RÉPUBLIQUE FRANÇAISE
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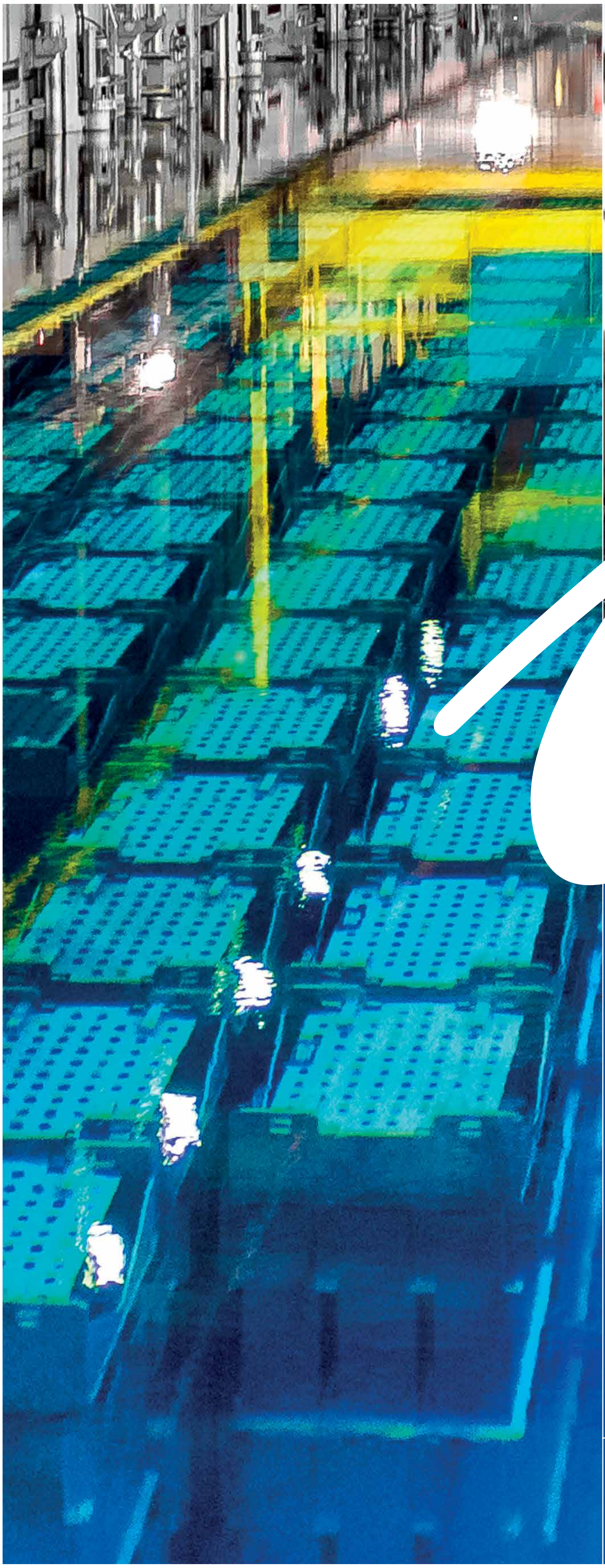
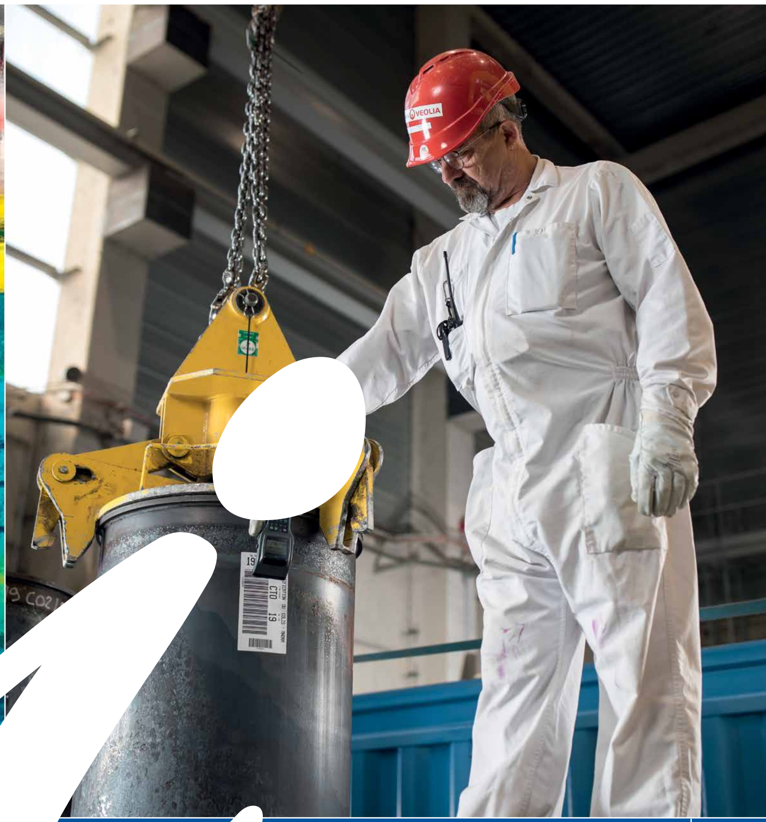
Agence nationale pour la gestion des déchets radioactifs



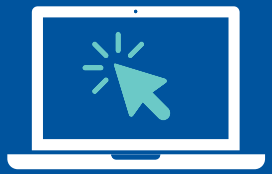


National Inventory
of Radioactive Materials and Waste

2024 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 2024 edition includes an update to the inventory of materials and waste in France on 31 December 2022. ***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.

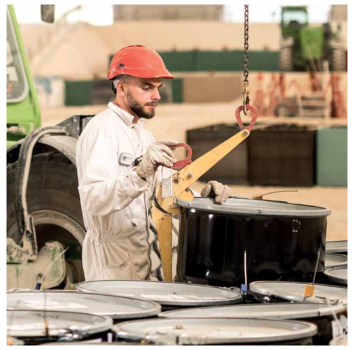
01

Radioactive materials and waste and their management methods

02

Inventory of radioactive materials at the end of 2022

03



Inventory of radioactive waste at the end of 2022

04

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

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 2022.

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 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 which has existed since the origin of the universe when atoms first formed. It is the phenomenon whereby, during their decay, some atoms - called radionuclides - expel energy in the form of radiation and/or particles. Radioactivity can also be created artificially by human activity.

NUCLEAR POWER INDUSTRY

Mainly nuclear power plants for electricity production, as well as facilities dedicated to producing nuclear fuel (mining and processing of uranium ore, chemical conversion and enrichment of uranium concentrate), reprocessing spent fuel and recycling a portion of the materials extracted from spent fuel.

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 for civil nuclear applications, in addition to research in the fields of medicine, nuclear and particle physics, agronomy, chemistry and biology, among others.

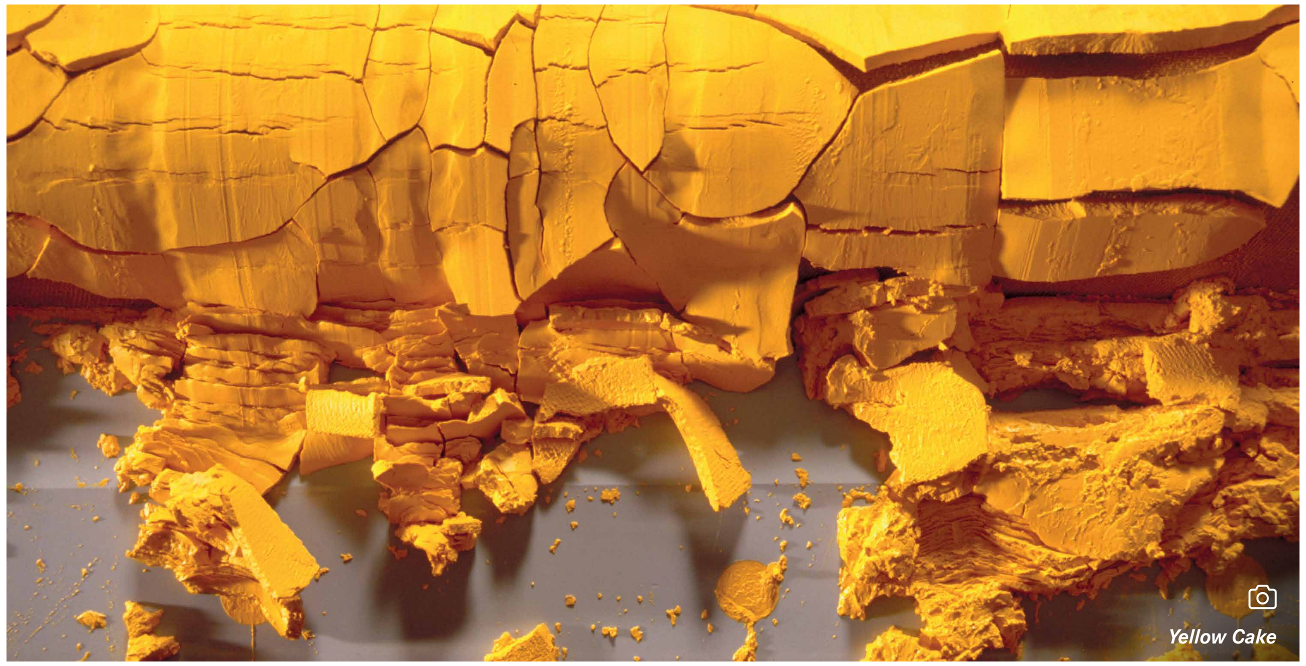
HEALTHCARE

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



Yellow Cake

NATURAL URANIUM

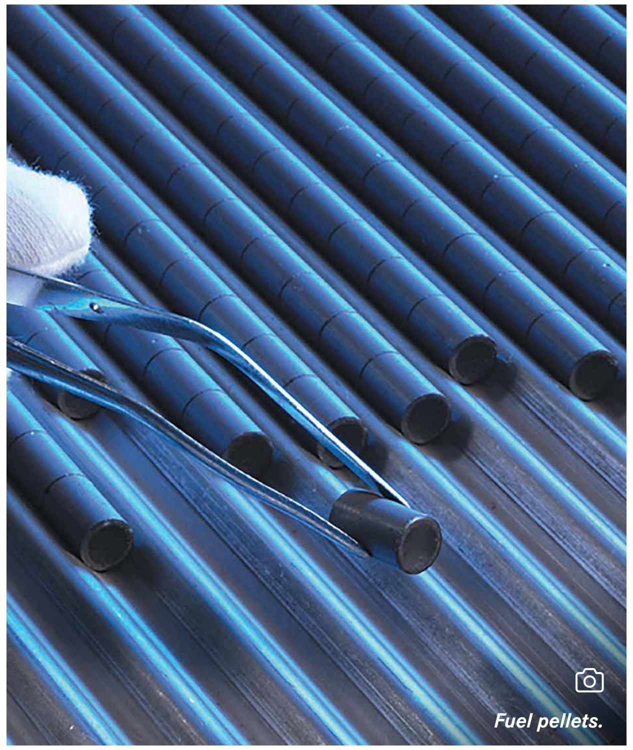
Mined natural uranium: uranium is a naturally-occurring radioactive metal found as an ore in certain rocks. It is mined, processed and formed into a solid uranium concentrate known as *Yellow Cake*. There are no longer any open uranium mines in France; all uranium is sourced from abroad.

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

Depleted uranium is obtained during the natural uranium enrichment process, transformed into a solid, chemically stable, incombustible, 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), recovered during the reprocessing of spent fuel, can be used to make new fuel.



Fuel pellets.

NUCLEAR FUEL

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

This is true for:

- **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 fuels, made from mixed uranium and plutonium powder** used in some nuclear power plants.

It may also refer to:

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

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;
- **suspended solids**, from the processing and neutralisation of chemical effluents, comprising residual rare earths that will be re-used.

Madagascar monazite.

Radioactive material management methods

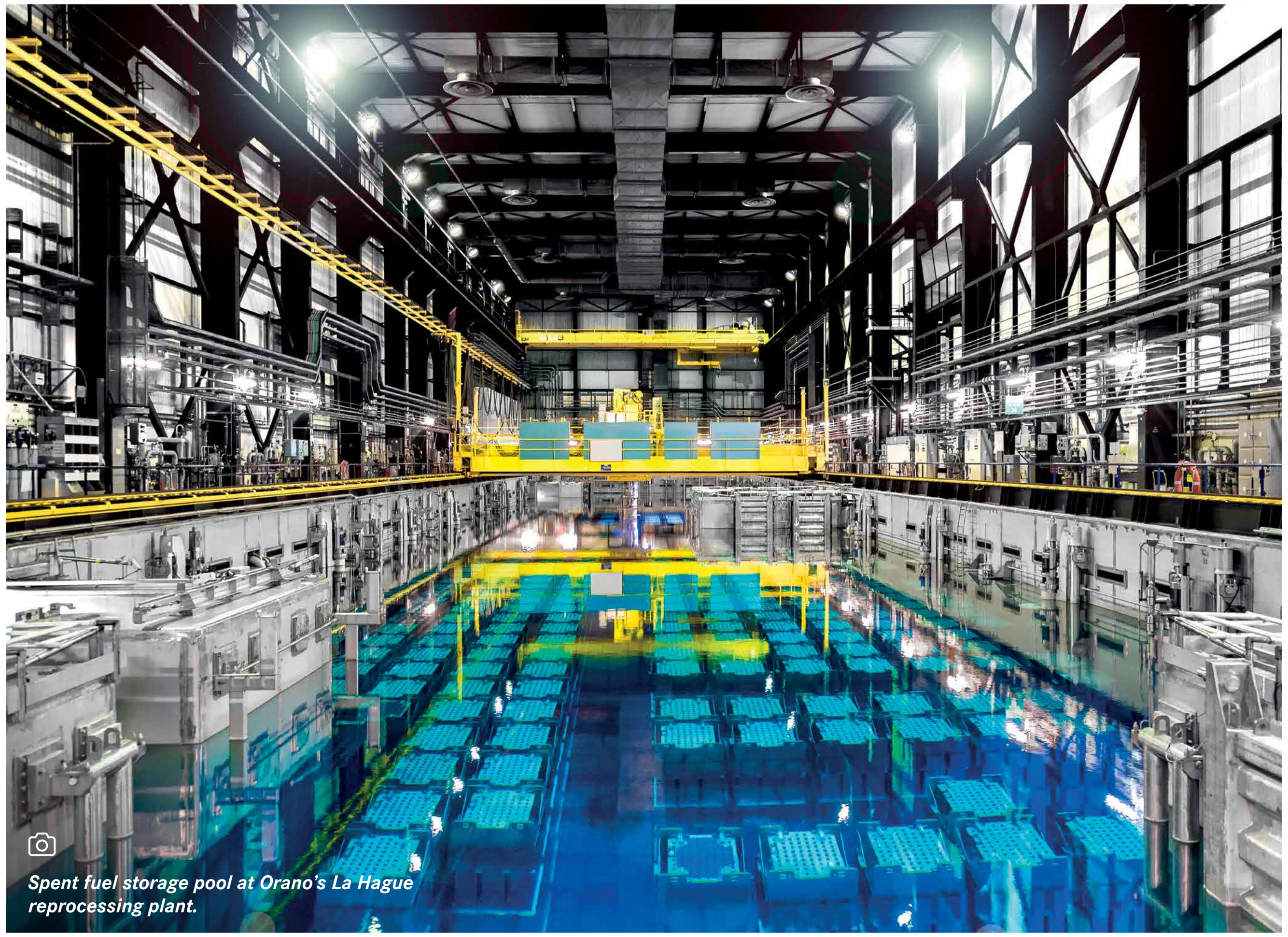
Radioactive materials are stored in facilities suited to their characteristics until they can be used or reused. For some materials, such as plutonium from reprocessing spent uranium oxide fuel, a process enabling their reuse in industry has already been in place for more than thirty years.

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 Orano's La Hague reprocessing plant.

RADIOACTIVE WASTE AND ITS 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.

Radioactive waste categories and associated management solutions

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	VSLW Management through radioactive decay	VLLW Surface disposal facility (Cires - Industrial facility for grouping, storage, and disposal)	
Low-level waste (LLW) between a few hundred Bq/g and one million Bq/g		LLW-SL Surface disposal facility (Aube and Manche disposal facilities)	LLW-LL Planned near-surface disposal facility
Intermediate-level waste (ILW) in the range of one million to one billion Bq/g			ILW-LL Deep geological disposal facility under development (Cigeo project)
High-level waste (HLW) on the order of several billion Bq/g	Not applicable	HLW Deep geological disposal facility under development (Cigeo project)	

* Half-life of the radioactive elements (radionuclides) contained in the waste.
** Radioactive waste activity level.

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

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

- very short-lived waste, which contains radionuclides with a half-life shorter 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 of more than 31 years.

ACTIVITY LEVEL

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 gramme;
- low-level, if the activity level is between a few hundred becquerels per gramme and one million becquerels per gramme;
- intermediate-level, if the activity level is between one million and one billion becquerels per gramme;
- high-level, if the activity level is about several billion becquerels per gramme.

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 formation 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 residues 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 formation under development[1]

This primarily includes waste from the metal structures surrounding the fuel (hulls and end fittings), which come from the reprocessing of spent fuel[2] and, to a lesser extent, technological waste from the operation and maintenance of nuclear facilities, waste from the treatment of liquid effluents (bituminised sludge) and activated waste after a period in a nuclear reactor.

Hulls from the zirconium alloy cladding covering fuel pellets.

LLW-LL LONG-LIVED LOW LEVEL WASTE

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

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 21), and operating waste from the La Hague reprocessing plant.

Graphite sleeve with wire locks.

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

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

This principally comes from operations (the processing of liquid effluent or filtration of gaseous effluent, etc.), maintenance (clothing, tools, gloves, filters, etc.) and the dismantling of nuclear plants, fuel cycle facilities and research centres. A small portion of it also comes from medical research.

Waste from using 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 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 waste from dismantling

VSLW VERY SHORT-LIVED WASTE

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

This mostly comes from the medical and research sectors.
Medical waste may constitute liquid or gaseous effluent, or contaminated solid or liquid waste generated by the use of radionuclides in this field.

Decay tanks.

Activity level.
Time needed for 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.

1 Cigeo project, whose licence application was filed in January 2023.
2 Reprocessing spent fuel makes it possible to separate recoverable materials (plutonium and uranium) from the final waste that constitutes HLW and ILW-LL. These materials can be recycled to produce new fuel. The waste is stored at reprocessing sites pending disposal.
3 Disposal facilities in the Aube (CSA) and Manche (CSM).
4 In view of their very low activity, time is not a criterion in the classification of this waste category.
5 Industrial facility for grouping, storage and disposal in the Aube (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.

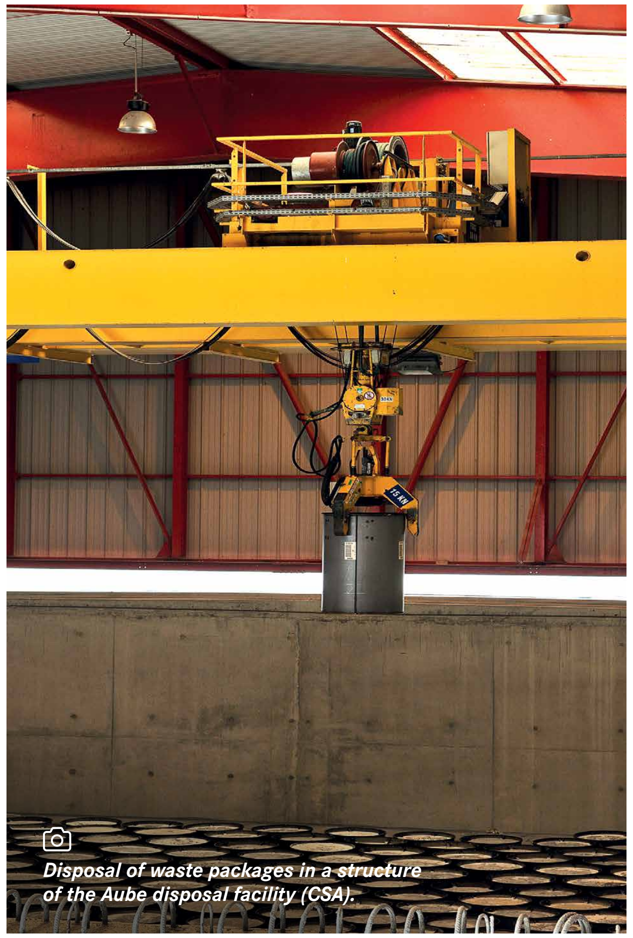
- surface disposal facilities: two facilities operated by Andra in the Aube department have been used since 2003 for the disposal of very low-level waste (VLLW) and since 1992 for the disposal of low- and intermediate-level waste, mainly short-lived (LILW-SL). There is also the Manche disposal facility,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

The initial choice of management solution depends on the waste characterisation studies and the processing and conditioning methods. The final decision is based on the characteristics of the produced package.

Disposal

The disposal of radioactive waste is the operation consisting in placing these substances in a facility that has been specially designed to hold them on a potentially permanent basis [...], without the intention to retrieve them at a later date.

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



Disposal of waste packages in a structure of the Aube disposal facility (CSA).

In the case of very short-lived waste (VSLW), radioactivity decreases significantly within a few months, or even a few days or hours. It is therefore stored on site until radioactive decay has occurred, then disposed of using the conventional waste solution suitable for its physical, chemical and biological characteristics.

Lastly, certain items of radioactive waste cannot yet be treated and conditioned in a way that makes them suitable for an identified management solution, generally due to their special 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

Production of radioactive materials and waste by the nuclear power sector in France

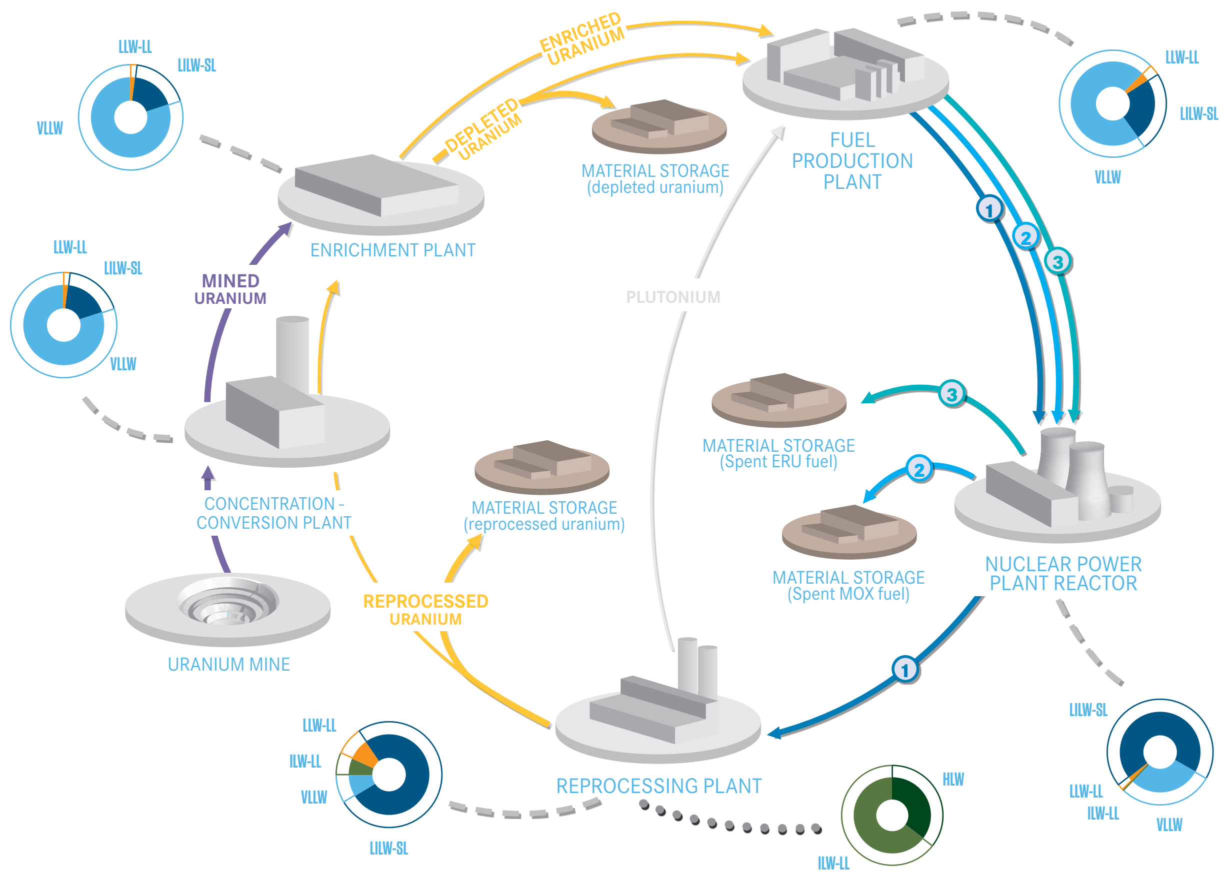
Most radioactive materials and waste produced by the nuclear power sector result from the operation of the facilities that manufacture, use and then reprocess nuclear fuel.

This includes both the operation of the facility and its dismantling.

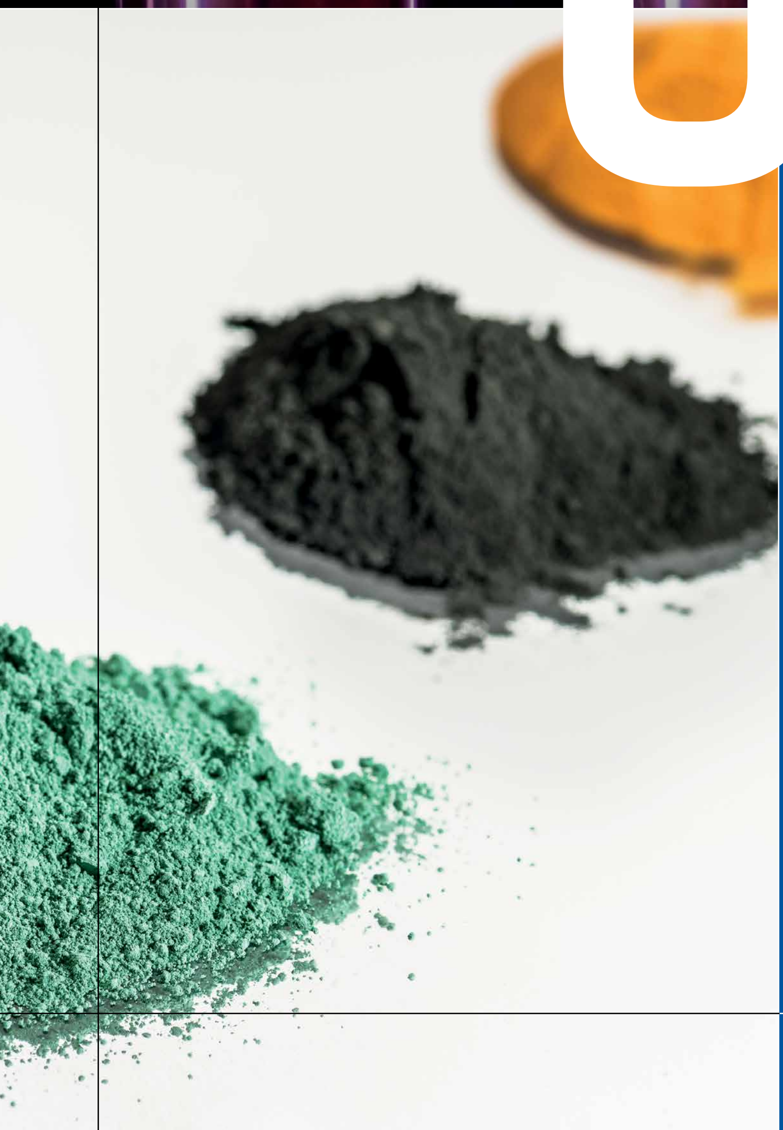
Most of the waste produced by the operation of these plants is taken to Andra's industrial facilities in the Aube (Cires and CSA). Intermediate-level long-lived waste (ILW-LL) and high-level waste (HLW) are also produced and stored at the production sites, pending the creation of a disposal facility designed to receive it: Cigeo. 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). To improve material recycling, research is under way into the potential recovery of the materials contained in spent MOX and ERU fuel assemblies in Pressurized Water Reactors (PWR) and, *ultimately*, in Fast Neutron Reactors (FNR).



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 2022
Residual waste after reprocessing spent fuel - Inventory at the end of 2022



02

End 2022 inventory of radioactive materials

MATERIALS RECORDED

Andra performs an annual inventory of all France-wide radioactive materials on 31 December every year, based on the information provided by the holders of these 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 Institute for Radiological Protection and Nuclear Safety (IRSN) in accordance with Article R. 1333-154 of the French Public Health Code.

For fissile materials, the material holders are organisations involved in the nuclear fuel cycle, all operators of nuclear reactors (nuclear power, defence and research facilities) and chemical industry stakeholders that hold radioactive materials as part of their activities (e.g. mining rare-earth metals).

The foreign materials in France referred to in Article L. 542-2-1 of the Environmental Code are also counted in the overviews. These foreign materials are intended to be returned to the original owner countries.

Unit of measurement

The unit used to present the quantities of radioactive materials is the tonne of heavy metal (tHM), a unit which represents the quantity of uranium, plutonium or thorium contained in the materials, except in the case of fuel for defence purposes, which is expressed in 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 volume" (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 2022, 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 RADIOACTIVE MATERIALS (IN tHM, EXCEPT SPENT FUEL FOR DEFENCE PURPOSES, WHICH IS INDICATED IN TONNES OF FUEL ASSEMBLIES)

NO.	Material category	End of 2022	2022/2021 trend	Foreign share
1	ENU fuels before use	874	+141	-
2	ENU fuels in use in nuclear power plants	3,490	-480	-
3	Spent ENU fuels pending reprocessing	11,500	+300	0.3%
4	ERU fuels before use	-	-	-
5	ERU fuels in use in nuclear power plants	-	-	-
6	Spent ERU fuels pending reprocessing	628	-2	-
7	Mixed uranium-plutonium fuels before use or under manufacture	25	+14	-
8	Mixed uranium-plutonium fuels in use in nuclear power plants	190	-25	-
9	Spent mixed uranium-plutonium fuels pending reprocessing	2,460	+70	-
10	Non-irradiated mixed uranium-plutonium fuel scrap awaiting reprocessing[1]	359	+22	-
11	Non-irradiated uranium fuel scrap pending reprocessing	-	-	-
12	Spent FNR fuels pending reprocessing	125	-	-
13	Research reactor fuels before use	0.06	-	-
14	Fuel in use in research reactors	1	-	-
15	Other civil spent fuel	61	-	2%
16	Spent fuel for defence purposes	203 tonnes	+1 tonne	-
17	Non-irradiated separated plutonium, in all its physical-chemical forms	70	+5	20%
18	Mined natural uranium, in all its physical-chemical forms	35,900	-1,900	-
19	Enriched natural uranium, in all its physical-chemical forms	3,540	+250	-
20	Enriched uranium from spent fuel reprocessing, in all its physical-chemical forms[2]	22	+22	-
21	Uranium from spent fuel reprocessing, in all its physical-chemical forms[2]	34,600	+400	8%
22	Depleted uranium, in all its physical-chemical forms	331,000	+7,000	-
23	Thorium, in the form of nitrates and hydroxides	8,510	-	-
24	Suspended particulate matter (by-products from processing of rare earth ore)	5	-	-
25	Other materials[3]	70	-	-

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 2021, can be explained by:
- one year of operation of nuclear power plants, in line with the recorded production capacities of the fuel cycle plants;
- reduced production at the Melox plant due to operating problems, offset by additional ENU fuels;
- the recovery of the ERU sector expected for 2023, implying the enrichment of reprocessed uranium during the year 2022.

In the current nuclear power generation context, reprocessed radioactive materials (plutonium and uranium generated from reprocessed spent fuel) are intended for use as fuels, while other materials from the French fuel cycle are stored pending recovery.

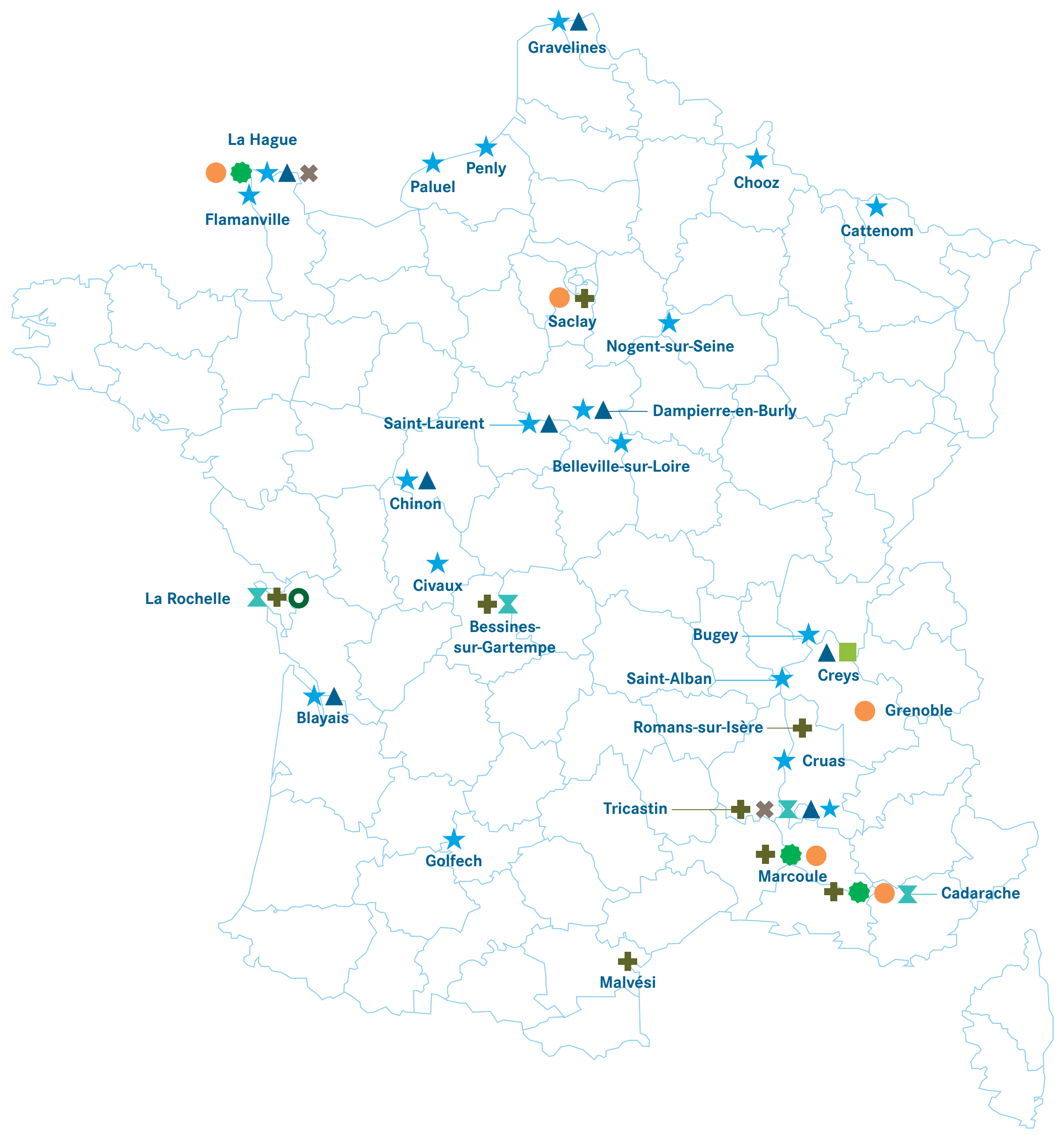
1 The residue from non-irradiated mixed uranium-plutonium fuel awaiting reprocessing will eventually be reprocessed and recycled in nuclear power reactors.

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".

FOCUS

Location of radioactive materials on French territory as of 31/12/2022



- 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

End 2022 inventory of radioactive waste

Andra performs an annual inventory of France-wide radioactive waste as at 31 December of every year, based on the information provided by the 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 BY MANAGED BY ANDRA

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

For overview purposes, a uniform counting unit has been adopted: the “conditioned equivalent volume”.

For waste that has not yet been conditioned, the conditioned equivalent volume is estimated.

In the specific case of the Cigeo 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 an immobilisation or embedding material.

Disposal of LILW-SL waste packages at the Aube disposal facility

OVERVIEW AND DIFFERENCE IN VOLUMES (IN m³) FOR WASTE ALREADY DISPOSED OF OR DUE TO BE MANAGED BY ANDRA

Category	Inventory at the end of 2022	2022/2021 trend
HLW	4,420	+100
ILW-LL	39,600	+100
LLW-LL	104,000	+1,000
LILW-SL	989,000	+7,000
VLLW	654,000	+21,000
DSF	344	+40
Total	~ 1,790,000	+30,000

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

The differences between the quantity of waste at the end of 2021 and that at the end of 2022 can be accounted for by ongoing waste generation for all categories.

OVERVIEW OF THE VOLUMES (m³) OF WASTE AT PRODUCER/HOLDER SITES DISPOSED OF AT ANDRA FACILITIES AT THE END OF 2022

Category	Total	At producer/ holder sites	Disposed of at Andra facilities	Capacity of existing disposal sites
HLW	4,420	4,420	-[1]	-
ILW-LL	39,600	39,600	-[1]	-
LLW-LL	104,000	104,000	-[1]	-
LILW-SL	989,000	90,000	899,000	1,530,000
VLLW	654,000	203,000	451,000	650,000
DSF	344	344	-[1]	-
Total	~ 1,790,000 m³	~ 441,000	~ 1,350,000	2,180,000
		25%	75%	

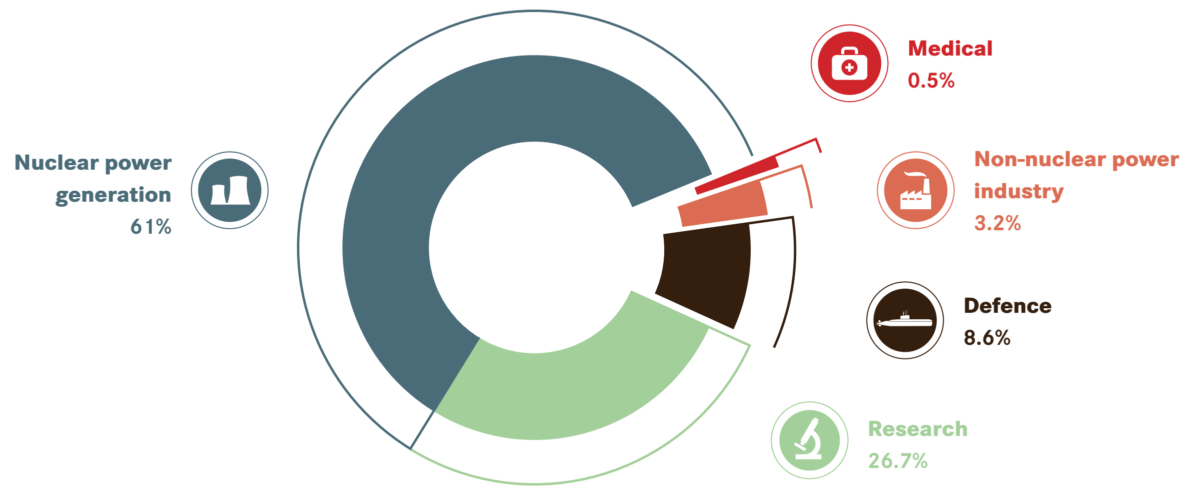
LILW-SL and VLLW waste is stored at the production site for retrieval, conditioning or removal to Andra disposal facilities.

VLLW waste at Cires

VLLW waste is disposed of at the Cires facility. By the end of 2022, this facility had reached approximately 69% of its licensed disposal capacity of 650,000 m³. In its current configuration, Cires will not be sufficient to dispose of the VLLW waste 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 over 900,000 m³, without modifying the current surface area of the disposal area and while maintaining the same safety level (Acaci project).
If licensed, this increase in capacity will allow Cires to operate for an extra ten years or so, i.e. up to around 2040.

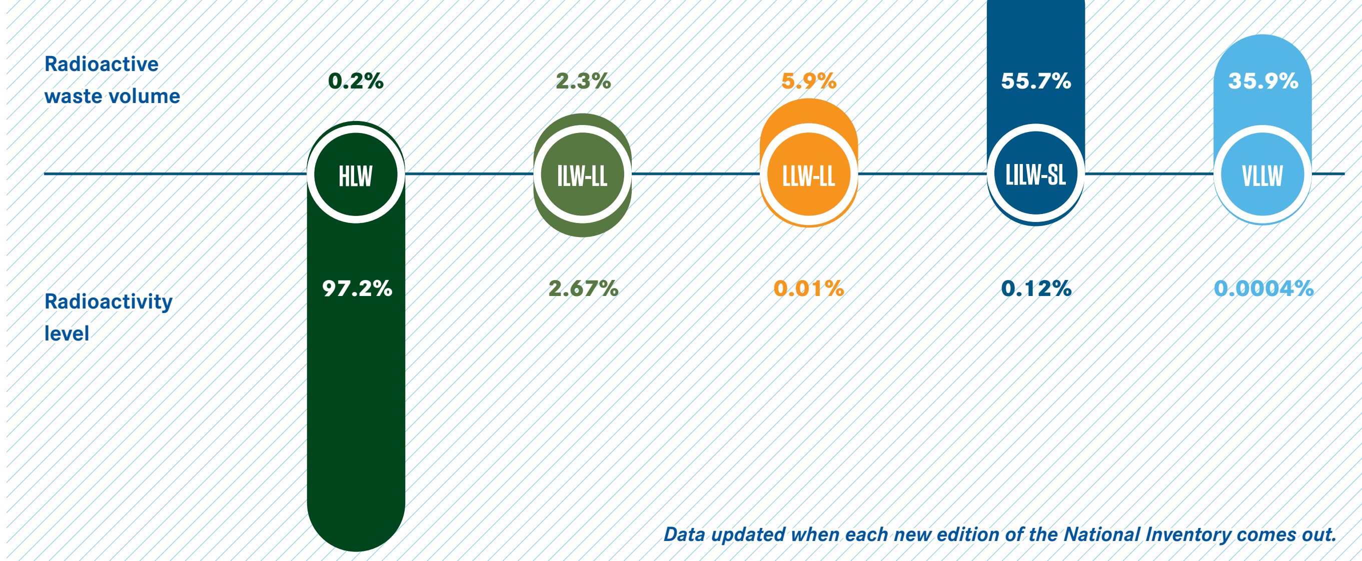
END-2022 BREAKDOWN OF WASTE VOLUMES BY BUSINESS SEGMENT (CONDITIONED EQUIVALENT) ALREADY DISPOSED OF OR DUE TO BE MANAGED BY ANDRA



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

1 *This waste has not yet been disposed of: the disposal solution for HLW and ILW-LL (Cigeo) 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.*

THE FOLLOWING BREAKDOWN OF VOLUMES AND RADIOACTIVITY IS TAKEN FROM THE 2023 EDITION OF THE *NATIONAL INVENTORY*.



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

WASTE NOT INTENDED TO BE MANAGED BY ANDRA

Very short-lived waste

OVERVIEW AND DIFFERENCE IN VOLUMES (m³) FOR VERY-SHORT-LIVED WASTE MANAGED BY DECAY

Category	Inventory at the end of 2022	2022/2021 trend
VSLW	2,476	+310

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 under way 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).

OVERVIEW AND FORECAST VOLUMES OF RESIDUAL URANIUM CONVERSION TREATMENT STORED AT THE MALVÉSI SITE (m³)

	Inventory at the end of 2022	2022/2021 trend
Settling ponds	9,600	-29,400
ECRIN facility *(ex legacy RTCU)*	270,000	+12,000
Evaporation ponds *(ex nitrated effluents)*	372,000	-

These volumes are not included in the overviews.

The variation recorded is due to the detection of an increase in pond volume (+11 000 m³ due to the deformation of the shape of the bottom of pools B5 and B6) and sludge densification operations during their transfer from pools B5 and B6 to the PERLE disposal site built at the ECRIN basic nuclear installation.

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 or near the perimeter of nuclear facilities or plants.** The corresponding activity is of the order of a few becquerels per gramme (several thousands of tonnes).
- **Tailings from processing uranium ores** at former mining sites. These are long-lived tailings with an activity level comparable to that of VLLW (approximately 50 million tonnes).

Former Bellezane mine.

- **Waste containing naturally-occurring radioactive material (NORM) managed through on-site disposal.** This waste is generated by the processing of raw materials that contain naturally-occurring radionuclides, but are not used for their radioactive properties. Much of this 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.

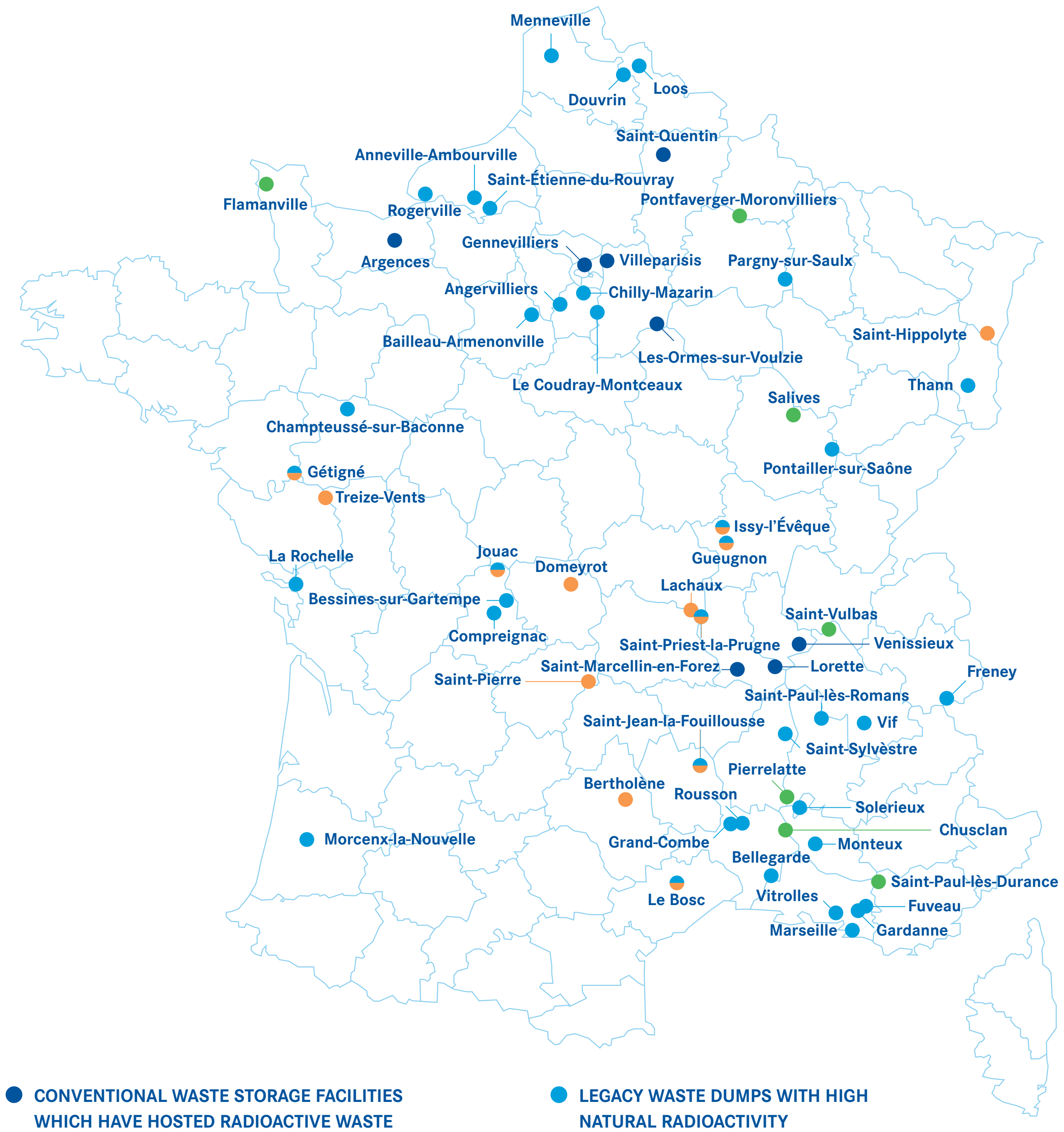
- **Waste disposed of in conventional waste disposal facilities** (excluding waste which is naturally highly radioactive). Some of these facilities have received waste with low quantities of radioactivity, around a few becquerels per gramme. This is mainly sludge, soil, industrial residues, rubble and scrap from conventional industry or from the civilian or military nuclear industry. This practice has not been permitted since 2004.
- **Defence disposal facilities in French Polynesia**: France carried out nuclear experiments in the South Pacific, in French Polynesia, between 1966 and 1996. The waste produced by these experiments and by the decommissioning of the associated facilities was disposed of on the spot in shafts 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 at sea.

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.

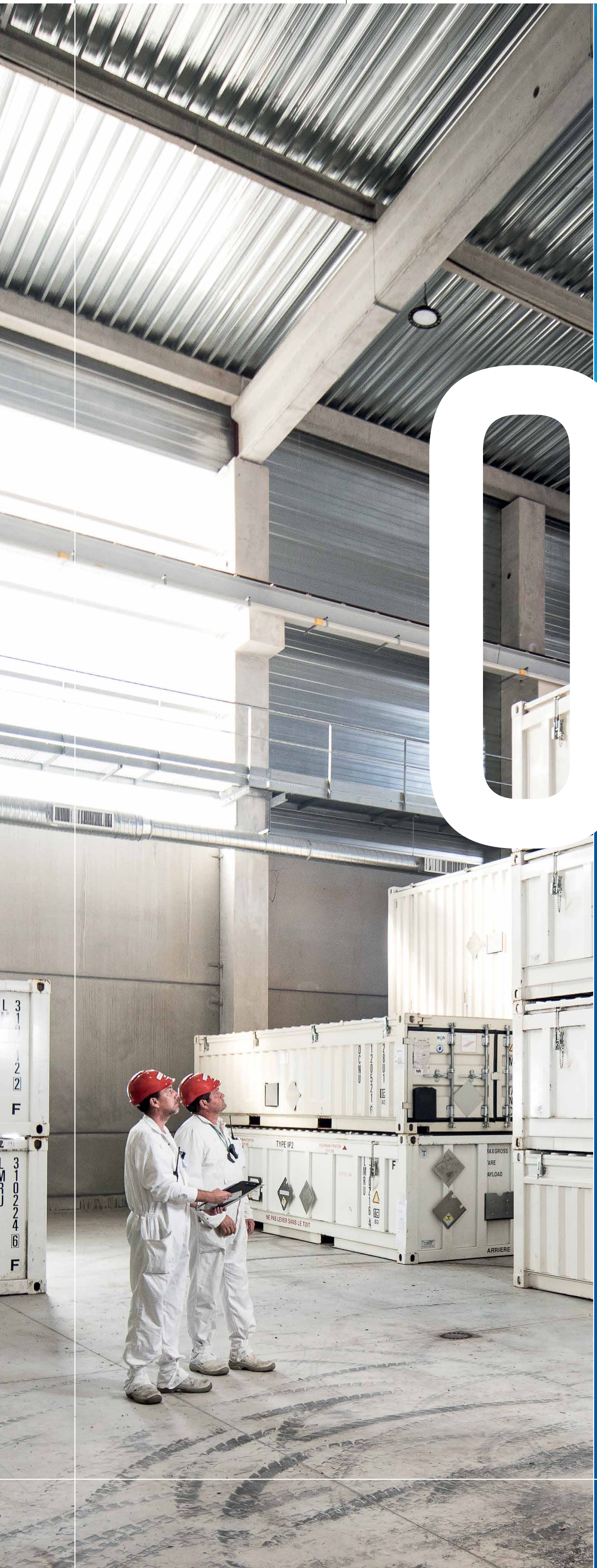
FOCUS

Locations of mine waste and tailings subjected to specific management methods (mainland France)



- CONVENTIONAL WASTE STORAGE FACILITIES WHICH HAVE HOSTED RADIOACTIVE WASTE
- LEGACY WASTE DUMPS WITH HIGH NATURAL RADIOACTIVITY
- LEGACY WASTE DISPOSAL FACILITIES WITHIN OR CLOSE TO BASIC AND SECRET BASIC NUCLEAR INSTALLATIONS
- URANIUM TAILINGS

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.

To do this, Andra prepares assessments and forecast inventories, based on reports from the nuclear power industry, whether they are waste producers and/or holders or waste 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 to coordinate the management of radioactive materials and waste, 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 national energy strategy. These scenarios cover a range of contrasting energy policy developments: the continuation of nuclear power generation using different fuel reprocessing strategies, or the cessation of nuclear power generation.

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* is completed with a chapter on "Prospects" describing:

- elements 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 are currently active: 56 reactors in use and the EPR reactor at Flamanville (due for commissioning mid-2024);
- a reactor operating life equal to 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);
- the renewed use of reprocessed uranium (RepU) for manufacturing fuel;
- the 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;
- the 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, rate of deployment and type of 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 of spent fuel from nuclear power plants, of any type: above types, ENU fuels, but also 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 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	218,000 m³	218,000 m³	218,000 m³	218,000 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

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.
* ***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.***

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.

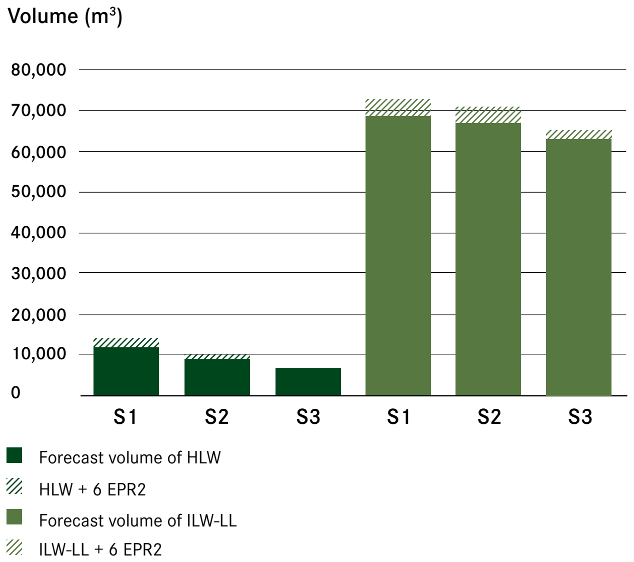
It is important to take note that, regarding the three scenarios including the renewal of the nuclear fleet, the forecast estimates only relate to waste produced by current power plants, and do not take account of any waste or materials generated by the possible future replacement reactors mentioned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

PROSPECTS

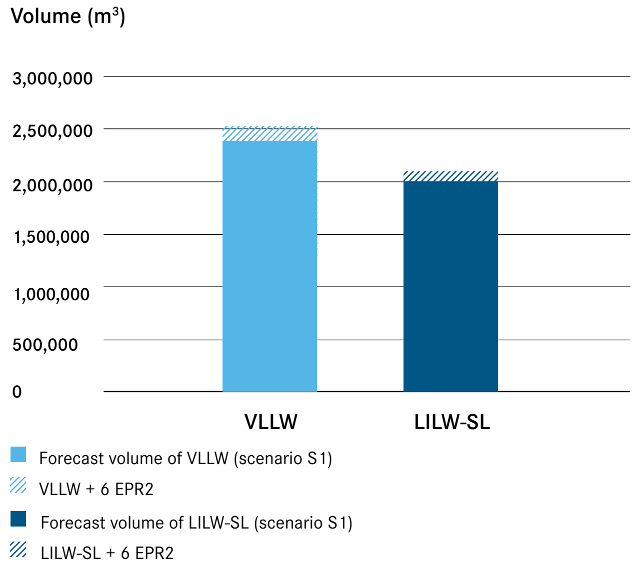
Estimated volumes of radioactive waste produced by the operation of six EPR2S

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.

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



If we compare with the forecast 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:

- in terms of HLW, depending on the fuel recycling strategy, around 16% (multi-recycling) or 11% (mono-recycling). If reprocessing is ceased, 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 radioactive waste is produced by operational EPR2 reactors.

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

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 ASN'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.

CONDITIONED VOLUME OF OPERATING WASTE FOR ONE REACTOR IN ONE YEAR

Category	
HLW	About 3 m³
ILW-LL	About 3 m³
LILW-SL	Between 110 and 150 m³
VLLW	Between 60 and 80 m³

IMPACT OF 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, SMR or AMR, 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, SMR and AMR 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*

Nuclear fuel assembly

Disposal of packages of very low level waste at the Industrial Facility for Nuclear Waste Grouping, Storage and Disposal.

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Comprehensive data on radioactive materials and waste is available at inventaire.andra.fr

inventaire.andra.fr, the reference website for all France-wide radioactive materials and waste.