capacity initially announced when designing the plant.

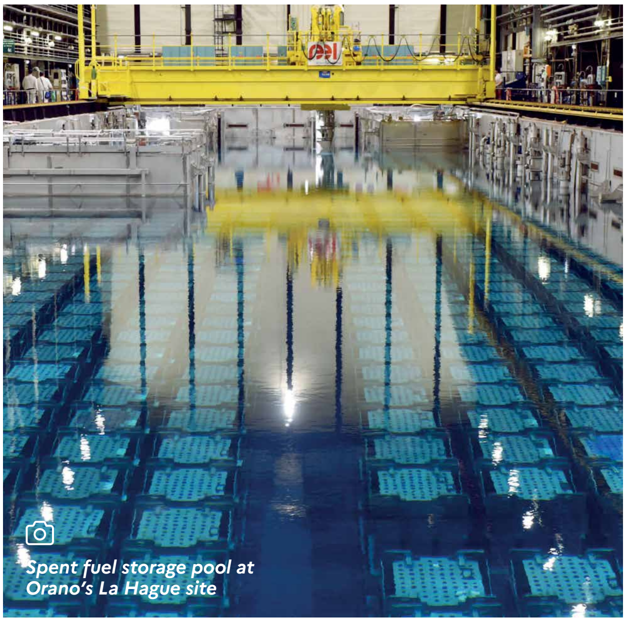
Orano's Georges Besse II enrichment plant

CHANGES TO THE CENTRALISED POOL PROJECT FOR THE STORAGE OF SPENT FUEL

In October 2024, EDF and Orano announced their intention to replace the centralised pool project for the storage of spent fuel led by EDF with the creation of new storage options as part of the project led by Orano involving the construction of new plants for the back end of the cycle at La Hague (MOX fuel production and processing plant). This project follows on from the announcements made by the French nuclear policy board (Conseil de politique nucléaire) in February 2024 on processing & recycling policies in France. The project, as is, provides for the commissioning of new storage capacities which are at least equivalent to the capacity provided for in the initial centralised storage pool project by 2040.

OPENING OF A NEW ORANO SPENT FUEL PACKAGING PRODUCTION PLANT

Orano opened a new spent fuel packaging production plant in Cherbourg in October, with the name "TN Eagle Factory". This plant will be dedicated to the assembly of a new-generation packaging, the "TN Eagle" designed for the transport and dry storage of spent nuclear fuel, and will meet the needs of reactor operators, primarily in Europe, Asia and the United States.



Spent fuel storage pool at Orano's La Hague site

TN Eagle Factory

PUBLIC DEBATES ON THE CONSTRUCTION OF A METAL RECYCLING FACILITY FOR VERY LOW LEVEL WASTE (TECHNOCENTRE)

Further to the public debates organised during the preparation of the fifth edition of the National Radioactive Materials and Waste Management Plan (PNGMDR), potential changes to the regulations applicable to the management of VLLW were raised: the French decree of 14 February 2022 lays down potential targeted derogations allowing for the case-by-case recycling of metal VLLW after melting and decontamination.

The Technocentre planned by EDF in Fessenheim is intended to provide a metal recycling plant for very low level waste (VLLW) from the maintenance and dismantling of nuclear reactors. Public debates on these plans ran from 10 October 2024 to 7 February 2025.

Scan this QR Code to find out more about the public debates

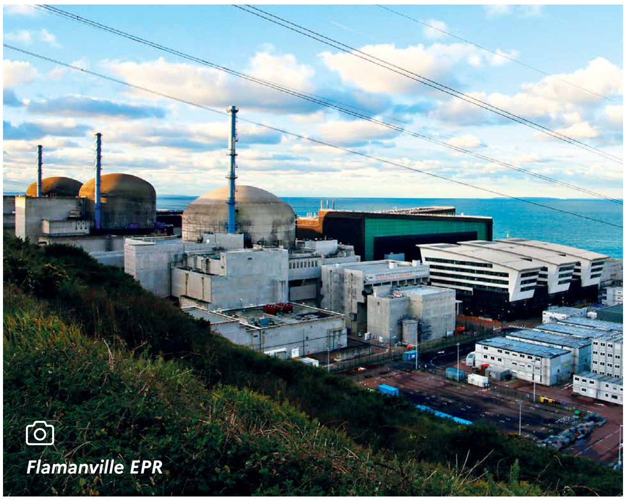
Metal VLLW

COMMISSIONING OF THE FLAMANVILLE EPR

The French Nuclear Safety Authority (ASN) licensed the start of criticality for the EPR reactor core at Flamanville in September 2024. Several technical requirements had to be met prior to starting up the reactor, and some items of equipment had to be replaced subsequent to startup. During the progressive power ramp-up phase for the reactor, EDF ran a series of startup tests in order to obtain ASN's authorisation, followed by ASNR's authorisation, to exceed specific thresholds. The plant was fully commissioned on 3 September 2024, and was connected to the French power grid on 21 December 2024.

PUBLIC DEBATES ON THE CONSTRUCTION OF TWO EPR2S AT GRAVELINES AND BUGEY

The National Public Debate Commission (CNDP) organised public debates running from 17 September 2024 to 17 January 2025 on the construction of two "EPR2" type nuclear reactors at the Gravelines site in the Nord department. This project is part of the relaunch of the French programme for new nuclear reactors, starting with the EPR2 project planned for Penly in 2022. The CNDP also announced the organisation of public debates on the EPR2s at Bugey from late January 2025 onwards.



Flamanville EPR

Gravelines Nuclear Power Plant

VLLW DISPOSAL CAPACITY AUTHORISED

In July 2024, Andra obtained the prefectoral order for an increase in the licensed disposal capacity of Cires, which will now be able to host a total of approximately 950,000 m^3 in very low-level waste (VLLW) packages instead of the 650,000 m^3 authorised under the initial licence, with no need to increase the disposal footprint. This increase in capacity was achieved by optimising the disposal cells in various ways since the site was commissioned in 2003. Two disposal sections are now required to host 650,000 m^3, instead of the initial three sections.

This licensing authorisation for the expansion and implementation of the Acaci project is necessary under the National Radioactive Materials and Waste Management Plan (PNGMDR), and will allow the VLLW disposal facility to remain operational for an additional fifteen or so years.

Andra''s Industrial facility for grouping, storage and disposal in the Aube department

VLLW MANAGEMENT OPTIONS

Volumes of VLLW will increase in the coming decades. This trend has encouraged public authorities to reconsider some types of VLLW in view of the very low levels of radioactivity involved and recycling options, as part of a more virtuous logic. On this basis, under the 5th version of the PNGMDR, Andra, in coordination with waste producers, defined VLLW management options. These management options primarily aim to recycle certain materials such as metal waste, and plan ahead for the need for a new and centralised VLLW disposal facility. These options are analysed as part of a multi-party framework aiming to prepare the industrial plan for the management of VLLW in 2025.

VLLW

Scan this QR Code to find out more about VLLW management

Scan this QR Code to open the studies and works completed as per the PNGMDR 2022-2026 (DGEC)

SUBMISSION OF STRUCTURAL REPORTS FOR THE LLW-LL MANAGEMENT SOLUTION

As per the National Radioactive Materials and Waste Management Plan (PNGMDR) 2022-2026, Andra submitted two reports on LLW-LL management in 2024, in coordination with waste producers.

- the first report detailed the different potential long-term management options for this type of waste. These options will be discussed by a multi-disciplinary working group during 2025. This is the first step towards defining the industrial reference plan;
- the second report describes technical and safety options for the shallow disposal of some LLW-LL at the site located in the Vendeuvre-Soulaines municipalities. Andra has worked on this option for many years, and it is one of the reference solutions detailed in the first report. ASNR is currently processing this option.

LLW-LL radioactive lightning conductor head

FUTURE PUBLIC DEBATES ON THE NEXT EDITION OF THE PNGMDR

On 11 December 2024, as mandated by the French government, the CNDP decided to organise public debates on the preparation of the 6th edition of the National Radioactive Materials and Waste Management Plan (PNGMDR) for the 2027-2031 period. These public debates will be held in 2025.

LA commission nationale du débat public CNDP

MA PAROLE A DU POUVOIR

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