Overview of Foreign Practices of SNF and RW Management

Moscow 2022
National Operator for Radioactive Waste management FSUE

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Belgium

The strategy of spent fuel management

A moratorium on the processing of spent nuclear fuel (SNF) has been imposed since 1993, the official policy of SNF handling has not yet been approved (according to current plans, SNF is subject to direct burial without preliminary processing).

Administrative authorities

<table>
<tr><td>Government agency in charge of SNF and RAW (radioactive waste) management</td><td rowspan="2">ONDRAF/NIRAS — Belgian National Agency for Radioactive Waste and enriched Fissile Materials Management acting under the jurisdiction of Ministry of Economy, Small and Medium Enterprise and Energy (www.ondraf.be, www.economie.fgov.be).</td></tr>
<tr><td>Organization responsible for the radioactive waste disposal project (project development, R&D, licensing, construction and operation).</td></tr>
</table>

Regulatory bodies

The State Regulation Body on the safety and security in the field of atomic energy	FANC — Federal Agency for Nuclear Control (www.fanc.fgov.be)
State regulatory agency in the area of environment protection	Federal Public Service responsible for the Healthcare system, Safety of Production and Marketing of Commodities and Environmental Protection (www.health.belgium.be)

1. The history of Belgian nuclear industry generation and its main capacities

The development of peaceful nuclear development in Belgium began after the end of World War II. Belgium led the development of "peaceful atom" technologies in the early 1960s. For several years, Belgium's nuclear industry has been involved almost in all activities within the nuclear fuel cycle.

Belgium has become one of the founding countries of the European Center for Nuclear Research[1], (CERN) – the world's largest laboratory of high-energy physics, studying the interaction of elementary particles and atomic nuclei at collision energies. In addition, the Kingdom of Belgium is the country that originally signed the Treaty Establishing the European Atomic Energy Community[2].

The Belgian Centre for Nuclear Research (SCK CEN)[3] was established in 1952. After the commissioning of the BR1 research reactor and the material testing reactor BR2 in the city of Mol

[1] The official website of European Center for Nuclear Research, (CERN), URL: https://home.cern.
[2] Establishment agreement of European Atomic Energy Community (Euratom) from March 25, 1957, URL: https://docs.cntd.ru/document/901771693.
[3] The official website of ehe Belgian Centre for Nuclear Research SCK CEN, URL: https://www.sckcen.be/en/about-sck-cen.

[3] The official website of the Belgian Centre for Nuclear Research SCK CEN, URL: https://www.sckcen.be/en/about-sck-cen.

BR3 became the first pressurized water reactor in Europe (PWR)[4]. BR3 first entered industrial use on August 19, 1962 and was connected to the power grid on October 25 of the same year. June 30, 1987 BR3 also became the first PWR in Europe to be stopped.

The country's first commercial nuclear power plant was commissioned in 1974: the Doel nuclear power plant - in Flanders (northern Belgium), a year later the Tihange nuclear power plant was launched - in Valonia (southern Belgium). Over the past five decades seven reactors in the country have generated nearly half of Belgium's entire electricity flow[5], summing up to combined 5,942 MW.

SCK CEN coordinates IAEA Support Programme on Safeguards in Belgium. The Belgian Centre for Nuclear Research also performs most of the Support Program's tasks, related to the development of safeguards approaches for geological repositories and the MYRRHA-driven system. In excess to that SCK CEN provides its experts and facilities to countercheck IAEA courses content and pertinent equipment to conduct better safeguards inspections according to Nuclear Weapons Non-Proliferation Treaty and its Additional Protocol.

NPP	Reactor title	Type of the reactor	Capacity (MW)	Commissioning start date (year)	Decommissioning date (year)
Mol	BR-3	PWR	10	1962	1987
Doel	Doel 1	PWR	445	1974	2025
	Doel 2	PWR	445	1975	2025
	Doel 3	PWR	1006	1982	2022
	Doel 4	PWR	1038	1985	2035
Tihange	Tihange 1	PWR	962	1975	2025
	Tihange 2	PWR	1008	1982	2023
	Tihange 3	PWR	1038	1985	2035

Table № 1. Belgian nuclear power plants

2. Legislative regulatory framework of radioactive waste and spent fuel safe management in Belgium

System of RAW and SNF management in Belgium meets the requirements of international and European conventions, treaties and protocols, signed by the country, along with the requirements of European directives, rules and decisions, paying due consideration to the internationally recommended principles and standards.

[4] SCK CEN Infrastructure, «BR3 – Learning experience for dismantling projects», URL: https://www.sckcen.be/en/about-sck-cen/corporate-information/infrastructure.
[5] Nuclear Industry in Belgium (as on March, 2022), World Nuclear Association, URL: https://world-nuclear.org/information-library/country-profiles/countries-a-f/belgium.aspx.

Legislative regulatory framework of RAW and SNF safe management in Belgium is divided into three units: nuclear security, nuclear safety and radiation protection; RAW and SNF management; licensing.

Legislative regulatory acts in the field of population and environment protection from ionizing radiation risks: Table № 2[6].

Statutory instrument	Subject
The Law of 15 April 1994 on "the protection of the population and the environment against the hazards of ionizing radiation and on the Federal Agency for Nuclear Control" constitutes the basic law that sets out the basic elements for protecting the workers, the public and the environment against the adverse effects of ionising radiation. The same law also creates the FANC as the Safety Authority.	• establishes Federal Agency for Nuclear Control (FANC); • indicates main tasks and roles of Federal Agency for Nuclear Control.
The Royal Decree of 20 July 2001 provides the basic nuclear safety and radiological protection regulations pertaining to population and environment against the hazards of ionizing radiation.	• stipulates licensing practice for RAW of class I management system • regulates the scheme of units for conditioning and storage of RAW; • sets basic standards for protection against the hazards of ionizing radiation; • contains a number of paragraphs concerning RAW; • enables operators to request permission from Federal Agency for Nuclear Control (FANC) on waste discharge, elimination of waste, processing or recycling of liquid and solid RAW; • sets the concept of operating with natural radioactive materials (NORM).
Royal Decree of March 24, 2009	• regulates import, export and transit of radioactive substances.
Royal Decree of November 30, 2011 on the safety requirements for nuclear facilities (hereafter referenced as "SRNI-2011").	• the decree administers the rules of safety management of various nuclear installations, including nuclear power plants and waste management and disposal facilities; This Royal Decree incorporates all the WENRA RHWG (Reactor Harmonization Working Group) reference levels into the Belgian regulations. This Royal Decree has a wider scope than the NPPs, as some generic reference levels are applicable to other nuclear facilities (for example, the obligation to proceed to periodic safety reviews, to maintain a safety analysis report, to have an integrated management

[6] A complete list of Belgian regulations, relating to radiation protection and nuclear safety can be found at the website of JURION, FANC, URL: https://www.jurion.fanc.fgov.be/jurdb-consult/consultatie?language=fr.

	system) including waste management and disposal facilities. A section for decommissioning of nuclear installations requirements is included. A specific chapter on the safety requirements for waste and spent fuel storage facilities has been added on May 29th, 2018.
The Royal Decree of October 17, 2003 defines the nuclear and radiological action plans in case of emergency in Belgium.	• the Decree also presents notification (of the Government by operator) criteria in case of emergency occurring; • submits the action plan provisions on in case of a nuclear or radiological crisis; • emergency declaration lies under the competence of the Secretary of State for Home Affairs and the subordinate services: Federal State Service of the Interior (FOD), the Main Directorate of Civil Security and the Main Directorate of the Crisis Center
The Royal Decree of March 1, 2018 (replaces the Royal Decree of October 17, 2003)	• submits the provisions of the nuclear and radiological emergency plan (Nuclear emergency plan, NEP) effective at the territory of Belgium.

Table № 2. Legislative regulatory acts in the field of Statutory instrument on the protection of the population and the environment against the hazards of ionizing radiation

There are six fundamental legal acts enacted in Belgium, regarding legal requirements to the RAW and SNF management system (see table № 3). System of radioactive waste (RAW) and enriched fissile materials (EFM) management is governed by specific legal framework, that defines the competence and tasks of Belgian Agency for RAW and EFM – ONDRAF/NIRAS. Belgian Agency for RAW and EFM was created by the relevant law, dated August 8, 1980. Then Belgian authorities decided to delegate control over the RAW management system to a single body under civilian oversight to ensure public’s interests prevalence in all the decisions made in the area of RAW management.

Statutory instrument	Subject matter
The Law «ONDRAF/NIRAS» The law dated August 8, 1980 (article 179) on the budgetary programmes for 1979-1980 (as amended in particular by the laws of December 29, 2010 and June 3, 2014), which, in particular:	•creates ONDRAF/NIRAS (§ 2 — hereafter the “ONDRAF/NIRAS Law”); • assigns it various missions (in particular, the inventory and management of radioactive waste, including non-reprocessed spent fuel declared as waste, and missions relating to decommissioning) (§ 2); • recognizes the need for societal integration of a disposal facility at the local level and allows ONDRAF/NIRAS to create a mid-term Fund for covering the societal costs of integration; • stipulates that national policies for the management of radioactive waste and spent fuel are to be established and maintained by Royal Decree, debated in the Council of Ministers, on ONDRAF/NIRAS’ proposal and after FANC’s opinion.

Royal Decree ONDRAF/NIRAS dated March 30, 1981	determines the missions and setting out the functioning rules for the public body for the management of radioactive waste and enriched fissile materials (hereafter the “ONDRAF/NIRAS Royal Decree”), this way implementing the ONDRAF/NIRAS Law.
Ministerial letter dated February 10, 1999	• asserts the provisions, concerning the General Rules for the establishment of acceptance criteria by ONDRAF/NIRAS for conditioned and non-conditioned waste
Royal Decree dated November 18, 2002	• decrees governing of the technologic level of storage, treatment and conditioning facilities for RAW by the instrumentality of ONDRAF/NIRAS • the Decree concerns the matter of facilities and equipment (including methodologies), designed for RAW radiological characterization
Decision of the Council of Ministers of June 23, 2006	• decrees, that the long-term management approach for the RAW of category A should become surface disposal method at the Dessel municipal territory, as a part of a project, incorporating technical and societal aspects, and developed through a participative process

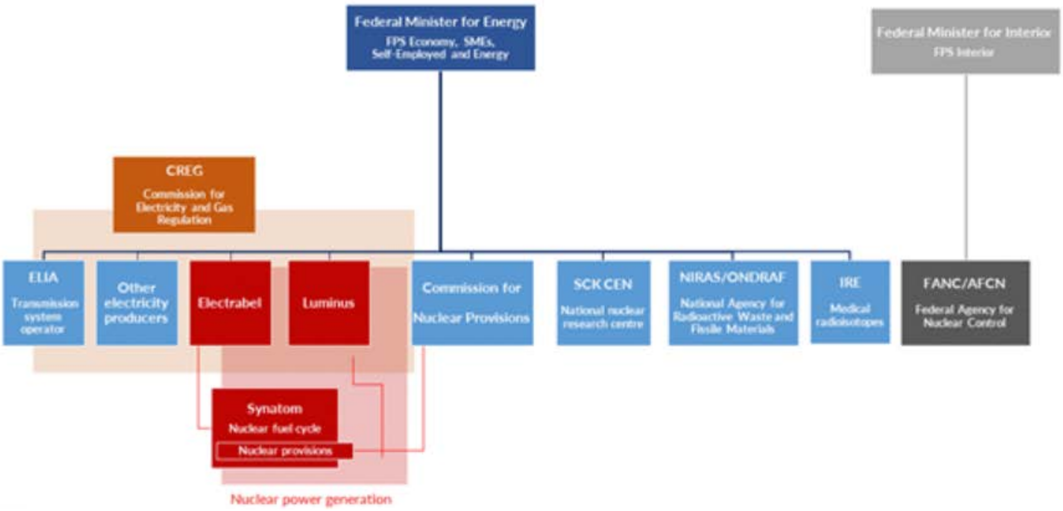
Table № 3. Statutory instrument on the RAW and SNF management system

The licensing for RAW and SNF management system in Belgium provides, that each facility, where activities related to use of radioactive substances are carried out is subject to a preliminary license for the construction and operation, issued by the competent authority. The licensing procedure has to be followed is described in GRR-2001 and it varies according to preassigned class of a facility, ranging from I to IV. Facilities also containing radioactive substances in amounts or concentrations that do not exceed the exclusion levels, set out in

GRR-2001, are classified as facilities of Class IV. An application for a license is submitted to the Federal Agency for Nuclear Control (FANC). Depending on the class (I – IV), it is referred for consultation at certain authorities, such as local: municipal or provincial, Scientific Council on Ionizing Radiation (FANC) and European Commission. Regulatory body evaluates an application for a license and submits its opinion to FANC, whereafter Agency issues a facility construction or operation license outright. A license at an object of Class I is an exception, as such licenses can be issued only by a special Royal Decree (see Table № 4. Licensing system, assigned for the Class I facilities). Licensing of the radioactive waste management facilities in most cases follows the same pattern as obtaining a license for the I Class facilities. In this regard, obtaining a license for construction, handling, storage or final isolation of RAW facilities is carried out in accordance with the scheme, indicated below.

1. **The cooperation structure between administrative bodies and organizations within the field of RAW and SNF management**

Policies, related to the nuclear sector, including in particular nuclear fuel cycle, research, applications – in both nuclear fusion and fission are not only Belgian federal authorities and national economy responsibilities, it is also a responsibility of small and medium-sized enterprises, self-employed and energy industry in general[7].



We will take a closer look at the main actors, involved in RAW and SNF management. Among main actors are owners of RAW and SNF, **ONDRAF/NIRAS** – the organization responsible for radioactive waste safe management, its subsidiary – Belgoprocess, FANC - the regulatory body, responsible for protecting public and the environment from the risks of hazardous ionizing radiation, including its subsidiary Bel V.

The Federal Agency for Nuclear Control (FANC) is an autonomous government agency, led by a Board of Directors, consisting of 14 members. The independence of FANC and its directors is guaranteed by the incompatibility of their mandates with certain occupational titles in the nuclear and public sectors. FANC's primary mission is to provide effective protection of the public, workers, and the environment from the hazards of ionizing radiation[8]. Licensing of

[7] "Current organizational structure of the nuclear sector in Belgium", Nuclear Power Profiles of Countries, IAEA (IAEA, Belgium, Country Nuclear Power Profiles, 2.2.1. Current Organizational Structure), URL: https://cnpp.iaea.org/countryprofiles/Belgium/Belgium.htm.
[8] «Who are we? », an official website of the Belgian Federal Agency for Nuclear Control (FANC), URL: https://afcn.be/fr/lafcn/qui-sommes-nous.

activities, related to the nuclear fuel cycle, including management of RAW and SNF, can be singled out among the main functions of the Agency. FANC exercises its powers over nuclear operators through unilateral administrative legal acts such as granting, rejection, change, suspension and withdrawal of licenses or permits. It organizes inspections to verify compliance to the conditions, stipulated in the licenses and applicable regulations. FANC's activity is fully and directly funded by companies, organizations or individuals who it provides its services. Practically, it is manifested through carrying of one-time charge and annual taxes of the license applicants or RAW owners.

In 2007 FANC established a subsidiary - Bel V, a non-profit foundation, endowed with "observation" functions, this way, Bel V operates in Belgium at the principle of international regulation and supervision of the IAEA in the nuclear field. Under the Belgian law and following its own authority, Bel V has adopted IAEA operational guidelines and safety standards in relation to the legal and governmental infrastructure. Bel V is responsible for such activities as on-site inspections and control, safety assessment of the nuclear installations and environmental impact assessment, emergency preparedness and response.

ONDRAF/NIRAS is the only government agency, designated to ensure the long-term management of RAW and SNF. ONDRAF/NIRAS, under the supervision of the Minister of Energy and the Minister of Economy, is legally responsible for the safe transport, handling, conditioning, storage and disposal of all RAW, generated in the country. Nevertheless, the Agency has certain obligations in the field of decommissioning of nuclear installations and ensures that RAW owners and RAW operators create all the necessary conditions (funds) to finance a future program for the nuclear installations dismantling.

ONDRAF/NIRAS operates at prime cost and collects fees from clients of their services – producers of RAW, no more and no less than the amounts, necessary to ensure the safe management of RAW, in accordance with the "polluter pays" principle[9].

Moreover, Agency collects and evaluates information, related to decommissioning programs, approves these programs and forces them into application at the request of third parties or in case of operator’s refusal to pursue this issue. With a view to standardize the plan of nuclear installations decommissioning ONDRAF/NIRAS issued a list of recommendations for the development of decommissioning plans in accordance with IAEA safety standards, decommissioning requirements and manuals. ONDRAF/NIRAS is responsible for compiling a list of all nuclear installations and all facilities, possessive of radioactive substances in Belgium, including control of sufficient funding presence for accomplishment of decommissioning and remediation programs of the nuclear installation sites.

ONDRAF/NIRAS bears prime responsibility for research and development in radioactive waste management field and in the RAW disposal sphere either.

In 1986 ONDRAF/NIRAS discovers its subsidiary – an industrial company Belgoprocess, whose Dessel site serves as the major recycling and conditioning center at ONDRAF/NIRAS and also as a storage facility for the conditioned radioactive waste of all categories. Belgoprocess is also responsible for decommissioning of the shut-down nuclear facilities at the sites of the former Eurochemic plant (BP1) and the former SCK CEN waste department (BP2).

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[9] Mission ONDRAF/NIRAS, an official website of ONDRAF/NIRAS, URL: https://www.ondraf.be/notre-mission-et-d%C3%A9claration-strat%C3%A9gique.

SCK CEN has accumulated nearly 25 years of experience in decommissioning and decontamination (remediation) of reactors, hot chambers, radioactive contamination laboratories and “exotic” installations. SCK CEN was tased with decommissioning the BR3 and was also actively involved in managing the dismantling of the former Belgonucleaire MOX plant in Dessel. On a socially useful basis, SCK CEN conducts research in the field of safety of nuclear installations, radioactive waste management, protection of people and the environment form ionizing radiation, protection of strategic materials and social consequences of the use of nuclear energy.

Synatom (a subsidiary of Electrabel) is responsible for first stage fuel cycle management (i.e. supplying of enriched uranium to seven nuclear power units) and general fuel cycle management (i.e. managing of all SNF-related activities).

Synatom is the “exclusive owner” of nuclear fuel (as defined in the Article 87 of the EURATOM treaty) from the moment of its manufacture till the day it will be assigned to the Belgian national Agency for the radioactive waste and fissile materials Management – ONDRAF/NIRAS, starting from the stage, when it was classified as radioactive waste. Consequently, Synatom is a priority owner and producer of irradiated fissile materials.

Moreover, Synatom is legally entrusted with management of all Belgian NPP dismantling, farther with charges, associated with its SNF handling.

2. Policy and discipline of RAW management in Belgium

There are several types of radioactive waste distinguished In Belgium, its description along with the management practices is presented in the following table:

Type of Liability	Current practices/ Facilities	Long-term management policy	Funding of Liabilities	Planned Facilities
Spent Fuel	- On-site wet and/or dry storage of spent fuel (SF) from NPPs - Storage (at Belgoprocess) or reprocessing of SF from research reactors	Long term management policy still to be defined: disposal of waste from reprocessing or direct disposal	NPP operators contribute to the fund managed by SYNATOM; Various funds fed by state for spent fuel of research reactors	Geological disposal still to be confirmed by policy decision. (disposal and pre-disposal facilities to be decided)
Nuclear fuel cycle waste	Centralised storage at Belgoprocess site of all SL-LILW, LL-LILW and HLW transferred to ONDRAF/NIRAS	SL-LILW : Near surface disposal LL-LILW and HLW: policy still to be defined	Producer pays, contribution to the ONDRAF/NIRAS long-term fund; Various funds for historical liabilities fed by state	Surface Disposal for SL-LILW at Dessel, including the disposal facility and other facilities for waste packaging for disposal. (Gov. Decision taken in 2006, license application in 2013) Storage building for the ASR non-conform waste at Belgoprocess Geological disposal of LL-LILW and HLW still to be confirmed by policy decision. (disposal and pre-disposal facilities to be decided)
Non-power reactors waste	Centralised storage at Belgoprocess site of all SL-LILW, LL-LILW and HLW transferred to ONDRAF/NIRAS Radium waste storage at Umicore/Olen	SL-LILW: near surface disposal LL-LILW: policy still to be defined Radium waste : policy still to be defined	Producer pays, contribution to ONDRAF/NIRAS long-term fund; Insolvency fund; Radium waste: Producer pays	Idem
Decommissioning Liabilities	Present projects : BR3 Research Reactor; Eurochemic reprocessing plant; SCK CEN waste department; FBFC UO2 fuel fabrication plant; Radio-element production facility ex-"Best Medical Belgium"	Responsibility of operator; approval of decommissioning plan by ONDRAF/NIRAS SL-LILW: near surface disposal LL-LILW policy still to be defined	NPP operators contribute to the fund managed by SYNATOM; various funds for historical liabilities fed by state; Transfer of financial means to ONDRAF/NIRAS (waste funds managed by ONDRAF/NIRAS) when waste is transferred to ONDRAF/NIRAS	Idem
Disused Sealed Sources	Return to supplier, decay storage or transfer to ONDRAF/NIRAS	Implementation of EU directive, recovery of orphan sources	If no return, holder has to set up financial guarantee	idem

Table 5: Types of radioactive waste and its handling methods

Radioactive waste management

The directive of the European Union Council № 2011/70/EURATOM obliges its members to establish national policy on the safe management of radioactive waste and SNF of all present types, likewise to estimate national program, aimed at this policy implementation. These functions had been defined by the Act of June 3, 2014, and with its Article № 6 National Program Committee was instituted, whose subdivisions are:

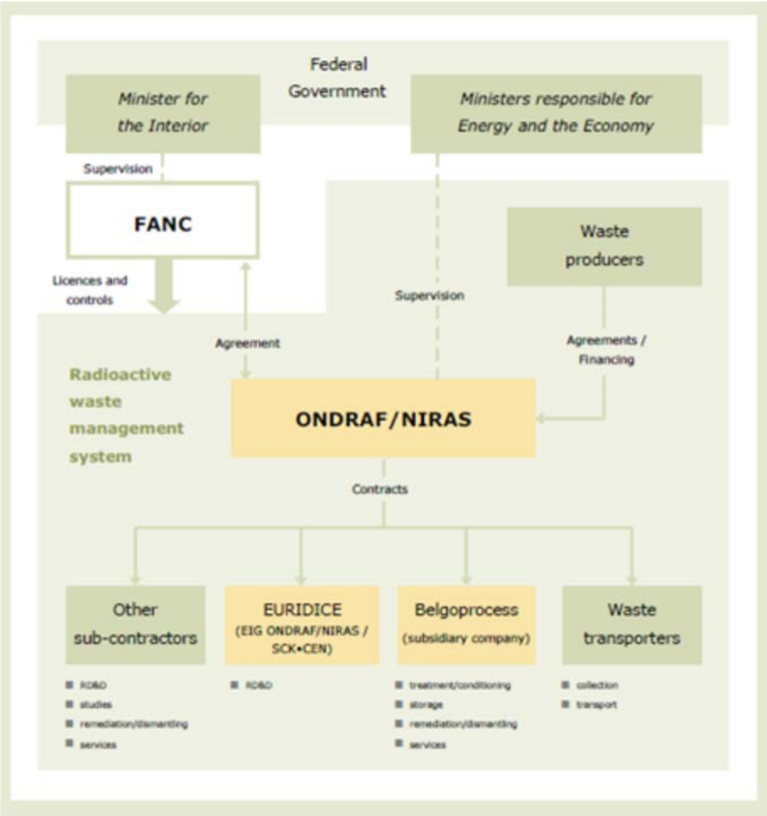
- Directorate General on Energy;
- ONDRAF/NIRAS;
- Synatom.

In 2015 the National Program Committee developed National RAW and SNF Management program in compliance with the Act of June 3, 2014; this law sets the state of affairs in the field of RAW and SNF management as of December 31, 2014.

On April 10, 2015 FANC/AFCN provided their references on the project, Strategic Environmental Assessment Committee (SEA) of the Federal Public Health, Food Chain and Environment Service's offered its testimonial on September 11, 2015.

On June 30, 2016 was established a ministerial decree, sanctioning the first National Program on the RAW and SNF Management. This tool serves as a strategic guide for the short-, medium- and long-term management of radioactive waste and spent fuel in Belgium.

In the table № 6 provided "Simplified diagram of the radioactive waste management system in Belgium"



RAW, generated during normal operation of nuclear facilities in Belgium, is processed and conditioned at the site of the precise facility by the operator or by ONDRAF/NIRAS – at the central facility in Dessel (for processing, storage and conditioning of RAW). Those facilities are managed by the Belgoprocess – its manufacturing subsidiary. Belgoprocess is responsible for the safe processing of RAW (produced in Belgium), that cannot be recycled by its producers, but such waste must be returned to its country of origin. The company also deals with the storaging of such type of RAW in a holding pattern of its disposal.

Belgium and Luxembourg signed a bilateral agreement on the matter of Luxembourg's radioactive waste management and its consecutive final isolation in Belgium. This bilateral agreement was ratified by Luxembourg in 2018 and Belgium in 2019.

Low-level radioactive waste storage at the NPP Doel

Facility № 150 had been set into operation in 1986, when Belgium attached to the international moratorium on the isolation of conditioned low-level waste in the sea. Facility's basin, capable of holding 1929 m^3, has almost been filled to the full capacity since late 1980s. At the end of 2020, it contained 1922 m^3 of conditioned waste which is equal to about 3330 packages.

Facility № 151 had been set into operation in 1988. It is a modular building, originally consisting of two storage facilities. In 1993 two more lodgings were upbuilt with the total capacity expanding from 6 300 m^3 to 14 700 m^3. The new decision on the enlargement of the facility 151 had been approved in 2018. In 2019 had been obtained the permission on storing at the site 151 of additional conditioned RAW amount. These measures led to the aggregated capacity extension up to 15 300 m^3. The drums are stored by the instrumentality of the remote-controlled track frame. By the end of 2020 at the 151 site 15,002 m^3 of conditioned waste (37,032 packages) had been stored. The design of 151E warehouse module considers a number of special options:

- output buffer storage for the conditioned low-level waste, obtained from the CILVA incineration plant, in a holding pattern for its acceptance at ONDRAF/NIRAS;

- temporary storage for the low-level conditioned radioactive waste, obtained from CILVA incineration plant, that had not been considered disposable;

- capacity of approximately 5 000 m^3 in 400-liter casks in the pyramidal stockpile.

The warehouse had been set into operation by the end of 2020.

Radioactive waste storage at the Belgoprocess site

Facility № 127 had been set into operation in 1978. The block passed through two stages of expansion and rebuilding, the last iteration took place in 1988, when its total capacity amounted to 4,650 m^3. The site № 127 was divided into four bunkers of same size with reinforced concrete walls of 80 cm thick. Feeding of casks is carried out by using a remotely controlled roller track. 3,901 m^3 of conditioned radioactive waste (or 15,963 packages) was placed into 127th ILW facility by the end of 2020.

ONDRAF/NIRAS develops the project of a new storage facility, that would meet the highest safety standards to replace facility № 127 at the BP1 site. The preparation of conceptual design and the fundamental research start is planned for 2022. Construction start is expected in 2025.

Block № 155 is a dedicated storage facility for processed and conditioned radium and plutonium containing LLW. Set to operation in 2005, facility consists of two separate storage lodgings: one for radium-containing wastes and the other for plutonium-containing waste. Bloc's (№ 155) storage capacity could be expanded, as it has to be sufficient for the entire amount of radium and plutonium-containing waste casks present inventory and for RAW predicted to be produced. 4,079 m^3 of conditioned waste (approximately 9,366 packages) had been stored in the 155 blocks by the end of 2020.

Block № 129 had been set to operation in 1985. By the end of 2020 within the space were stored 390 packages, containing 70 m^3 of vitrified HLW, 468 packages, containing 83 m^3 of compacted ILW (intermediate-level RAW), acquired as a consequence of contaminated carcasses and edge reinforcement processing, which had been returned from France along with the 123 drums, containing 69 m^3 of radioactive wastes, from Dounreay (Great Britain). Which is equal to 222 m^3 of the conditioned waste or 2 335 packages.

Final isolation of category A wastes

In 2012 ONDRAF/NIRAS applied for a license to the FANC/AFCN (Nuclear Safety Authority under the conditions, set out in the federal government decision of June 23, 2006) to establish a near-surface disposal facility for short-lived LLW and ILW ("Category A") in the municipality of Dessel.

The project on the radioactive waste disposal is integrated into a wider project, that will provide additional benefits to the region, taking into account its problems and aspirations of the local community. In this regard two local partnerships – STORA in Dessel and MONA in Mol had been taking part in all the selection rounds in the course of RAW final isolation project development path definition.

The process of license obtaining continued in 2020. Once the license is issued, the repository can be put into operation in four years, the operations for the disposal of radioactive waste and the closure of the NSRWR (near-surface radioactive waste repository) will last about 100 years.

Projected category A waste disposal facility

Long-term management of Categories B and C radioactive waste

An extensive R&D program, started in 1974, to evaluate clay formations application in the capacity of a potential host rock for the final isolation of long-lived LLW and ILW ("Category B") and short- or long-lived HLW of "Category C". By this time no resolution at the national policy level regarding management long-term of mentioned above waste categories had been made.

On this subject ONDRAF/NIRAS launched the initiative to set up a unified plan of the long-term HLW and/or long-lived radioactive waste management, considering the crucial details, in order that the Government in the availability of coherent practical picture would be able to adopt a critical decision in regard to long-term management of the Categories B and C radioactive waste.

The waste disposal plan is accompanied by the Strategic Environmental Assessment Procedure (SEAP), that contains the assessment on alternative options for the long-term management of a repository in a clay geology layer. The assessment (SEAP) not only covers the environmental impact, but also the scientific and technical basis of various projects and methods, their economic aspects likewise related ethical and social aspirations.

The final plan for the radioactive waste final isolation, arranged considering the results of public hearings and all the necessary supporting documents, was adopted by the ONDRAF/NIRAS Board of Directors on September 23, 2011. ONDRAF/NIRAS had assumed the following obligations:

- ensuring of the near-surface repository reversibility and exploring the measures potentially contributing to the processes of natural recovery of facility after its complete or partial closure;
- maintaining control over the proper operation of the disposal system, which will complement regulatory oversight;
- preparation of the most effective and efficient system for knowledge transferring, related to the repository and the waste contained inside of it, to future generations.

The proposal was negotiated along with the attached Environmental Impact Statement (EIA), is undergoing a legal process, that requires consultation with several authorities integrally with public consultation. Public consultations were held from April 15 to June 13, 2020.

Whatever the method of long-term management of categories B and C radioactive waste is, the implementation of the chosen technical solution will inevitably be long, gradual and public, which, in all probability, can take up to several decades before the chosen methodology will bring its benefits.

From scientific and technical point of view construction of a geological repository takes about 10-15 years after the license was issued. It is likely, that the time frame from the beginning of the repository's construction to its complete closure can protract to a century long period.

SCK CEN launched an R&D program on the separation and processing of HLW using MYRRHA's accelerating system, developed under the European conditions. Program's goal is in analyzing of this technology's feasibility from a technical, economic and industrial point of view within the framework of the European Union strategy. MYRRHA may provide an opportunity of geological repository's optimization by converting long-lived radioactive substances into less toxic or short-lived radioactive substances. MYRRHA is recognized as Europe's foremost research infrastructure.

The United Kingdom of Great Britain

SNF management strategy	Processing of SNF till 2018. Change of SNF management method to dry storage by 2045 with a view of its sequential disposal to a deep geological disposal facility (approximately planned for 2080)	
RAW Register		
RAW category	Volume of waste accumulation, m^3 (as of April 1, 2019)	Projected volumes of accumulation, m^3 (in absolute value, indefinitely)
HLW	2,150	1,310
ILW	102,000	247,000
LLW	27,400	1,480
LILW	1,040	2,830

Register of SNF		
An object	At the reactor plant (in tons of material)	In storage, outside the reactor area (in tons of material)
NPP Magnox	149	625
Advanced gas cooled reactors	1,500	2,200
Pressurized water reactors	~ 90	~530
Various types of reactors	~ 21	3
Other	-	one

Organizations in the field of radioactive waste management

Government body in the field of SNF and RAW management	DECC – Department of Energy and Climate Change, led by the Nuclear Development Authority. www.decc.gov.uk
Organization responsible for the implementation of the radioactive waste disposal project (project development, R&D, licensing, construction, operation)	RWMD NDA – Nuclear Waste Management Authority under the Department of Energy and Climate Change. www.nda.gov.uk BGS – British Geological Survey, R&D. www.bgs.ac.uk
Body of state regulation of safety in the field of atomic energy	ONR – Office for Nuclear Regulation. www.onr.org.uk
State regulatory body in the field of environmental protection	EA – Environmental Protection Agency. www.environmentagency.gov.uk SEPA – Scottish Environment Protection Agency (no nuclear installations in Northern Ireland). www.sepa.org.uk NRW – Natural Resources Protection Wales. www.naturalresources.wales

1. Status and prospects for the development of the nuclear energy industry in the United Kingdom

The first country to establish a state program in the field of the peaceful use of atomic energy was the United Kingdom, having opened the Calder Hall nuclear power plant in 1956. The NPP capacities were connected for the first time to the civil infrastructure power supply networks. Today, 15% of the electricity in the country is generated by nuclear power plants, and its average capacity is 7 GW. According to the approved state plan, by the end of this decade, most of the nuclear reactors that exist today should be decommissioned. At the same time, first nuclear power plant of new generation is being built in the UK. By 2050, the UK Government plans to increase the part of nuclear electricity to 25% in the country's energy system.

All currently operating nuclear power plants in the country are owned and operated by EDF Energy, a subsidiary of the French EDF. Most reactors at nuclear power plants made in the UK are second-generation gas-cooled reactors (Advanced gas-cooled reactor, AGR), but at this stage the reactors are operating at significantly lower capacities than at earlier stages or as presupposed by the design of such a reactor.

Table 1. Operating nuclear power plants in the UK (as of June 2022)

Nuclear power station	Reactor	Reactor type	Power (MW)	Commissioning (year)	Decommissioning (year)
Hartlepool	Hartlepool A 1	AGR	590	1983	202 4
	Hartlepool A 1	AGR	595	1984	2024
Heysham	Hasham A1	AGR	485	1983	2024
	Hasham A2	AGR	575	1984	2024
	Hasham B1	AGR	620	1988	2028
	Hasham B2	AGR	620	1988	2028
Hinkley	Hinkley B1	AGR	485	1976	2022
	Hinkley B2	AGR	480	1976	2022
Sizewell	Sizewell B	PWR	1,198	1995	2035
Thorness	Thorness 1	AGR	595	1988	2028
	Thorness 2	AGR	605	1989	2028

In 2022, the UK Government announced the need to accelerate the development and renewal of the domestic energy sector significantly in order to ensure long-term energy independence and security. This strategy assumes an increase in the country's energy capacity to 24 GW by 2050.

Criteria of RAW definition and classification

Radioactive waste is defined in EPR16 (for England and Wales), EASR18 (for Scotland) and RSA93 (for Northern Ireland). The definitions provided in these regulations can be used to define RAW as a substance, item or object that is not subjected to further use, has be conditioned and isolated, and contains levels of radionuclides, exceeding specific threshold levels defined by legislation.

The categories of radioactive waste extant in the United Kingdom: very low-level radioactive waste (VLLW), low level radioactive waste (LLW), intermediate level radioactive waste (ILW) and high-level radioactive waste (HLW).

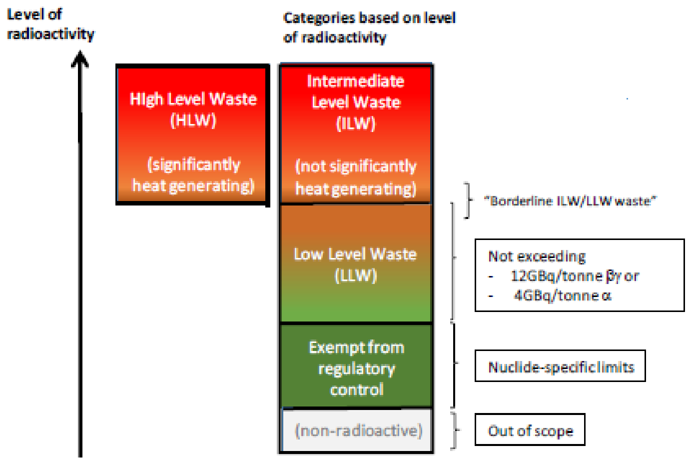


Figure 1: Radioactive waste categories used in the UK

Spent fuel and some nuclear materials (depleted plutonium and uranium) are not currently classified as radioactive waste. If in the future is made a decision not to use these materials recurrently, it will be classified and treated as radioactive waste. The geological disposal of such materials would be possible if Radioactive Waste Management Ltd. – the authority responsible for the establishment of the DGR (deep geological repository) would consider it appropriate to include a certain amount of spent fuel and nuclear material stockpiled in the United Kingdom into its inventory plan as wastes, that may be disposed in a geological disposal facility.

2. Policy and strategy for radioactive waste management

The main strategies in the field of radioactive waste management have not undergone significant changes over the past 3 years. At the same time, the Government has begun work on updating and consolidating its policy in the field of decommissioning NPPs and other nuclear facilities.

General Policy for the Management of Radioactive Waste

The legal and regulatory framework for radioactive waste management is an area currently under development, as UK Government continues to develop policy and regulatory framework in the atomic energy field.

In this regard, producers and owners of radioactive waste:

- do not produce unplanned quantities of waste unless they have reliable means for their proper handling and/or conditioning, storage or final disposal;

- must neutralize the waste as soon as possible;

- characterize and, where appropriate, sort the waste in order to ensure its optimal handling in the future;

- perform strategic planning of nuclear waste production and management processes, including the development of programs for RAW accumulated at the sites of their production disposal, including waste generated as a result of the decommissioning of standby facilities.

Producers and owners of radioactive waste in the United Kingdom are responsible for the costs associated with the management and final isolation of RAW, generated by their activities.

HLW handling

The legislative and regulatory system in the field of radioactive waste management is an unresolved issue. The HLW management policy is set separately for England, Wales and Scotland; (Northern Ireland does not have its own HLW management policy). Relevant policies and strategies are described below.

HLW policy in England. Public relations

The updated conditions for the long-term management of high-level radioactive waste determine the policy of the Government of the United Kingdom in the field of management of HLW through the implementation of their geological disposal. A new document has been published to replace the “White Paper – Implementing Geological Disposal – Working with Communities in England” from 2014. In December 2018, the Government of the United Kingdom began searching for a proper site for construction of a deep geological RAW disposal facility. That was an example of a consent-based approach, which requires the community to be mentally prepared for such changes and act in a collaborating way in the process of the project development. Implementation of exploratory activity is only possible after the public hearings stage successful completion.

The UK government and regulators agreed that the purpose of RAW deep geological disposal is their final isolation, and waste is planned to be placed into the DGR without intent of its subsequent retrieval, however it is supposed that wastes could potentially be retrieved if there would be a significant reason for this. Based on the forecast amount of RAW, subjected to deep geological disposal, RWM Ltd. recognizes that the DGR is able to operate accepting new waste streams for approximately one hundred years, while increasing its disposal capacity. After decommissioning, the DGR has to be permanently closed at the earliest opportunity for the reasons of safety and minimization of future generations burden.

UK policy on the long-term HLW management recognizes the value of exploring the alternative DGR options for the long-term disposal of some HLW streams. The Government’s Nuclear Decommissioning Authority (NDA) is required to search for this kind of alternatives.

The Scottish Government is in favor of a similar policy in the field of HLW management.

The Nuclear Decommissioning Authority is investigating alternative options for managing wastes of classified between intermediate and low levels of radioactivity, including options for disposal of HLW in RWD. The Government will review the conclusions of the NDA upon completion of their work and, according to the commission conclusions, will form the direction of government policy in the field of HLW management. However, it is clear that in any realistic future scenario there remains a need for some form of deep geological disposal facility.

Waste policy in Wales

The policy of the Welsh Government in respect of RAW is broadly in line with the policy of the United Kingdom Government in this regard. One of the main goals of the policy is to organize measures for geological disposal for the reason of providing long-term management of radioactive waste.

The Welsh Government published its policy: "Geological Disposal of High-Level Radioactive Waste. Outreach" in 2019, now Wales is at the stage when close engagement with communities is required on the matter of siting for a possible DGR. Welsh Policy clearly states that a DGR can only be constructed only in case its community gives its agreement to host it.

In Wales there is a special policy document, complementing the UK Government's "Working with the Communities", however there are some important differences such as administrative boundaries, planning system and obligation to use the Welsh language in the public activities.

HLW policy in Scotland

The Scottish Government does not support the idea of DGR project, but remains committed to the responsible management of radioactive waste generated in Scotland.

In January 2011, the Scottish Government published its policy on the long-term management of HLW, which is based on the HLW disposal program into near-surface disposal facilities. This program excludes HLW disposal, as no waste of such level is produced in Scotland, meanwhile SNF is not currently classified as radioactive waste, this way spent fuel is permanently transported to the Sellafield site.

The RAW policy includes the following key points:

- long-term RAW management should be carried out at near-surface facilities;
- these facilities should be located as close as possible to the place of waste generation (principle of proximity);
- the designers of near-surface disposal facilities projects have to demonstrate the way, how future facilities will be monitored; the ways of RAW retrieval should also be installed into a disposal facility project as an option.

LLW management policy and strategy

Policies and strategies for managing LLW in the United Kingdom are the same for England, Wales, Scotland and Northern Ireland.

The policy covers aspects, such as production, management and regulation of LLW. The policy provides the organizational arrangements and separate LLW management solutions can be applied flexibly to ensure safety, environmental safety and cost-effectiveness.

The United Kingdom's overall strategy for the management of solid low level radioactive waste was updated in 2021. Strategy itself was developed by the Nuclear Decommissioning Authority on behalf of the UK Government and the devolved administrations (i.e. Wales, Scotland and Northern Ireland). The strategy is reviewed every five years to reflect significant changes since the previous review and to bring it in line with the set objectives.

The key goal of the strategy is continuous development and maintenance of an efficient, sustainable waste management infrastructure, as well as a range of alternative routes for treatment, conditioning and final isolation of LLW. The strategy requires from waste generators to manage its RAW according to the existing waste management hierarchy within a broader integrated framework of optimized waste management system using the most appropriate routes. The implementation of strategy led to the fact that a significant amount of LLW has been redirected to a specialized storage facility.

The National Program for the Management of low-level radioactive waste was established in order to implement all the leading strategies in the field of LLW management. LLWR Ltd. manages this program on behalf of the Nuclear Decommissioning Authority in collaboration with all the UK LLW producers to ensure its effective implementation through a series of specialized programs and activities.

The UK's Natural Radioactive Material Waste Management (NORM) Strategy was developed and published jointly by the UK Government and designated administrations in 2014.

SNF management policy

In the UK, the question whether spent nuclear fuel should be reprocessed or managed alternatively should be considered by the owner of SNF to the extent it complies with all relevant legal and regulatory requirements (the decision may differ from the view of the storage operator). The concept of the UK Government is that SNF should not be classified as radioactive waste as long as its reprocessing still remains possible and practical use of renewed fuel is envisaged in the future. By this moment the Government does not currently anticipate any ways for reprocessing SNF from new NPPs, therefore SNF produced at these plants may eventually be categorized as HLW.

3. SNF and RAW management practice in Great Britain

SNF handling practice

The United Kingdom has the experience of handling various types of spent nuclear fuel (from Magnox reactors, gas-cooled AGR and pressurized PWR, nuclear submarine reactors, research reactors and the reprocessing and fuel fabrication facilities at Dounreay).

More than 55,000 tons of SNF from Magnox reactors across the UK have been removed and in October 2019 all Magnox reactors were checked to be free of fuel. As of May 2020, more than 99% of all Magnox SNF accumulated over decades of these reactors operation has been reprocessed. Any spent fuel residue, that has not been reprocessed by the time the reprocessing plant shut down, will be safely stored at the Sellafield site in queue to special final conditioning and disposal.

Practice of radioactive waste management

The UK Radioactive Waste Inventory (UKRWI) provides detailed information on current estimates of RAW collected in the nuclear industry. This register does not contain data on volumes of naturally occurring radioactive materials (NORM). 95% of the total waste inventory in the United Kingdom of Great Britain is LLW (including VLLW) summing up to ~4.3 million m^3.

The 2019 update of the UK waste inventory showed that as of April 2019, the volume of accumulated unburied LLW is about 27,400 m^3 (of which 15,700 m^3 is located at the Dounreay site). Most of the LLW is in temporary storage waiting for processing/final isolation/disposal.

A small proportion of the total amount of LLW stockpiled in the UK is not suitable for LLW storage or disposal at a landfill because it does not meet the appropriate acceptance criteria at these sites. Such waste requires the development of new methods of its processing and conditioning, this kind of RAW could be subjected to in the same way of treatment as HLW.

Newly generated wastes should be minimized considering a wide range of options, including recycling, before being subjected to the disposal scenario. Revised policies and strategy of LLW management guarantee, that RAW producers have access to a wide range of treatment, conditioning and final isolation options.

The practice of handling radioactive waste of an intermediate level of radioactivity (ILW)

ILW is placed into the storage facilities until adopting of a decision to dispose it in a DGR in England or Wales, or at near-surface facilities in Scotland. Now it is expected, that the ILW will be conditioned to a passive-safe form for their further storage in the shortest possible time. RWM Ltd. mandatory disposal suitability assessment provides assurance that waste containers with conditioned ILW can suite the regime of RAW geological disposal.

The Sellafield site hosts the majority of ILW stock, taking into account that ILW typically is being placed at the sites of nuclear installations, where it was produced. As of April 1, 2019, 102,000 м^3 of ILW had been collected in the United Kingdom.

RAW management facilities. LLW storage. Methods of disposal and management of radioactive waste

The only national disposal facility for radioactive waste in the United Kingdom is the LLW storage facility operated by LLWR Ltd. –Low level radioactive Waste Repository Ltd. Waste in this storage is placed in ISO containers, which after that are placed into near-surface storage facilities, armed by a concrete reinforced construction. As of April 1, 2019, ISO containers had already occupied about 233,000 m^3 of storage capacity.

The success of the National LLW management program has stimulated commercial investment in tackling the country's radioactive waste problem, which has provided the operators an access to the reliable radioactive waste management infrastructure.

The UK LLW strategy has been implemented since 2016 through the National LLW management program, externalized by the LLWR Ltd., bringing together waste producers, treatment and disposal operators and regulators.

Disposal suitability assessment: Radioactive Waste management Ltd. Conclusion on compliance with the requirements of the regulator

Radioactive Waste management Ltd. (RWM Ltd.) is the company, designing the DGR repository. It is recognized to be a competent authority to provide the advisory to the nuclear site operators on the packaging and conditioning of HLW for the purpose of their subsequent geological disposal. This advice is provided by Radioactive Waste management Ltd. as a part of the process of evaluating the suitability of a particular waste consignment for the deep geological disposal method application.

Radioactive Waste management Ltd. has developed the concept of geological system for radioactive waste disposal – GDSSC, geological disposal system safety concept. The GDSSC contains a set of necessary specifications and requirements, along with the design and description cases of safe RAW deep geological disposal, regardless particular site. The GDSSC set of document provides the rationale that a disposal facility can be established in a suitable geological environment and that HLW can be safely disposed there. The GDSSC provides a safety case for each stage of the repository's life cycle: waste transportation, operation (including placement of containers with HLW into interim storage or final isolation facility), monitoring the facility's condition after closure. As the concept of disposal evolves, GDSSC should be updated periodically (its first edition was released in 2010). In November 2018, the Office for Nuclear Regulation and the Environmental Protection Agency have published a joint assessment of the GDSSC-2016 document.

Based on the GDSSC, RWM Ltd. has developed a wide range of documentation to assess the suitability of certain RAW for deep geological disposal. This is the so-called set of specifications with guidance on geological waste disposal.

The process of assessing the suitability of waste for disposal consists of a series of assessments, of the technique and safety of a particular method of conditioning and packaging of HLW. If RWM Ltd. comes to the conclusion that the packaged RAW will be suitable for disposal in the deep geological repository (DGR), the waste owner issues a Letter of Compliance on congruity with the regulator requirements to the waste, subjected to geological disposal.

The policy of Scottish Government regarding HLW does not envisage its final geological disposal. However, the region's regulators allow a scenario, when containers with conditioned waste, certified for geological disposal, could be placed as a measure of long-term management into near-surface repositories.

Temporary storages for the intermediate-level waste (ILW)

ILW located at the licensed nuclear sites are mostly located in the specialized temporary storage facilities or located (like reactor core graphite) in the not dismantled structures in compliance with all the safety requirements, awaiting for its probable disposal into a DGR in England or Wales. It is also possible to bury such ILW into near surface facilities in Scotland. It is expected, that after certification of relevant technologies the ILW will be transferred to a passive-safe state to the maximum extent possible.

Development of the radioactive waste management system infrastructure

The UK government approves the construction of new nuclear power plants in England and Wales, although at the same time these initiatives are not supported in Scotland, where the government encourages the development of renewable and other low-carbon energy sources. The British government policy on waste management provides for the following mechanism: before issuing permits for the construction of a nuclear power plant, it is necessary to make sure that there are or will be effective methods for waste management and disposal.

At the moment, there are no plans to create new plants for the processing of spent nuclear fuel accumulated at long-standing plants, as well as new nuclear power plants. The new nuclear power plant under construction at Hinkley Point C is being built with the condition that spent nuclear fuel, generated from operations, will not be reprocessed, and to the same extent this condition applies to the only functioning pressurized water reactor at the Sizewell site. B. On a similar basis, all plans, regarding the financing of radioactive waste management in the future, will be implemented. The Government has concluded that it is technically possible to dispose of the predicted HLW in the DGR and that a deep geological disposal site is the best way to manage any radioactive waste from the new NPPs, including SNF.

In 2018, UK Government Resolution confirmed, that the document “Implementation of a Geological Disposal – Working with Local Communities” will remain in the same form as it is. RWM Ltd. assessed the suitability to the geological disposal method of the RAW, expected to be collected as a result of the of new reactors in England and Wales operation. Comprisal: in case of a suitable disposal site acquisition, these wastes will be subjected to geological disposal there.

Public outreach leading up to the establishment of the DGR

Finding a suitable site for the DGR is a process that takes quite a long time. The UK and Wales governments are pursuing a parallel but unified policy aimed at finding a region where citizens would be ready to host a DGR on their territory. The Government of Great Britain, as well as Wales, has developed a social program of work with municipalities in order to inform the public and gain confidence in the project from local residents.

At the next stage of the process, scientific research will be carried out over a number of years in order to draw up a detailed characterization of the selected site. In case of successful preparation of a safety study for the DGR project and in the presence of the continued interest of the local community, the next step is to drill deep research wells to study the geological conditions of the environment, if there is an agreement on the project for the creation of a DGR in all instances controlling the process, as well as permission from environmental organizations.

Studying the selected site in detail may take about 15 years, depending on the types of studies, that are necessary for preparing a geological map of the area, along with obtaining justifications, that the site is designed to safely and reliably isolate and store radioactive waste. When RWM Ltd. collects enough information ensuring that DGR project in the particular location will be able carry out the task of safe and successful RAW storage and disposal, local community at the same time declares its readiness to host this repository in their region, RWM Ltd. starts the procedure of obtaining the permission for the construction of a facility from regulatory authorities.

Prior to obtaining of a regulatory approval for the deployment of DGR in a specified region, RWM Ltd. has to obtain public support for the implementation of this project in the form of a survey. This way, deployment of a DGR in a particular region requires permission from the Office for Nuclear Regulation and regional institutions, controlling issues of environmental protection.

4. Regulation of the radioactive waste management system in the UK

The Nuclear Decommissioning Authority (NDA) is a Governmental agency established by the Department of Business, Energy and Industrial Strategy (BEIS). The NDA is legally responsible for the decommissioning of the majority of industrial nuclear power plants in the country and for ensuring the subsequent safe management of radioactive waste, resulted from this process. The NDA also determines the general strategy for nuclear facility decommissioning, initiates the allocation of budgetary funds necessary for these needs. The NDA sets targets and monitors the progress of decommissioning activities, but does not directly carry out decommissioning operations at the nuclear facilities. The NDA executes its goals through six licensed specialized professional companies. These six companies have the primary responsibility for radiational safety and environmental protection in accordance with the established law, and therefore must demonstrate that they adhere to the correct practice of radioactive waste management at every operational level for the safety of society and the environment.

The main independent regulators in the UK are the Office for Nuclear Regulation (ONR) and the regional environmental agencies of England, Scotland, Wales and Northern Ireland.

5. Legislative changes in the system of RAW and SNF management

The legislation of the United Kingdom in the field of radioactive waste and spent nuclear fuel management has undergone some changes as a result of the implementation of the European Union Directive on Basic Safety Standards (2013/59/EURATOM), as well as new regulations being introduced in Scotland. The most significant changes:

- The Ionizing Radiations Regulations 2017 – IRR17 (together with the Ionising Radiations Regulations (Northern Ireland) 2017 (IRRNI17), replacing the 1999 regulations;

- Updates to the Environmental Permitting (England and Wales) Regulations 2016 (EPR16) - amended in 2018;

- Introduction of the Environmental Authorisations (Scotland) Regulations 2018 (EASR18), which provide an integrated authorisation framework for radioactive substances in Scotland, replacing the Radioactive Substances Act 1993 (RSA93);

- Introduction of the Radiation (Emergency Preparedness and Public Information) Regulations 2019 (REPPIR19) (replacing REPPIR2001) covering preparedness and response to radiation emergencies, along with an Approved Code of Practice (ACoP);

- Amendments to the Nuclear Reactors (Environmental Impact Assessment for Decommissioning) Regulations (EIADR), to bring it in line with its parent EU directive;

- A significant step forward on implementing a GDF was made with the publication of an update to government policy (‘Implementing Geological Disposal – Working with Communities’) setting out a consent-based approach to siting a GDF in England based around close partnership with communities. Welsh Government has also published its equivalent policy (Geological Disposal of Higher Activity Radioactive Waste: Working with Communities);

- Progress to improve the regulation of the final stages of nuclear site decommissioning and clean up; and

- Progress with the development and implementation of integrated waste strategies, to optimise waste management at site- and national-level.

6. Tasks of the United Kingdom of Great Britain on the way of development in the field of radioactive waste management

In October 2019, the UK hosted a full-scale mission of the IAEA Integrated Nuclear Assessment Service. Despite the withdrawal from EURATOM, the United Kingdom continues to exchange professional experience with foreign colleagues.

On January 31, 2020, the UK left the European Union and EURATOM. The transition period lasted until December 31, 2020. During the transition period, were implemented the measures, that allowed the country's RAW management industry to continue operating in accordance with high safety standards and principles of the environmental protection system. Great Britain started negotiations with the European Commission on the matters of cooperation in the field of nuclear energy production. It is noticeable that, in accordance with the Northern Ireland Protocol, in the scope of the UK Withdrawal Agreement, Northern Ireland continues application of separate European Union standards regarding radioactive waste management. Activity within the Northern Ireland Protocol will not lead to a significant change in the SNF or RAW management order in the United Kingdom generally.

In December 2018, the United Kingdom Government Policy on implementation of DGR for RAW had been published in the document “Geological Disposal Implementation: Public Outreach”, which provides an updated concept for the long-term management of high-level radioactive waste. The Policy for Geological Disposal of Radioactive Waste supersedes the “White Paper” dated 2014. In January 2019, the Welsh Government had also published the related policy: “Geological Disposal of High-Level Radioactive Waste: Public Outreach”.

The main challenges for the UK in the field of RAW management for today are:

- continuation of work on decommissioning and recovery of highly irradiated and hazardous facilities at the Sellafield site;
- decommissioning of a number of shut down Magnox NPPs;
- determination of a suitable site for the creation of a deep geological disposal facility;
- maintenance of the SNF and RAW management infrastructure;
- maintaining knowledge base and scientific data in the field of SNF and RAW management, particularly on the nuclear installation decommissioning matter.

Hungary

State Strategy for SNF Management	Direct burial method without pretreatment

Authorized institutions in the field of radioactive waste management in Hungary

Government body in the field of SNF and RW management	Radioaktiv Hulladekokat Kezelő (RHK) Kft . (English: Public Limited Company for Radioactive Waste Management, PURAM) Organization responsible for the implementation of the RW and SNF disposal project: project development, R&D, licensing process, construction and operation of disposal facilities.
Hungarian state regulator in the field of nuclear energy	Orszagos Atomenergia Hivatal , O.A.H. (Engl.: Hungarian Atomic Energy Authority, HAEA).
Magyar Tudomanyos Academy Atomenergia Kutatointézet , KFKI AEKI– scientific - research institute atomic energy Hungarian academies Sciences .	Main areas of work: reactor physics, thermohydraulics , study of fuel properties, materials science, applied computer science (simulators, reactor core monitoring), development of programs to protect the health of citizens, environmental protection, nuclear electronics and chemistry. AEKI organizes the technical support of the Paks NPP and provides power enhancement, safety, life extension and maintenance of the plant. The main activities of the institute are improving the efficiency and safety of nuclear reactors, extending licenses, participating in international collaborations created to develop fourth-generation nuclear reactors.

7. Legislation in the field of radioactive waste management

The basis of the Hungarian legislation in the field of radioactive waste management is the Atomic Energy Law of 1996, developed on the basis of codes and guidelines of the IAEA, as well as recommendations of the European Union and the OECD Nuclear Energy Agency (OECD NEA).

The law declares the priority of the safety of the use of nuclear energy and imposes obligations on the government to ensure control and supervision of the safe use of nuclear energy. The government performs its functions through the Ministry of Health, which has complete organizational and financial independence [10]. The Law on Atomic Energy also provides for the need to appoint a sovereign organization responsible for the final disposal of radioactive waste, temporary storage of spent nuclear fuel, and decommissioning of nuclear installations. The author substantiates the creation of the Central Nuclear Financial Fund, intended exclusively for financing the final stage of the nuclear fuel cycle, the final isolation of radioactive waste, the temporary storage of spent nuclear fuel and the decommissioning of nuclear installations. According to the Atomic Energy Law, radioactive waste management facilities (eg storage facilities) are by definition not considered nuclear installations, but are treated as a separate category.

[10] Sixth National Report prepared under the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, Hungary, 2017, p. 35.

Nuclear weapons nonproliferation

Since 1969, Hungary has been a party to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) as a state that does not possess them. Hungary is also a member of the Nuclear Suppliers Group, since 2004.– EURATOM . The Additional Safeguards Protocol with the IAEA entered into force in 2000.

Licensing

Licensing issues related to SNF and RW management are also regulated by the 1996 Law.

The operation of the RWDS and the equipment that ensures its safety is subject to licensing by state regulatory authorities in accordance with the types of activities.

The right to operate a RWDF in Hungary is confirmed by the following licenses:

- permission to transport radioactive waste and other polluting materials;
- permission for conditioning received RW and operation of waste treatment systems;
- permission for long-term (several tens of years) intermediate storage of conditioned RW that cannot be disposed of at the site of the current location;
- permission for disposal of conditioned short-lived LLW and ILW.

Permits are granted by the National Public Health and Medicine Service (ÁNTSZ, Állami Népegészségügyi és Tisztiorvosi Szolgálat) and/or the National Health Fund (NNK, Nemzeti népegészségügyi központ) who are responsible for inspections to verify compliance with the requirements of the licenses they issue.

In addition to licenses issued for core activities, licenses are also required for other operations such as security, allowable operational releases of radioactive material and investment projects.

An environmental impact statement must be prepared prior to the start of construction of the facility in order to make a comparative assessment of control data in subsequent periods.

8. Hungarian nuclear power industry

By decision of the Government, Hungary plans to increase the share of nuclear energy in the country's energy balance to 60% by 2030 (to build 6,000 MW of new power facilities).

Hungary has two reactors that do not produce energy for industrial purposes: the Budapest Research Reactor on the premises of the Research Institute of Atomic Energy of the Hungarian Academy of Sciences and the educational nuclear reactor of the Institute of Nuclear Technology of the Budapest University of Technology and Economics.

In Hungary, the Paks nuclear power plant operates 4 VVER-440 nuclear power units. The Paks nuclear power plant generates more than 50% of the electricity in the country.

Paks NPP, 1000-1600 MW each) are planned to be put into operation in 2025-2030. On August 25, 2022, the National Atomic Energy Authority of Hungary completed the administrative procedure for granting licenses. ROSATOM received permission to build the 5th and 6th NPP units. This permit is issued for a period of 10 years.

The launch of an additional phase of the nuclear power plant will help curb the rise in electricity prices and solve the problem of energy shortage in the country. In addition, commissioning a new capacity at an existing site will cost significantly less than building a nuclear power plant from scratch.

Paks NPP, its completion fell on the period from 2012 to 2017. A feasibility study for extending the life of the reactors by 20 years was carried out in 2000 and revised in 2005. In November 2005, the Hungarian Parliament overwhelmingly supported the project to extend the life of the Paks nuclear power units by another 20 years. The Hungarian Regulatory Authority (HAEA) approved the reactor lifetime extension program submitted in November 2008, and in December 2012 also approved a 20-year lifetime extension license for the Paks 1 unit.

All deliveries of nuclear fuel for the Paks NPP are carried out under contracts with TVEL JSCIn the 1990s, the possibilities of storage, processing and disposal of spent nuclear fuel from the Paks nuclear power plant in Hungary were studied. The country's government approved the decision to create a temporary SNF storage facility, and in September 1992, an agreement was signed with Alsthom (Great Britain) for the construction of a dry modular SNF storage facility. The modular design provided the advantage of increasing the SNF storage area as needed. The SNF reception building and the first three storage modules, designed to store fuel for 50 years, were built in 1997. Four new modules were built in 2000, one in 2003, and five more modules were created in 2007, thus appeared 13 total capacity 7,200 SFAs.

9. Scenarios for NPP Paks decommissioning

The decommissioning of nuclear facilities in Hungary is regulated by §40 of the Atomic Energy Law, which states that the responsibility for the maintenance, control and protection of nuclear facilities from the moment of their closure until the completion of dismantling lies with the National Agency for Radioactive Waste Management (PURAM). PURAM is also responsible for the demolition and reclamation of the area.

After studying five feasible options for decommissioning a nuclear power plant, a scenario was chosen as the base one, involving a shutdown with monitoring over the next 70 years. According to this decommissioning model, the non-radioactive components of the NPP, after SNF is unloaded, must be dismantled and placed in an interim storage facility, and the structural elements and equipment of the former plant containing radioactive materials will have to remain in place on the site under supervision for 70 years. In December 2006, this NPP decommissioning project was revised, as a result of which it was decided to reduce the observation period to 50 years.

The costs of decommissioning NPP units will be compensated by contributions made by Paks to the Central Nuclear Financial Fund. The costs of handling SNF generated at other nuclear facilities operated by state-funded institutions, including the educational reactor of the Institute of Nuclear Technology of the Budapest University of Technology and Economics and the research reactor of the Institute of Nuclear Energy Research of the Central Research Physics Institute, are compensated by the budget annually on the extent to which such costs are incurred.

10. SNF preparation process

The nuclear fuel cycle can be implemented as:

- open, in which SNF is disposed of without reprocessing,
- closed, when SNF is reprocessed with the possibility of subsequent use.

The most practical method for Hungary today is recognized as the method of SNF disposal in deep geological formations. The responsibility of the Public Limited company for Radioactive Waste Management (PURAM).

The disposal of HLW in deep stable geological formations always implies the previous implementation of a complex long-term research work to prepare a justification for its safety. The DGRDF will be able to provide simultaneous disposal of SNF and HLW obtained during the reprocessing of spent nuclear fuel. According to the forecast, over 30 years of operation at the Paks NPP, 11,266 fuel assemblies containing 1,307 tons of waste in uranium equivalent will be accumulated, not including SFAs sent to the Russian Federation (previously to the USSR).

11. Near-surface RAW disposal facilities in Hungary

Initially, radioactive waste in Hungary was generated as a result of the use of a number of isotope technologies and stored at the sites of the Atomic Energy Research Institute of the Hungarian Academy of Sciences, KFKI AEKI, the main consumer of radioisotopes.

RAW management facility Solymár

In Solymár, a disposal facility for isotopes produced at KFKI was established in 1960, then its management had been replaced from the Hungarian Atomic Energy Committee to the National Public Health and Medicine Service (ÁNTSZ). A few years later, the Solymár RWDF (radioactive waste disposal facility) began accepting wastes for disposal from different nuclear concernments of Hungary. The RWDF in Solymár carried out operations for the reception and disposal of waste till 1975, 900 m^3 of radioactive waste had been disposed in it.

In 1976, the second RWDF in Hungary was put into operation near the town of Püspökszilágy, then the question of RWDF Solymár possible liquidation was raised.

When considering a proposal to extend the service life of the Solymár RWDF, it was decided to stop operating the storage facility due to its proximity to the developing its population country's capital and on the reason of the insufficient ground waterproofing of the facility site.

This operation was carried out within 1977 and 1980. In the period of the facility liquidation, 650 drums of RAW, 3,000 of disused sealed sources of ionizing radiation were repackaged, transported and placed in the new radioactive waste storage facility – Püspökszilágy.

Püspökszilágy RAW Management Facility – Characteristics and Design

Püspökszilágy is a Hungarian Radioactive Waste Treatment and Disposal Facility (hereinafter RWTDF) was built on the border of the suburban areas of the cities Püspökszilágy and Kisnemedi. Design capacity – 3 540 m^3. The RWTDF project is a system of vaults and pits for RAW disposal. The first waste streams were disposed of in the RWTDF Püspökszilágy in 1977, and the recent license for operating of this facility was obtained in 1980. Initially, the RWTDF received all RAW generated as a result of Hungarian nuclear technologies use, a particular volume of sealed ionization sources of medical origin and devices containing fissile isotopes, previously stored in temporary stockrooms at the sites of various nuclear installations in the country.

In August of 1983 first power unit of Paks, and in November of 1984 second power unit of the NPP was put into operation, right after that the amount of low- and intermediate-level radioactive waste generated annually began to increase. The project of NPP had the capacity of placement of low- and intermediate-level waste into the temporary storage facility at its site. RWTDF Püspökszilágy was being filled with the waste from 1983 to 1989. Expansion of the near-surface RWTDF was not possible due to safety concerns.

The specialists of Paks NPP developed measures to implement the task of disposing exploitational LLW and ILW at a separate disposal site, but these attempts failed in January 1990 due to public opposition to the construction of a RWDF in Ofalu (Pécsvárad district). As a result, a decision was made to dispose waste in RWTDF with an increase of the storage capacity up to 5,040 m^3 at the expense of Paks NPP financial resources. The safety of the project of the storage facility capacity expansion had been repeatedly criticized during the licensing procedure by specialists of the Hungarian Institute of Geology and Geophysics (Magyar Földtani és Geofizikai Intézet) and this request had been revised within four iteration procedures.

Transportation of radioactive waste to the RWTDF site Püspökszilágy was suspended in 1990 due to protests of the local population. In 1991 the infeed of radioactive waste into the disposal facility resumed, and from 1992 to 1996 1,580 m^3 of exploitational waste from the Paks nuclear power plant had been loaded into Püspökszilágy site.

The storage was filled to the limit in 2005, since that time the repository had been used as a temporary storage for radioactive waste. There still is a possibility to increase the capacity of this repository through more efficient use of the areas designed for temporary storage and final isolation of radioactive waste.

Centralised State Repository for LLW and ILW Bataapati

Bataapati National Low and Intermediate Level Radioactive Waste Disposal Site

In December 2012, the centralized state storage facility for LLW and ILW Bataapati, located to the south of the Paks NPP, was opened.

Bataapati is a national repository for radioactive waste in the southwest of the country began operating in October 2008 and had been running for 15 years. The price of a project amounted to $310 million. Prior to construction of the facility, specialists at Bataapati executed an extensive program of sampling, analysis and assessment of the water characteristics in the region.

The Batapaati site is designed to store low-level and short-lived intermediate-level waste resulting from the operation and subsequent decommissioning of the Paks nuclear power blocks. Accordant to the project design, the capacity of the facility allows to place ~70,000 m^3 of LLW and ILW from Paks NPP. Some amount of long lived ILW and HLW will be stored outside the Bataapati in a specialised facility.

Additional prepared Bataapati sites allow to create some new vaults for RAW disposal of ~1 mil m^3 total capacity, which will guarantee RAW disposal over the next 40 years with a 50% reserve.

The facility is intended for the disposal of low and intermediate level waste generated resulting to the operation of nuclear power plants, that are temporarily stored in specialized storage facilities at the reactor sites, packed in drums (200 l). Liquid wastes are placed into the temporary storage at the reactor site of the NPP in tanks. Currently, only solid waste is sent directly to landfill. In this regard, it is necessary to carry out the procedure for solidification of liquid radioactive waste. LRW, which will appear during the dismantling of the nuclear power plant, will also be subjected to solidification.

Waste disposed of in a vault must meet the acceptance criteria interposed by the Hungarian government regulator. To ensure compliance with the acceptance criteria waste control begins since the moment when RAW stream is being transported from the NPP territory to the other facility. Each drum is inspected for damage, is measured for the levels of gamma irradiation at a distance of a meter and checked for contamination on the surface. The computer program additionally checks whether the activity of the radionuclides contained in the barrel meets the acceptance criteria for disposal.

RAW is transported along the road Paks – Boniad – Bataapati by the special licensed vehicle. Waste transfer operations carried out through this route comply to the provisions of the European agreement on the international transportation of dangerous goods (originally: "Accord relatif au transport international des marchandises dangereuses par route", ADR). As the vehicle arrives at the central building of the RWDS site the inspection is being conducted, then the vehicle is moved to the acceptance control area. After the final check the transporting platforms with the radioactive waste containers are moved to the storage facility by means of a crane.

Inspection measurements and pre-disposal conditioning are carried out in the waste acceptance facility of total capacity on 3,000 drums. The RWDF site is designed with an inbuilt radiation protection system.

There is an opportunity of the repository expansion the way, when there will be a separate deep geological repository for the high-level radioactive waste built-on to the main facility. The repository will be facilitated with an automatic control system. RAW is subjected to be stored at the depth of 200-250 m in granitoidal hosting rock. Facility will be accessed through the tunnels designed at a particular angle of slope. As the tunnels got filled with waste, the shafts would get suffused with clay and concrete compositions with the addition of 50-60% crushed granite, which will block the migration of radioisotopes into the environment for long time. The repository design makes possible its extension in case of Paks NPP capacity increase.

12. Interaction with the public in the creation and RWDS operation

One of the most important tasks to be fulfilled in the operation of a radioactive waste disposal facility is the demonstration of its safe, stable and unfailing operation.

In 2003, a media center of the Isotope Information Association was opened in Kisnemedi, near the town of Püspökszilágy. In the media center visitors can gain knowledge in the field of peaceful use of atomic energy, natural radioactivity and the origin of radioactive materials used in non-nuclear fields.

Regional offices of the Social Association for Control and Information (TETT) are working to ensure interaction with the public of management and administration of municipalities at the territorial districts where radioactive waste disposal facility is planned to be placed. The purpose of TETT 's work is to support research activities at the site of future radioactive waste disposal facility and inform the public about its results.

PURAM gained the support of the local population through effective communication with the public. At the state, regional and local levels, information about the activities surrounding the RAW repository construction is systematically disseminated (including press releases, brochures, the monthly publication of the Regional Chronicles (Térségi Krónikás) and informational announcements of the TETT Association. «Tersegi Krónikás" is produced in quantity of 4,600 copies and is subjected to targeted distribution – to each household. Every year, PURAM, in cooperation with TETT, organizes "emergency preparedness" days. Such events are held in the format of a trip to an environmental camp, where, in a lecture and communication format, nuclear industry experts provide an opportunity for representatives of social groups representatives, media agents and administration deputies to learn specific information and take part in various programs to strengthen ties with local residents. The results of social surveys indicate successful interaction with the public. Most of the population living in the region are in the picture about the processes taking place at the RWDF site, including ongoing and planned work.

Germany

Authorized institutions in the field of RW management in the Federal Republic of Germany

Federal Ministry of the Environment, Nature Conservation and Nuclear Safety, Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, BMU	Public Administration and Safety Regulation Body in the field of atomic energy (including the management of SNF and RW)
The Federal Office for the Safety of Radioactive Waste Management (under the jurisdiction of the BMU), Bundesamt für die Sicherheit der nuklearen Entsorgung, BASE	Performs the functions of regulation and supervision in the field of disposal of radioactive waste, as well as the authorization and granting of licenses for the construction and operation of RW disposals
Federal Office for Radiation Protection, Bundesamt für Strahlenschutz, BfS	Organization responsible for the implementation of the project for the disposal of spent nuclear fuel and radioactive waste
Federal Ministry of Education and Research, Bundesministerium für Bildung und Forschung, BMBF	Providing funding for research institutes (and projects), general regulation of German education policy
Deutsche Gesellschaft zum Bau und Betrieb von Endlagern für Abfallstoffe mbH**	Main contractor for the construction and operation of waste disposal sites
Ministry of Economy and Climate Protection, Bundesminister für Wirtschaft und Klimaschutz, BMWK	Federal Ministry of Economy and Climate Protection of Germany. The department deals with the development of entrepreneurship, business support, the introduction of new technologies into the economic system, as well as R&D
Bundesamt für Wirtschaft und Ausfuhrkontrolle, BAFA	Federal Office for Economics and Export Control (part of the Ministry of Economics and Climate Protection, BMWK)
Bundesgesellschaft für Endlagerung, BGE	State Agency for the Management of Radioactive Waste, which is responsible for the construction and operation of burial sites
Entsorgungskommission, ESK	Radioactive Waste Management Commission
Strahlenschutzkommission, SSK	Radiation Protection Commission
Kerntechnischer Ausschuss, KTA	Commission for Standardization in the Field of Nuclear Safety
Reactor Safety Commission, RSK	Nuclear Reactor Safety Commission
Wismut (Wismut GmbH)	Wismut GmbH – state-owned enterprise entrusted with the reclamation of the lands on which the development of uranium mines was carried out by the Soviet-German joint-stock company "Bismuth" from 1947 to 1990 in the east of the country, the Lands of Saxony and Thuringia. Wismut GmbH (limited liability company) was established in 1991 a year after the transfer of the mining enterprise to the ownership of the united Germany. The company's head office is located in Chemnitz.
Gesellschaft für Nuklear-Service mbH Company, GNS	GNS is a joint venture established in 1974 as part of an agreement between the operators of SNF and RW formed as a result of the operation of German nuclear power plants. GNS provides services in the field of waste disposal, decommissioning of nuclear installations, and

	also manages several subsidiaries for the temporary storage of SNF and RW (such as in Gorleben and Ahaus).
Bundes Gesellschaft für Zwischenlagerung mbH, BGZ	The Federal Alliance of Enterprises for Temporary Storage of Raw and Spent Nuclear Fuel, was formed in 2017 with the joint participation of specialized divisions of BMU and GNS.

1. The history of nuclear power in Germany

Scientific research in the field of the use of atomic energy for civilian purposes began in 1955 after the official signing of Germany's refusal to develop and possess nuclear weapons.

At that time, the research program was based on intensive international cooperation and included the construction of several experimental nuclear reactors, demonstration reactors, the development of concepts for a closed nuclear fuel cycle and the disposal of radioactive waste in deep geological formations. In 1955 The German Government established the Ministry of Nuclear Affairs, from that moment Germany became one of the founders of the European Atomic Energy Community (EURATOM), as well as the Nuclear Energy Agency of the Organization for Economic Cooperation and Development.

Nuclear research centers were established on the territory of West Germany:

• 1956 - in Karlsruhe, Jülich and Geesthacht,

• 1959 - in Berlin and Hamburg,

• 1964 - in Neuherberg near Munich

• 1969 - in Darmstadt.

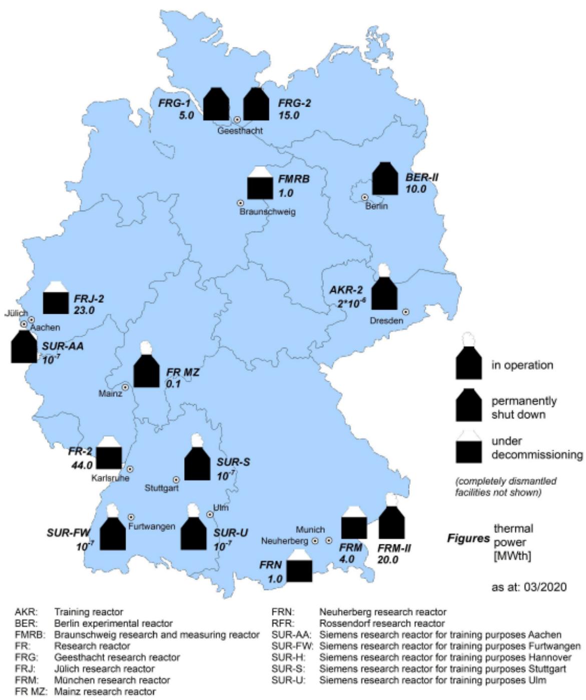
In the former GDR, the peaceful use of nuclear energy began with the development of a nuclear research and technology program in 1955. During this period, the political leadership of the GDR accepted a proposal from the USSR to contribute to the development of nuclear research. The Soviet Union's assistance meant the provision of research reactors, as well as the necessary equipment to provide infrastructure, which would become a catalyst in the process of creating its own nuclear research institutes. In 1956 The Central Institute for Nuclear Research was founded in Rossendorf (near Dresden), and in 1957 the institute launched a research reactor supplied by the Soviet Union. During the same period, departments in the specialties of nuclear physics and engineering were increasingly opened in the universities of the GDR.

Thus, a full-fledged base was formed in the GDR for conducting fundamental research in the field of nuclear physics, radiochemistry, for the production of isotopes, as well as for research on the scientific and technical foundations of the use of nuclear energy.

At the turn of 1991-1992, the stopped nuclear installations and the possessions of the Central Institute for Nuclear Research were transferred to the management of the Research Center named after him. Helmholtz (Helmholtz-Zentrum Dresden-Rossendorf) for decommissioning and research.

Dynamics of changes in the structure of nuclear energy production in the recent period of the country's history

Germany currently operates six research reactors.



Location of research reactors on the map of Germany. Numerical designations on the map - reactor power in MW.

In Germany, 17 nuclear reactors were operated, which provided a quarter of the total electricity produced in the country. The total capacity of nuclear installations exceeded 20 GW until the accident at the Japanese Fukushima-1 nuclear power plant occurred in 2011. In the same year, the German reactor fleet was reduced to 9 reactors with a total capacity of 12 GW. At the moment, 3 power units are in operation in Germany, supplying 4 GW of electricity to the country's power grid.

Decommissioning plan for the last three industrial nuclear reactors in Germany:

NPP	Reactor	Type	Power (MW)	Commissioning (Year)	Decommissioning (Year)
Izar	Izar 2	WER	1410	1988	2022
Emsland	Emsland	WER	1335	1988	2022
Neckarwestheim	Neckarwestheim -2	WER	1310	1989	2022

2. Legislation

The new EURATOM Directive No. 2014/87, updating the community rules for the parties to the Joint Convention in the field of Nuclear safety and nuclear installations that are members of the European Union, was integrated into German law through the adoption of the fifteenth Law on amendments to the Law on Atomic Energy of June 1, 2017.

The sixteenth Law amending the Law on Atomic Energy of July 10, 2018 regulates the issues of financial compensation to electric power companies for the gradual abandonment of the commercial use of nuclear energy.

On December 5, 2018, a Resolution on further modernization of the Law on Radiation Protection was published in the Code of Federal Laws.

The new Decree on Radiation Protection entered into force on December 31, 2018, as well as the new Decree on radioactive Waste Management.

Within the framework of national legislation, the Federal Republic of Germany has taken all necessary regulatory and management measures to fulfill its obligations under the Joint Convention. The constant adaptation of regulations to the latest scientific achievements ensures the maintenance of an appropriate level of technical development of the nuclear energy industry in Germany.

Legislation and administrative bodies of the civil nuclear sector provide the basis for the system of protection of life, health and property of citizens from the dangers associated with the use of nuclear energy in general and the harmful effects of ionizing radiation, as well as for the regulation and supervision of safety during the construction, operation and decommissioning of nuclear installations. In accordance with the requirements of legislation in the field of nuclear energy, ensuring safety takes precedence over the economic interests of the country.

One of the main objectives of the German Federal Government's safety policy in the field of nuclear energy has been and remains that operators of nuclear installations and facilities are obliged to maintain and develop a safety culture within their area of responsibility.

Structure

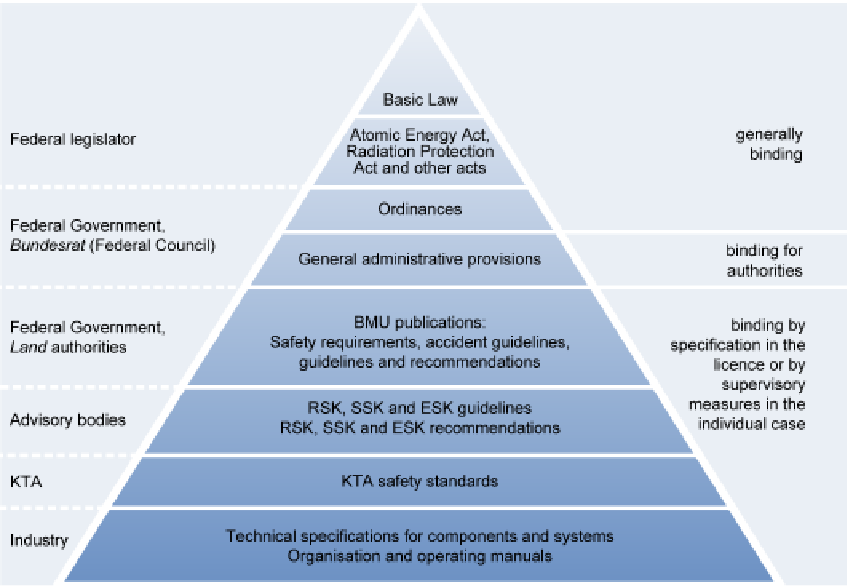
The Reactor Safety and Radiation Protection Manual contains all regulatory and mandatory guidance documents that are valid in Germany in the following areas:

- nuclear safety;

- transportation;

- disposal;

- protection against ionizing and non-ionizing radiation.



Hierarchy of bodies and systems regulating nuclear safety issues in Germany, in accordance with their sphere of responsibility.

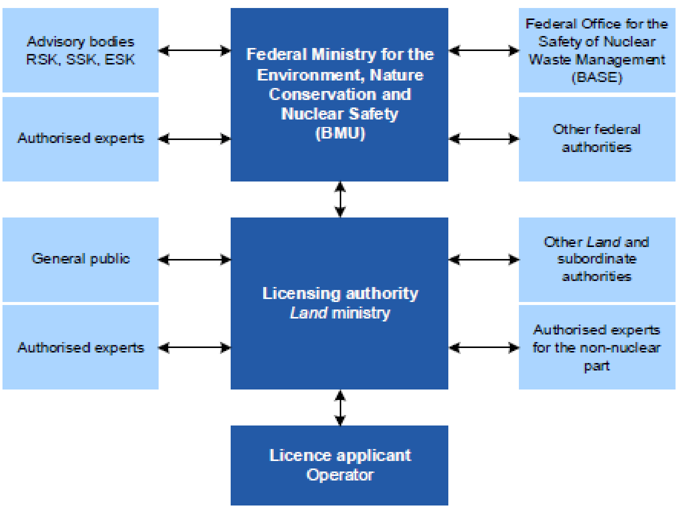
The Basic Law contains the main principles applicable to nuclear law. It also contains provisions on the legislative and administrative powers of the German Government regarding the use of nuclear energy. As defined in Article 73 of the Basic Law, the Government of the Federal Republic of Germany has exclusive legislative powers in relation to "the production and use of nuclear energy for peaceful purposes, the construction and operation of facilities serving such purposes, protection in emergency situations related to the proliferation of nuclear energy or ionizing radiation, as well as the burial of radioactive substances."

The Atomic Energy Law was adopted on December 23, 1959 after Germany officially renounced any use of atomic weapons, and since then it has been amended several times. The purpose of the Atomic Energy Law, after its amendment in 2002, is to gradually abandon the use of nuclear energy for its production for commercial purposes on a controlled basis. Another purpose of the Law is to ensure that Germany fulfills its international obligations in the field of nuclear energy and radiation protection.

The general Administrative Regulations (Allgemeine Verwaltungsvorschrift, AVV) regulate the actions of the authorities. The recommendations of the Commission on Radioactive Waste Management and Radiation Protection (Entsorgungskommission, Strahlenschutzkommission) play an important role in relation to licensing and supervision procedures in the field of SNF and RW management. These two independent expert commissions (ESK, SSK) advise BMU on issues related to radiation protection and waste management. The involvement in the ESK and SSK Commissions of experts from a wide range of technical specialties with different views on fundamental processes in the industry ensures the independence and impartiality of decisions made in these institutions.

The main task of the Commission for Standardization in the Field of Nuclear Safety (Kerntechnischer Ausschuss, KTA) is to establish safety standards and promote their application in the field of nuclear technology, where experience shows that experts representing manufacturers, builders and operators of nuclear installations, expert organizations and authorities will come to a consensus. The standards are developed within the framework of six subcommittees and adopted by the KTA.

Licensing system



Legal entities involved in the process of licensing nuclear power plants (according to Section 7 of the Atomic Energy Law, Atomgesetz).

Regulator

The German Government is authorized by the directive to determine the ministry responsible for nuclear safety and radiation protection in the country. Since June 1986, this competence has been assigned to the Federal Ministry of the Environment, Nature Protection, Nuclear Safety and Consumer Protection (Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz, BMU). Currently, the BMU has organizational powers and requests the allocation of the necessary human and financial resources from the federal budget to ensure nuclear safety and radiation protection systems in Germany.

With regard to the obligations under the Joint Convention, BMU is responsible for the activities of operators, federal authorities, as well as authorized experts in the field of nuclear energy, and guarantees protection from potential hazards associated with the use of nuclear energy for humans and the environment.

General safety provisions

With the entry into force of the Law on Radiation Protection (Strahlenschutzgesetz) and a number of directives included in it, the issue of radiation protection in Germany was settled.

On July 9, 2018, the fifth Directive 2018/843/EU of the European Parliament and of the Council of the European Union was issued amending Directive 2015/849/EU on the prevention of the use of the financial system for money laundering and terrorist financing, as well as amending Directives 2009/138/EC and 2013/36/EU. This regulation was integrated into the German legislative system by the implementation of the Law on the implementation of the fifth EU Anti–Money Laundering Directive - called Geldwäschegesetz, GwG.

The German Law on Money Laundering (GwG) introduced measures to ensure transparency of the radioactive waste management system, and also regulated the right of the Federal Office for Economics and Export Control (BAFA), which is part of the Ministry of Economy and Climate Protection (BMWK) to access all necessary information on the current processes of RW management.

Based on the amendments made to the Law on Atomic Energy (AtG) following the ratification of the Law on the Reorganization of Responsibility for Radioactive Waste Management, the process of decommissioning of nuclear power plants will henceforth have to begin immediately after the completion of the NPP.

The primary responsibility for the safety of facilities for the management of RW and/or SNF lies with the owner of licenses for certain types of activities within the framework of a nuclear installation. Inspections by regulators of RW management enterprises in Germany can only be carried out with the prior written consent of the license holder for the nuclear installation to be inspected (regulated by Section 12 b of the Atomic Energy Act, AtG).

3. Safety when handling SNF

Entsorgungskommission, ESK - Radioactive Waste Management Commission - at the end of 2018 issued guidelines on the creation of barrier systems to protect MANPADS from water penetration and flooding. In February 2019, the requirements of the Radiation Protection Commission (Strahlenschutzkommission) were taken into account regarding the barrier system of water protection of storage facilities for HLW, work began on studying various host rocks and relevant concepts for the safety of waste disposal sites in comparison.

The concept of safety in the handling of SNF is set out in the German Atomic Energy Act (AtG), the Radiation Protection Act (StrlSchG) and the Radiation Protection Ordinance (StrlSchV).

Safety measures for dry storage of SNF of light-water (LWR), high-temperature (HTR), experimental, demonstration, and research reactors are contained in the "Manual on Dry Storage of SNF and Fuel Waste" ESK.

The safety regulation for the use of wet type of SNF storage is the standard of the Commission for Standardization in the Field of Nuclear Safety (Kerntechnischer Ausschuss) No. KTA3602.

A separate standard No. KTA3303 regulates the processes of heat removal generated as a result of the nuclear decay process at the sites of SNF placement. Radiation safety under the conditions of criticality at nuclear power plants is regulated by standard No. DIN25712 of 2015, first published in 2007.

Based on § 8 of paragraphs 1 and 2 of the Radiation Protection Act (StrlSchG) and § 23 of the Law on the Closed Cycle of Materials Turnover and Waste Management (Kreislaufwirtschaft), AtG introduces a requirement (§2, 1A-3) to minimize waste generation within the SNF management system, as a result of which, thanks to the use of the latest technology in the field of nuclear energy and an optimized fuel management strategy, the volume of spent fuel has decreased.

4. Policy on RW and SNF

The reuse of SNF in Germany has been required by law since the industry was founded. The situation changed in 1994, when the owners of licenses for the operation of nuclear power plants were able to directly dispose of fuel, bypassing the stage of its reuse.

Until the centralized permanent storage for SNF is launched in Germany, the fuel will be placed at the same sites where it was produced until the opening of a specialized facility.

At the moment in Germany there is the only permitted way of handling SNF - burial. The implementation of the SNF disposal process is completed for the material with the status of "radioactive waste".

SNF handling

The spent nuclear fuel reprocessing program abroad - in France and the UK - ended in June 2005. The owners of licenses for the operation of nuclear power plants were able to provide documentation confirming the safety of the reuse of plutonium formed as a result of the use of MOX fuel, as well as justification for the possibility of safe storage of regenerated uranium. The remaining types of spent nuclear fuel produced in the country, which are not subject to processing, will be temporarily placed in specialized storage facilities at those facilities where they were produced until they were transported to the disposal point.

Treatment of RW

When Amendment 1A-7b was introduced to the Law on the Selection of a Site for the Disposal of Radioactive Waste (StandAG) in 2017, the procedure for selecting a site for the disposal of radioactive waste began. The Law on the choice of a site for the disposal of radioactive waste contains a requirement to create and provide a site for a repository that will provide the highest possible level of security for one million years. The selection of a site for the creation of a point for the disposal of HLW is planned to be completed in 2031.

In accordance with the legislation, the financing of the radioactive waste management process is carried out according to the "polluter pays" principle. Waste disposal is financed from funds formed by deductions from each MWh of electricity. BGE Technology is building this system in Germany. The amount of annual contributions to the funds may vary depending on the priorities of national programs for the management of raw materials, profit indicators, inflation rates and other factors. Considering that the funds are formed before the construction of the RW, and they must cover all the needs of the tasks for the final isolation of RW, authorized organizations provide various financial instruments to ensure long-term financing of disposal projects, for example, investments of funds from these funds. Forecasts for the use of funds are developed based on different levels of inflation and scenarios for the development of the nuclear industry (extension of the life of nuclear power plants, early closure of nuclear power plants and other scenarios). Despite the fact that approaches to financing the tasks of final isolation of RW have generally been developed and allow implementing long-term expensive projects, the task of reducing the cost of disposal of RW remains urgent.

5. Radioactive waste management practices

In Germany, for the storage of radioactive waste from the nuclear industry and nuclear power plants with low heat generation, there are both centralized and local smaller-scale storage facilities. Fuel-generating RAW materials can be stored both in local and centralized storage facilities. For RW formed as a result of the use of radioisotopes for the needs of science, industry and medicine, storage facilities under the jurisdiction of the Federal States of Germany are organized.

The final waste from the processing of SNF from German nuclear power plants, carried out in France and the UK, was conditioned abroad and returned to Germany. A similar cooperation existed with partners in Sweden, where waste from the operation of nuclear installations was delivered to air conditioning, and then transported back. In accordance with the Atomic Energy Act (1A-3), vitrified solutions of solid fission products obtained as a result of spent nuclear fuel processing abroad must be returned to the country for storage. Storage of vitrified waste until the end of 2013 It was provided at the facility in Gorleben.

Approved methods and high-tech mobile and stationary installations exist in Germany for the processing and conditioning of RAW materials. Mobile installations for RW conditioning are preferred in the process of processing and packaging nuclear waste. Stationary installations capable of conditioning various types of radioactive waste are used, in particular, in large research centers. There are also a number of air conditioning units operating directly at the waste producer's facility. In addition to waste management facilities of its own production, foreign equipment is also used in Germany for these purposes.

Spent nuclear fuel

Spent fuel discharged from the reactor core is initially stored in the spent fuel storage pools for several years. Then the SFAS are placed in barrels for dry storage and transportation.

Facilities for the management of SNF in Germany, operating in accordance with the standards and requirements of the Joint Convention on the Safe Management of SNF and RW, are:

- SNF storage facilities located at the reactor sites of nuclear power plants;
- federal-level SNF storage facilities in Ahaus, Gorleben and Rubenow;
- storage for AVR barrels (Arbeitsgemeinschaft Versuchsreaktor GmbH - "Communities of specialists in working with experimental reactors") in Jülich;
- experimental installation for air conditioning of RAW in Gorleben.

Radioactive waste

Nuclear installations or radioisotope equipment used in the fields of scientific research, trade, industry and medicine in Germany are in a continuous cycle of operation and decommissioning processes. In Germany, streams of RAW materials are continuously generated, which must be placed in storage until the point of their disposal is put into operation. The purpose of RW conditioning is to optimize them by processing and/or packaging in a container suitable for disposal in it and meeting the criteria for the acceptability of waste in the Konrad storage.

One of the important goals of air conditioning is to reduce the volume of stored radioactive waste to be disposed of. The method of waste conditioning is selected depending on their composition (organic, metallic, mineral) and aggregate state (solid, liquid). Also, the conditioning method depends on the radiation properties of the waste (crushing, burning, pressing, melting, etc. for HGW or drying/evaporation, cementing and glazing for LRW). It may also be necessary to use different methods of RW conditioning at successive stages of the process.

RW conditioning can be carried out using mobile or stationary installations. Frequently used stationary equipment for RW conditioning is a system consisting of: equipment for decontamination and dismantling, drying/evaporation plants, high-pressure pressing mechanisms, melting and cementing plants. There are enterprises equipped with such equipment and licensed to receive and process waste from external producers in Jülich, Karlsruhe, Krefeld, Lubmin and Rubenow.

With the gradual shutdown of German nuclear power plants, the need for stationary RW preparation will continue to decrease. At the same time, new facilities are being created at the reactor sites for air conditioning and storage of waste resulting from decommissioning.

RW storage facilities

Germany has a system of regulations for various types of radioactive waste, according to which they must be treated and isolated in accordance with their specific characteristics. One of the main and long-term stages of handling RAW materials is their storage until they are moved to the burial site.

The Law on the Transitional Period of Waste Management (EntsorgÜG) [1A-35], which entered into force on June 16, 2017, redefines the responsibilities for the storage of radioactive waste obtained as a result of operation, as well as the closure of nuclear power plants. The responsibility for the storage of RW, which was previously assigned to the operators of nuclear power plants, now falls on the Federal Government - after proper packaging of RW.

Currently, waste is stored not only at the NPP sites, but also in the nuclear waste repository "Unterwester" (AZU 1 and AZU 2), the radioactive waste repository "Biblis" (AZB 1 and AZB II), the radioactive waste repository "Agaus" (AZA) (in the west wing of the hall), the radioactive waste repository waste storage "Gorleben" (AZG), radioactive waste storage "Obrigeim" (AZO), radioactive waste storage "Philippsburg" (AZP), radioactive waste storage Stade (AZS), radioactive waste storage Würgassen (AZW), power system building in Mitterteich, The storage facilities of DAHER NUCLEAR TECHNOLOGIES GmbH (formerly Nuclear + Cargo Service GmbH (NCS)) in Hanau, the Northern Storage Facility (ZLN) in Rubenovo, the storage facility in Rossendorf (ZLR), as well as the storage facilities of Kerntechnische Entsorgung Karlsruhe GmbH (KTE).

The Deep geological repository

The place of burial of high-level radioactive waste, in particular, will be determined in accordance with the procedure of choice established by law. The procedure for selecting a site for this burial site should be completed by 2031. After the decision on the placement is made, the next steps will be the licensing procedure and the construction of a burial site.

For the disposal site, especially for heat-generating radioactive waste, the Site Selection Law provides for a method of final disposal, however, for 500 years from the date of the planned closure of the storage facility, the possibility of waste extraction should remain throughout this period.

The deep geological repository sites will be 100% owned by the state. On July 30, 2016, the Law on Changing the organizational structure in the field of Final Waste Isolation came into force. In accordance with this act, waste disposal operations will be carried out entirely at the expense of the state-owned company Bundesgesellschaft für Endlagerung mbH (BGE). The BGE operator will be the holder of the license to operate the facility until the expiration of the license.

The functions of regulation and supervision in the field of radioactive waste disposal will be concentrated in the future on the Federal Office for the Safety of Nuclear Waste Management (BASE; formerly BfE).

RW disposal sites

There are 2 sites in Germany: one in East Germany (Endlager Morsleben), the other in West Germany (Schachtanlage Asse). Neither of them meets the modern standards and norms of the Federal Ministry of Environment, Nature Protection, Construction and Safety of Nuclear Reactors in Germany, they cannot accept new batches of waste, accordingly, it was decided to find a new location.

6. Morsleben radioactive waste storage

After the reunification of Germany in 1989, the Morsleben Radioactive Waste Repository (ERAM) in Saxony-Anhalt came under the jurisdiction of the Federal Radiation Protection Agency (BfS) as an operator. In the period from 1971 to 1998, with interruptions, the ERAM stored ILW and LLW from the operation of nuclear power plants, as well as waste from scientific and research activities and medical institutions of the GDR, and after the reunification of Germany and the entire Federal Republic of Germany as a whole.

The validity period of the license for unlimited operation for the reception and disposal of radioactive waste was approved in paragraph § 57a (1) of the Atomic Energy Act and is limited to June 30, 2000. In 1992, BfS submitted an application to the Ministry of Agriculture and Environmental Protection of Saxony-Anhalt for a decision on the approval of the plan in accordance with § 9b AtG for the period after June 30, 2000. In 1997, this application was cancelled by filing an application for decommissioning of the storage facility.

7. *Asse II Mine*

From 1967 to 1978, radioactive waste was located in the former Asse II potash and rock salt mine, 50 kilometers from the German border with France and Belgium. After the disposal of radioactive waste, the mine was used until 1995 for research in order to develop and demonstrate methods of disposal of radioactive waste.

In 2008, the Federal Ministry of Environment, Nature Protection and Nuclear Reactor Safety (BMU), BMBF and the Ministry of Environment, Energy, Construction and Climate Protection of Lower Saxony (NMU) agreed that the Asse II mine will be considered as a burial site in the future in accordance with the Atomic Energy Law (AtG). This decision was implemented in the Tenth Law on Amendments to the Law on Nuclear Energy dated March 24, 2009.

On January 1, 2009, the Federal Radiation Protection Administration (BfS) assumed responsibility for the operation of this facility. To operate the installation, BfS used the services of the Asse-GmbH company, which is completely under state management.

In January 2010 The German Federal Office for Radiation Protection (BfS) has announced its intention to close the nuclear waste storage facility in the German Ass and remove 126 thousand containers with radioactive substances from there. This need arose due to the emergency condition of an abandoned salt mine equipped for a spent fuel warehouse 40 years ago. The German Federal Office for Radiation Protection (BfS) stated that three options were considered: moving waste to a safer site of the same mine, concreting waste with subsequent flooding, or removing all hazardous substances, and as a result, BfS settled on the latter method.

Currently, along with other substances, there are a total of 28 kilograms of plutonium in 126 barrels at the Asse facility. According to the 225-page report of the Federal Radiation Protection Service, excerpts from which are cited by Kölner Stadt-Anzeiger, such a high degree of threat of radiation contamination has not been observed in Germany before. According to experts, an immediate start of work on the evacuation of RAW and SNF is required. Meanwhile, the decision on the location of the transfer of SNF and RW has not been made.

The evacuation of waste from the storage facility in Assa may become one of the largest operations for the movement of spent fuel in history. According to various sources, the work may take from 8 to 10 years. Nothing is reported about the cost of the operation, but German engineering and consulting companies estimate the cost of the work at more than 2.5 billion euros.

8. *Conrad Storage*

A new place was found in the very center of Germany, in the city of Salzgitter, 8 kilometers from Braunschweig (Lower Saxony). The Conrad mine (German Schacht Konrad) (formerly an iron mine in Lower Saxony) should become the future disposal point for radioactive waste (deep geological repository). It is easy to develop, has stable conditions, is enclosed between other layers of rock and is covered with a layer of clay about 400 m thick.

On May 22, 2002, a permit was issued for the creation of a storage of raw materials on the basis of the mine. The Konrad storage facility can receive low-activity radioactive waste. The maximum volume of waste will be 303,000 m3.

In accordance with the law on changing the organizational structure in the field of radioactive waste disposal, on April 25, 2017, the operator's tasks were transferred to BGE TECHNOLOGY GmbH. The works started in 2007 were continued. The construction is scheduled to be completed in 2027. The OECD (Organization for Economic Cooperation and Development) report reports that the refinancing process of the Konrad mine will be slightly different in terms of the financing mechanism for the remaining deep geological repositories.

In the near future, the Konrad mine may become a nationwide disposal point for low and intermediate level waste, which is 99.99% of the total amount in Germany. All waste of the ILW and LLW type is packed in Germany in yellow 200-liter barrels. In Germany, the disposal of ILW and LLW is carried out by the method of burial both in near-surface storage facilities and in specially equipped engineering geological storage facilities deep underground.

Spain

SNF management strategy

Storage of spent nuclear fuel with the intention of its subsequent placement in a geological disposal site.

Inventory of available and projected RW and SNF

Waste type	Projected volumes of accumulation, m^3 (31.12.2019)		
	Accumulated as of 31.12.2019	Accepted	Total
Very low-level waste (VLLW)	24 600	98 900	123 500
Low and intermedium level waste (LLW & ILW)	52 000 (conditioned waste)	55 200	96 500
Solid waste	200	5 900	6 100
Spent nuclear fuel and HLW	7 450	2 950	10 400
The total volume for all categories of RW for a certain period	73 550	162 950	236 500

Organizational aspects	
The State administration body in the field of SNF and RW	Enresa — National Agency for RW (Empresa Nacional de Residuos Radioactivos)
Organization responsible for the implementation of the SNF and RW disposal project (project development, R&D, licensing, construction, operation)	
Main regulatory bodies	
The State regulatory body for safety in the field of atomic energy	MINETUR — Ministry of Industry, Energy and Tourism CSN — Committee for Nuclear Safety (Consejo de Seguridad Nuclear) under the jurisdiction of the Ministry of Industry, Energy and Tourism
The State regulatory body in the field of environmental protection	MAGRAMA —— Ministry of Agriculture, Food Supply and Environmental Protection

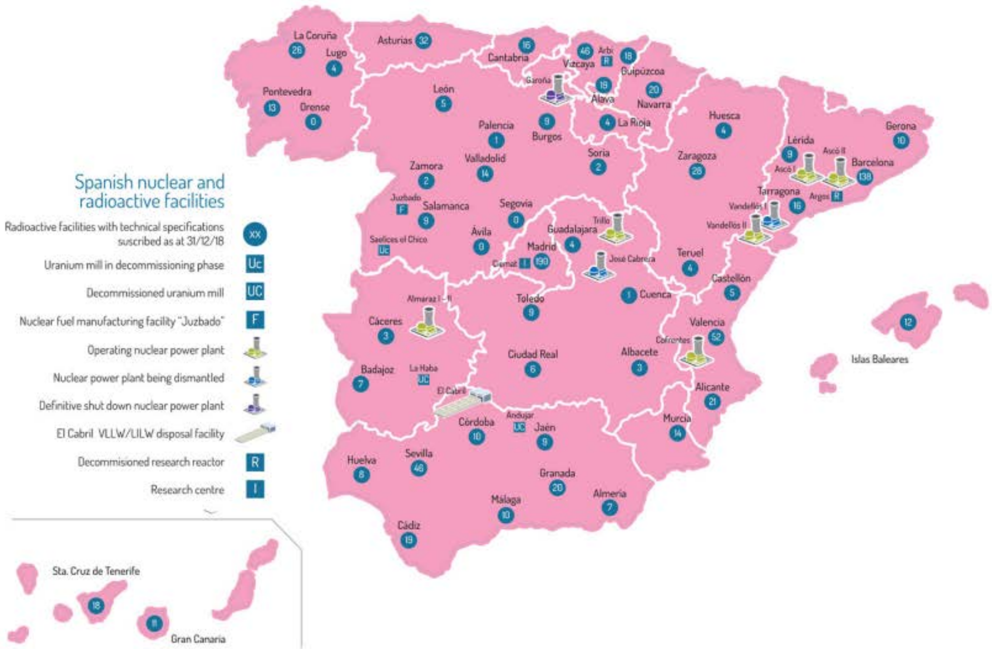
1**. History of the industry**

There are 7 nuclear reactors operating in Spain, generating 20% of the electricity in the country's energy balance. The first commercial nuclear reactor was put into operation in 1968.

NPP	Reactor	Type	Power (MW)	Commissioning (year)
Almazar	Almazar 1	PWR	1011	1981
	Almazar 1	PWR	1006	1983
Asko	Asko 1	PWR	995	1983
	Asko 2	PWR	997	1985
Confrentes	Confrentes	BWR	1064	1984
Vandelos	Vandelos 2 1	PWR	1045	1987
Trilo	Trilo 1	PWR	1003	1988

Operating nuclear power plants in Spain (as of the end of 2021)

Until 1983, part of the spent fuel was processed abroad, but now the entire available volume of spent fuel is placed in wet and dry storage facilities located at reactor sites. VLLW, LLW and ILW, including RW, formed as a result of the decommissioning of nuclear installations, are placed in the "El Cabril" near-surface disposal site.



Spain's nuclear energy infrastructure

2. Policy in the field of radioactive waste management

In 2007, Spain approved a program for the treatment of radioactive waste until 2070. The total cost of the program is €13,023 million, 48% of this amount will be spent on SNF and HLW management, 20% – on dismantling and decommissioning, 12% – on low- and medium–level waste management, 3% - on research activities in the field of RW management. Funds from several sources are concentrated in the fund under the control of the government. These funds are managed by Enresa under the supervision of competent government agencies. Such an organization of the workflow and its financing system allow you to quickly perform tasks in accordance with the plan and accumulate funds for future projects.

The Government is responsible for the development of a national policy and program for the management of radioactive waste, including spent nuclear fuel, and is also responsible for the dismantling and decommissioning of nuclear installations through the approval of the General Radioactive Waste Management Plan (hereinafter - GRWP).

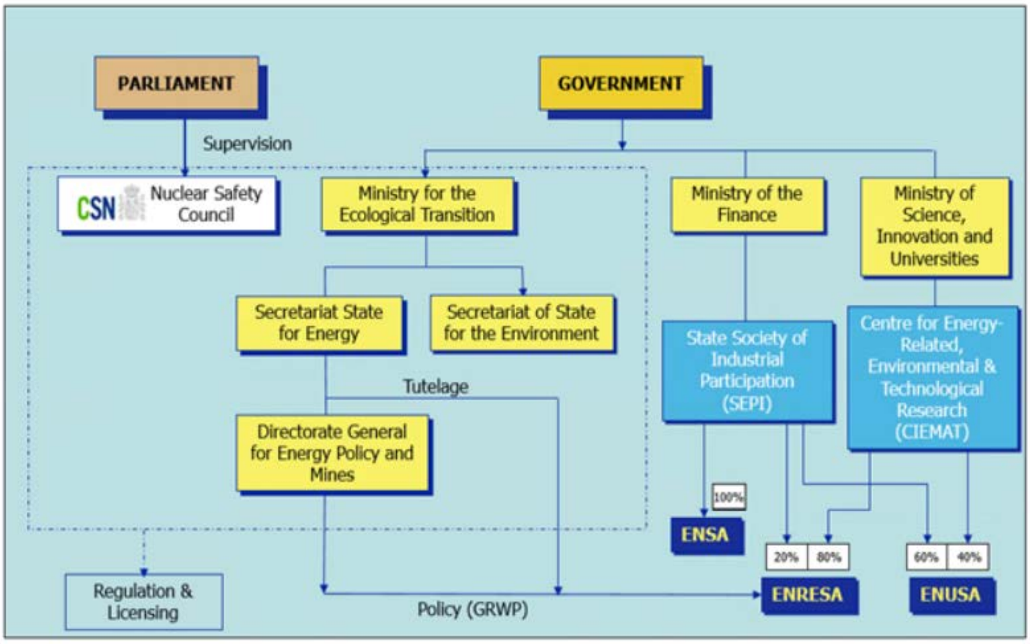
In accordance with Royal Decree 102/2014 of February 21, 2014, this Plan (GRWP) should ensure the safe and responsible handling of SNF and RW, as well as define actions, strategies and technical solutions for the dismantling and decommissioning of nuclear installations, including economic programs, financial regulations, measures and tools necessary for implementation these changes.

In order to verify compliance with GRWP requirements, the Spanish National Nuclear Waste Management Operator (Enresa) prepares and submits monitoring data and work plans in technical and economic aspects to the Ministry of Environmental Transformation and Demographic Problems (MITERD):

• in the first half of each year, a report is sent, including technical and economic aspects of activities for the previous year, data on the degree of compliance of the work carried out with the allocated budget, in addition to an updated economic/financial review of the cost of projects listed in the GRWP;

- annually, by November 30, a feasibility study of the budget for the coming year is developed and submitted, together with a forecast for the next four years;
- quarterly report on the expenditure of the relevant part of the budget is provided.

3. Agencies responsible for the implementation of RW disposal projects



The scheme of interaction of departments and organizations responsible for the implementation of projects for the disposal of radioactive waste

In March 2020, Enresa, in accordance with the provisions of Royal Decree 102/2014 of February 21, 2014 on responsible and safe management of spent nuclear fuel and radioactive waste, submitted a proposal to amend the GRWP to the Ministry of Environmental Transformation and Demographic Problems, initiating work on the project of the 7th GRWP. The draft of the updated Master Plan for the treatment of Radioactive waste was presented to the public on the Ministry's website.

In accordance with the provisions of the Nuclear Energy Act No. 25/1964, the GRWP Master Plan must be approved by the Government on the recommendation of MITERD, based on the review of the Nuclear safety and Radiation Protection report from the Nuclear Safety Committee (CSN). One of the necessary conditions for the approval of the Master Plan by the Government is its coordination with representatives of the public and the heads of Autonomous Regions involved in the field of nuclear energy in relation to the regulation of territorial issues and environmental protection.

The Master Plan (GRWP) also goes through the stages of strategic and environmental assessment in accordance with the Law on Environmental Assessment No. 21/2013 of December 9, 2013. At the initiative of the Secretary of State for Energy, the Secretary of State for Environmental Protection should provide the GRWP project to all involved state institutions and industry organizations, then consult on the submitted document to determine a plan for Strategic Environmental Analysis.

In order to predict the volume of RW, the following action scenario was included in the project of the 7th GRWP:

1) refusal of spent fuel reprocessing during a single (direct) fuel cycle;
2) phase-out of NPP operation in the period 2027-2035, in accordance with the Comprehensive National Energy and Climate Plan for 2021-2030;
3) commissioning of a centralized temporary storage facility for SNF and HLW in 2028 (with the planned completion date of installation work on the installation of a container for containers with RAW in 2026). The estimated life of this facility is 60 years;
4) immediate and final decommissioning of nuclear power plants with light-water reactors.

4. Legislative innovations in the field of nuclear safety

Over the past four years, legislation in the field of nuclear energy has undergone a number of changes:

1) Royal Decree 1400/2018 of November 23, 2018 approves the process of Regulation and management of the Nuclear Safety System and Nuclear Facilities (RSNIN);
2) Royal Decree 451/2020 of March 10, 2020 on the control and disposal of orphan radioactive sources. The key changes concerning this Royal Decree are set out in article 28 of this Law.;
3) Order ETU/1185/2017 of November 21, 2017 regulates the declassification of waste generated at nuclear facilities;
4) A royal decree establishing a single payment rate in favor of ENRESA by the owners of nuclear power plants, calculated at 0.798 euro cents per kilowatt-hour. This benefit is used to finance services for the management of spent nuclear fuel and radioactive waste, the dismantling and decommissioning of facilities, the allocation of funds to municipalities where these production facilities or storage facilities for spent fuel or radioactive waste are located, as well as taxes paid in connection with the storage task.

5. Classification and register of RW in Spain

There are 5 categories in the Spanish classification of radioactive waste: very low-level, low-level, medium-level, high-level and special RW.

Low and medium activity level wastes include wastes whose activity level is mainly due to the presence of beta or gamma nuclides with a short or intermediate half-life (less than 30 years) and with a very low, limited content of long-lived radionuclides. This group includes waste that can be temporarily stored, processed, prepared and disposed of at the El Cabril waste disposal facility in the province of Cordoba. It also includes very low-level waste (VLLW), LLW and ILW, with specific activity from one to 100 Bq per gram, potentially increasing to several thousand in the case of some radionuclides with low radiotoxicity or in small quantities.

Highly active waste contains long-lived alpha emitters with a half-life of more than 30 years in significant concentrations that emit heat during radioactive decay, they have high specific activity. The main element of this group is spent fuel (SNF) discharged from nuclear reactors, which, in accordance with Spanish policy, is classified as RW. Currently, it is stored in the pools of nuclear power plants and at individual temporary storage facilities (OIVH) at some sites. The plan for the future is that such waste should be placed for storage in a near-surface Centralized temporary storage after its commissioning and before their subsequent burial in a Deep geological storage.

The so-called "special waste" related to the components of nuclear fuel, neutron sources used by the internal devices of the station or replaced components obtained from the reactor vessel system and internal components of the reactor, usually metal, which, due to radiological characteristics, cannot be placed in the El Cabril burial site, are singled out among the RW. Temporary storage and disposal of long-lived waste of a significant level of activity is carried out by analogy with HLW

6. Practice in the field of RW and SNF management

The disposal site of the HLW, ILW and VLLW at the El Cabril facility

Since 1992, Spain has been operating a near-surface burial site for LLW and ILW El Cabril, located in the municipality of Hornachuelos in the north-west of the province of Cordoba. The complex was built on the territory of the mine, where small volumes of LLW were buried since 1961. The new complex was designed to receive 50,000 m3 of unconditioned RAW or 35,000 m3 of conditioned RAW. The center consists of three zones: two are allocated for the disposal of VLLW and low- and medium–level waste, one is for waste conditioning operations. The cured blocks of LLW and ILW are placed in the chambers of the near-surface burial site, each of which is designed to receive 320 containers. The burial of VLLW is carried out at the landfill type burial site. Basically, VLLW are RW with a specific activity in the range from 1 to 100 Bq/g, and the main source of such waste generation is the work on the RE of nuclear installations. Also on the territory of the center there is a laboratory for determining the quality of rejected radioactive waste.

In July 2016, Enresa started operation of storage No. 30 with an estimated capacity of 50,000 m3.

In September 2020, the center successfully conducted annual emergency exercises in accordance with the requirements set out in its Internal Emergency Action Plan (PEI).

According to the current assessment of experts, the capacity of the El Cabril facility will allow receiving waste generated in the country until about 2030.

Project of a centralized intermediate storage facility for SNF, HLW and ILW (Villar de Cañas)

In 2015, full-scale preparations began for the construction of a centralized intermediate storage facility for SNF in the municipality of Villar de Cañas (Cuenca province), located 135 km from Madrid. The storage time of SNF will be 60 years – it is planned to put into operation the national point of geological disposal of SNF and HLW by this time.

In July 2018, the Ministry of Environmental Development of Spain decided to cancel the permit for the construction of a radioactive waste storage facility in Villar de Cañas. The procedure for revoking the previously given permission has been launched. The Nuclear Safety Council was notified of this decision by the Ministry through a written request. The decision is justified by the fact that the country's development strategy in the field of energy for the next decade has not been developed.

The reasons for this decision were the high cost of the project, which together with the accompanying infrastructure reached a billion euros, as well as comments on the location chosen for the storage of raw materials (it did not receive full support from the regional authorities and causes disagreements among geologists). An additional factor was the fact that the Ministry of Environmental Development of Spain had not prepared an assessment of the impact of the nuclear energy facility on the environment.

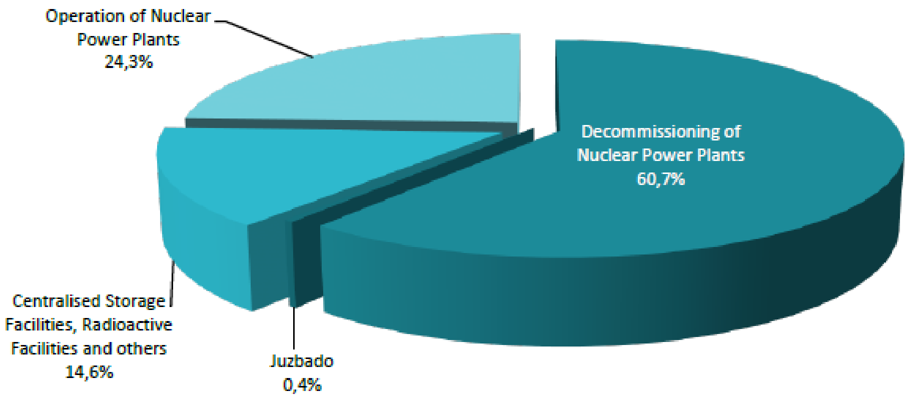
Thus, at the moment there is no storage facility in Spain that could accept HLW. The strategy assumes the placement of these materials in a temporary dry storage for SNF and HLW which guarantees the safety of people and the environment. Based on economic feasibility, it was proposed to put into operation a storage facility for SNF and HLW in 2050, where other RAW materials that cannot be placed at the existing El Cabril facility will be placed. But since 2018, the development of the project has been put on pause.

Project to create a single national disposal site for radioactive waste
In February 2020, the Spanish Government announced its readiness to suspend the project for the construction of a radioactive waste storage facility in Villar de Cañas (Cuenca) due to technical problems and the need for additional investments that will be required for its resumption, as well as due to doubts related to the geological conditions at this site. The Spanish government also announced its decision to start searching for new sites for this purpose. The Ministry of Environment admits the possibility of abandoning the idea of creating a single centralized repository and authorizing the distribution of radioactive waste to several facilities.

The Ministry of the Environment has not made an official decision to exclude Villar de Cañas from the list of candidates for the creation of a site for the storage of radioactive waste on this territory. The Ministry plans to find alternative sites for the construction of a storage facility where radioactive waste can be stored for 60 - 70 years.

The government defends the need to build a centralized facility for the disposal of radioactive waste for a long time, now the waste is stored in its own warehouses of each of the nuclear power plants. The scenario according to which the RAW materials will not be centralized in a single temporary storage facility, but will be placed in two or three separate facilities in Spain, is being studied by specialists.

7. Inventory of radioactive waste in Spain
Waste of very low, low and medium activity is given in predictive terms.



60.7% - waste generated during the closure and final decommissioning of nuclear power plants;

24.3% of VLLW, LLW and ILW waste as a result of NPP operation;

14.6% of VLLW, LLW and ILW are located in centralized storage facilities, at reactor sites of nuclear power plants, as well as on the territories of various licensed nuclear installations;

0.4% fuel element manufacturing plant in Salamanca ("Juzbado")

Also, a significant amount of waste was accumulated in Spain as a result of uranium mining and the production of concentrates (about 75 million tons of ore waste and about 14 million tons of technological waste), with a low content of radioactive substances. In most cases, the stabilization of waste "on site" has been the preferred method of treatment until now.

Name of the facility	Characteristics of the fuel elements	Total capacity/reserve core (number of elements)	Stored SF (number of elements)	Stored SF (tU)
Almaraz I Nuclear Power Plant	PWR 17x17	1,804/157	1,512	697
		ITS with capacity for 20 casks holding 32	64	30
Almaraz II Nuclear Power Plant	PWR 17x17	1,804/157	1,564	722
Vandellós II Nuclear Power Plant	PWR 17x17	1,594/157	1,332	606
Ascó I Nuclear Power Plant	PWR 17x17	1,421/157	1,096	502
		ITS with capacity for 16 casks holding 32	384	174
Ascó II Nuclear Power	PWR 17x17	1,421/157	1,164	534
		ITS with capacity for 16 casks holding 32	288	131
Cofrentes Nuclear Power Plant	BWR 8x8, 9x9	5,404/624	4,736	851
Sta. M. Garoña Nuclear Power Plant	BWR 8x8, 9x9	2,609/400	2,505	440
José Cabrera Nuclear Power Plant	PWR 14x14	ITS with capacity for 12 casks holding 32	377 (12 casks)	100
Trillo Nuclear Power Plant	PWR 16x16	805/177	556	263
		ITS with capacity for 80 casks, 32 casks holding 21 and 48 casks holding 32	736	347

Inventory data on RW (very low-level, low- and medium-active) by objects, at the end of 2019

Canada

RAW category	Volume of waste accumulation, m^3 (as for December 31, 2019)
SNF	12,718
ILW	15,681
LLW	2 075 022
Strategy for handling spent nuclear fuel in the country - direct disposal without pre-processing.	

Organizations in the field of radioactive waste management

Functions	Administrative body
Government body in the field of SNF and RAW management	NRCan - Ministry of Natural Resources of Canada
Organization responsible for the implementation of the radioactive waste disposal project (project development, R&D, licensing, construction, operation)	NWMO – Nuclear Waste Management Organization
Operation of radioactive waste disposal sites	OPG – Ontario Power Generation
The State regulator in the field of safety of the use of atomic energy	CNSC - Canadian Nuclear Safety Commission
The State Regulator in the field of environmental protection and protection	Department of Environment and Climate Change
State regulation in the field of radiation protection	Department of Health

1. General characteristics of the Canadian nuclear industry.

About 15% of Canada's total electricity is generated by nuclear power at 4 nuclear power plants (19 CANDU reactors) located mainly in Ontario. Nuclear reactors provide a total output of 13.5 GW of power. Previously, the Canadian government planned to expand nuclear capacity over the next decade until 2030 by building two new reactors but at the moment these plans have been postponed indefinitely.

For many years, Canada has been a leader in nuclear research and technology, exporting national reactor systems (the CANDU heavy-water reactor) and had a significant part in the international supply of radioisotopes used in medical diagnostics and cancer therapy.

Currently, 34 CANDU power reactors are operating in 7 countries around the world, as well as 13 "CANDU derivatives" reactors in India, and even more are in the process of construction. Canada exports both CANDU reactor systems (South Korea - 4, Romania - 2, India - 2, Pakistan - 1, Argentina - 1 and China – 2) and services, including engineering, for their construction and operation.

NPP	Reactor	Type	Power (MW)	Commissioning (year)
Bruce	Bruce-1	PHWR, CANDU-6	732	1977
	Bruce-2	PHWR, CANDU-6	732	1976
	Bruce-3	PHWR, CANDU-6	750	1977
	Bruce-4	PHWR, CANDU-6	750	1978
	Bruce-5	PHWR, CANDU-6	822	1984

	Bruce-6	PHWR, CANDU-6	822	1984
	Bruce-7	PHWR, CANDU-6	822	1986
	Bruce-8	PHWR, CANDU-6	795	1987
Darlington	Darlington-1	PHWR, CANDU	881	1990
	Darlington-2	PHWR, CANDU	881	1990
	Darlington-3	PHWR, CANDU	881	1992
	Darlington-4	PHWR, CANDU	881	1993
Pickering	Pickering-1	PHWR, CANDU	508	1971
	Pickering-4	PHWR, CANDU	508	1973
	Pickering-5	PHWR, CANDU	516	1982
	Pickering-6	PHWR, CANDU	516	1983
	Pickering-7	PHWR, CANDU	516	1984
	Pickering -8	PHWR, CANDU	516	1986
Point Lepreau	Point Lepreau	PHWR, CANDU-6	660	1982

2. Policy on RW and SNF. Classification system

The issues of the nuclear industry and the handling of radioactive materials in Canada are under the jurisdiction of the Government. Ministry of Natural Resources of Canada (NRCan) is developing a draft of State Policy in the field of nuclear energy, including radioactive waste management. The document should define the functions and obligations in relation to RAW of the Government, producers and their owners. The Federal Government is obliged to ensure a safe, environmentally friendly and economically optimal radioactive waste management process. The Government is responsible for policy development, regulation and supervision of producers and owners of RAW materials in order to ensure that they comply with legal requirements and fulfill their financial and operational responsibilities in accordance with the approved plan for the management of raw materials.

Guided by the "polluter pays" principle, producers and owners of RAW materials are responsible for financing, organizing, managing and operating storage facilities, final isolation facilities and other installations necessary for the disposal of their waste. At the same time, it is recognized that the agreements may be different both in relation to RAW and SNF, as well as uranium tailing.

The document "Fundamentals of Radioactive Waste Management and Decommissioning in Canada" (REGDOC-2.11) defines RAW as a material (in liquid, gaseous or solid state) containing a radioactive substance (§ 2), and, according to the owner, is waste. In addition to the fact that radioactive waste contains nuclear substances, it may also contain non-radioactive hazardous substances, as defined in section 1 of the "General Regulations on Nuclear Safety and Control".

Given that Canada has large deposits of natural uranium, the nuclear industry currently does not consider it necessary to process spent nuclear fuel. Therefore, in accordance with article 3 (1) of the Joint IAEA Convention, Canada declares that spent nuclear fuel reprocessing activities are not part of the SNF management program.

The Canadian Standards Association, in cooperation with industrial companies, government representatives and the Canadian Nuclear Safety Commission, has developed a standard that includes a classification system for radioactive waste (CSA N292.0, "General Principles for the Management of Radioactive Waste and Irradiated Fuel"), in accordance with the IAEA general safety guidelines GSG-1 – "Classification of Radioactive Waste", as well as the needs of Canadian industry. The latest edition of the document was published in 2019.

There are four main classes of radioactive waste distinguished by CSA № 292.0-19:

- Highly active radioactive waste (HLW);
- Medium-level radioactive waste (ILW);
- Low-level radioactive waste (LLW);
- Uranium tailings.

Highly active RAW (HLW)

HLW is used or irradiated nuclear fuel that has been classified as radioactive waste with significant heat release during radioactive decay (usually more than 2 kW/m^3). Activity concentration levels typically range from 104 to 106 TBk/m^3.

Waste category	Volume (as of December 31, 2019)	Percentage of total
High-level radioactive waste	12,718 m^3	0.6%

Volume and share of accumulated HLW in Canada (as of December 31, 2019)

In Canada, "irradiated nuclear fuel" or "spent nuclear fuel" are more accurate terms for SNF. Placement in deep, stable geological formations is considered the preferred option for long-term management of this kind of HLW.

Uranium tailing is a special type of radioactive waste, generated during the extraction and processing of uranium ore and the production of uranium concentrate. In general, long-term storage of waste in near-surface areas adjacent to mines is the only practical option for handling such waste, given the large volumes of tailings formed during mining and processing operations.

3. The practice of handling RW

Radioactive waste from medical and educational institutions is usually sent to Chalk River Laboratories (CRL) for disposal. These storages are shielded aboveground warehouses and concrete bunkers with holes for laying waste containers.

Canadian methods of radioactive waste management are similar to those used in other countries.

Since there are no radioactive waste disposal sites in Canada yet, the focus is on minimizing, reducing the volume, conditioning and intermediate or long-term storage of waste. All currently generated radioactive waste is stored in such a way that it can be recovered if necessary.

Like any nuclear industry facilities, radioactive waste management facilities must be licensed by the Canadian Nuclear Safety Commission (CNSC) and comply with all regulatory standards and licensing conditions. The purpose of the introduction of a unified industrial management system of RAW is the control and prevention of emissions of potentially harmful substances into the environment.

In accordance with the existing State Policy on Radioactive Waste, Canada applies various approaches to the management of HLW, ILW, LLW and uranium tailing. Long-term strategies are being developed and implemented regarding the handling of historical LLW in the regions of their location.

AECL and OPG corporations (operating 20 of the 22 Canadian reactors) are the owners of RAW and are responsible for 99% of the annual accumulated volume of ILW and LLW.

The two remaining CANDU reactors (owned by NB Power H-Q and Ontario's Cameco uranium processing and conversion facility) produce most of the remaining waste. ILW and LLW owners are required to obtain a license from the Nuclear Safety Commission of Canada for the management and operation of intermediate storage facilities for their RAW.

Activities related to the handling of inherited (historical) The RAW and decommissioning obligations of Atomic Energy Canada Limited (AECL) facilities are conducted under the supervision of Canadian Nuclear Laboratories (CNL) under a government agreement. Currently, a project is being developed in Canada to create two sites for near-surface disposal of radioactive waste in the area of Port Hope and Granby for the final isolation of the LLW "nuclear heritage". The initiative to participate in this project as a region providing a site for the placement of near-surface disposal was first put forward by the municipality of Port Hope, and then the community of Port Granby joined it. The aim of the project is to condition and safely bury 1.7 m^3 of historical LLW of Eldorado Nuclear Limited (formerly Canadian Drown Corporation), accumulated from 1933 to 1988. 1.28 billion US dollars of state subsidies have been allocated for the implementation of the project. Within the framework of one initiative, it is planned to implement two near-surface disposal projects in Ontario: “Port Hope” and “Port Granby”, both on the shore of the lake of the same name. The project developers guarantee the safety of the burial. The placement of these two near-surface disposals will not affect the habitual way of life of local communities, and the conditioning and final isolation of 1.7 m^3 of accumulated RAW will subsequently have a positive impact on the ecology of the region.

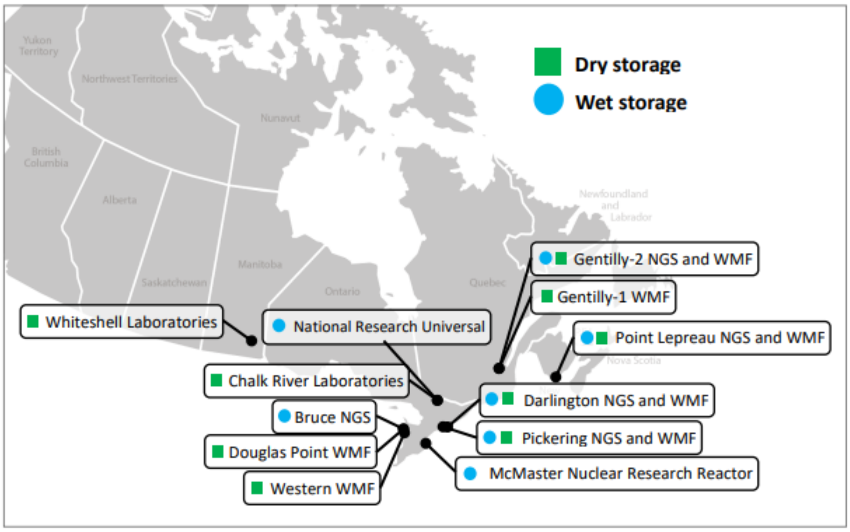
Map of the planned location and layout of the planned Near-surface disposals in Ontario in Port Hope and Port Granby

4. S*pent nuclear fuel* ***management practices***

In accordance with the current regulatory framework of Canada, SNF is recognized as one of the forms of radioactive waste, thus, legislation and policy in the field of radioactive waste management apply equally to both SNF and other forms of RAW.

Canada has adopted the practice of wet and dry storage of SNF. After several years of cooling in the SNF holding pool (from 6 to 10 years, depending on the needs of a particular site and control regulations), the SNF can be moved to dry storage. The process of transferring spent nuclear fuel to dry storage is supervised by IAEA specialists. The spent nuclear fuel placed in the intermediate storage is also under the control of IAEA specialists.

At each reactor site of a nuclear power plant in Canada, there is enough space to store all the spent nuclear fuel produced during its lifetime. The CANDU nuclear reactor with a capacity of 600 MW annually produces about 90 tons of spent fuel.



Layout of dry and wet SNF storage facilities on the map of Canada

In Canada, the entire volume of SNF is stored at the site where it was produced, with the following exceptions:

- a small amount of SNF is transported to research facilities for experimental and scientific purposes, then begins to be stored at these facilities;
- The SNF of the research reactor (Nuclear Power Demonstration) is located in dry storage at the site of the Chalk River Laboratory.

Facility	Number of spent fuel bundles in wet storage	Kilograms of uranium [1]
Bruce Power Nuclear Generating Station	736,290	13,942,460
Darlington Nuclear Generating Station	340,392	6,518,918
Gentilly-2 Nuclear Generating Station	5,725	109,264
McMaster Nuclear Research Reactor	13	13
National Research Universal [2]	804	2,646
Pickering Nuclear Generating Stations	428,809	8,458,694
Point Lepreau Nuclear Generating Station	33,460	636,805

[1] Inventory includes depleted uranium, enriched uranium, natural uranium, plutonium and thorium in spent fuel.
[2] Inventory is reported as fuel bundles, rods, fuel assemblies and/or other items.

Inventory of SFAS placed in wet storage facilities and the ratio of uranium contained in them, by objects (data as of December 31, 2019)

5. Legislative and regulatory systems in the field of RW and SNF management in Canada

The following regulations on the management of RAW and SNF are used to regulate the Canadian nuclear industry:

• Law on Nuclear Safety and Control;

• The Law on Nuclear Energy;

• The Law on Nuclear Fuel Waste;

• The Law on Spent Nuclear Fuel;

• The Law on Nuclear Liability and Compensation.

The nuclear industry is also subject to the Impact Assessment Act (IAA), the Canadian Environmental Protection Act (CEPA).

The NSCA Nuclear Safety and Control Act is the main piece of legislation that addresses safety issues.

The Law on Spent Nuclear Fuel defines SNF owners as responsible for developing long-term approaches to SNF management; obliges to create a separate legal entity - a SNF management organization to manage the entire range of activities for long-term SNF management; obliges SNF owners to create trust funds in the form of independent financial institutions to pay for contracts for long-term SNF management services with SNF; obliges to take into account the opinion of members of the public received during consultations on ways of handling SNF.

Within the framework of the Spent Nuclear Fuel Act, the Government of Canada is also responsible for the analysis of studies prepared by the unified operator for the management of RAW (SNF = RAW), as well as for the selection of a long-term disposal option and for ensuring supervision during the implementation of this program.

The Law on Nuclear Liability and Compensation entered into force on January 1, 2017, replacing the Law on Nuclear Liability. The Law on Nuclear Liability and Compensation establishes the legal regime that will be applied in the event of a nuclear incident that may cause damage to the civilian population.

In December 2018, the Canadian Nuclear Safety Commission (CNSC) issued the regulatory document REGDOC-2.11 "Standards for Radioactive Waste Management and Decommissioning of Nuclear Power Plants and Other Facilities of the Canadian Nuclear Industry". REGDOC-2.11 serves as the basis for the entire series of regulatory documents of the Nuclear Safety Commission of Canada on the management of radioactive waste. The document sets out principles consistent with the federal policy that regulate the activities for the treatment of radioactive waste. REGDOC-2.1 defines the need to create and use a program for the long-term management of radioactive and hazardous waste generated during licensed activities. In REGDOC-2.11, radioactive waste is defined as any form of waste containing a nuclear substance, in accordance with this comprehensive definition, SNF can also be classified as radioactive waste.

6. Regulatory body

The Nuclear Safety and Control Act established a body called the Canadian Nuclear Safety Commission.

The Nuclear Safety Commission of Canada carries out its activities in full compliance with the regulatory framework in the field of RAW and SNF management and decommissioning of nuclear energy facilities.

The Canadian Nuclear Safety Commission has been conducting, among other things, research in the field of creating deep geological repositories for RAW (since 1978). In 2008, in order to support initiatives to develop the concept of deep geological repositories, a coordinated Research and Analysis Program was implemented in Canada. As part of this program, the Canadian Nuclear Safety Commission collaborated with a number of different Canadian and international organizations in order to obtain experimental data and develop mathematical models, study the properties of bentonite as an insulating material and verify some aspects of the stability of the geosphere in order to assess the long-term effectiveness of deep geological disposal.

In September 2019, the IAEA sent an IRRS (Integrated Regulatory Review Service) mission to Canada. The mission concluded that a comprehensive framework for ensuring nuclear and radiation safety has been developed and put into effect in the country. The summary of the study recommends that the Government of Canada finalize the existing Policy by creating a strategy to implement the principles of radioactive waste management.

7. General security issues. Safety of RAW and SNF handling

In accordance with the "Act on Safety and Control in the Nuclear Industry", the responsibility for the safe handling of SNF and RAW in the country lies with the licensee and related organizations, the licensee cannot delegate this responsibility to other persons or organizations. Such responsibility implies the possession of the necessary human and financial resources to carry out their activities. Licensees are required to comply with all regulatory requirements and acts relevant to their activities, including acting within the framework of applicable laws.

The Radioactive Waste Management Organization of Canada (Nuclear Waste Management Organization, hereinafter – NWMO) participates in projects at the international level in order to maintain the level of professional competencies and exchange information in the field of radioactive waste management. NWMO cooperates with many international and national organizations for the management of radioactive waste in countries such as Sweden, Finland, Switzerland, France, Japan, the Republic of Korea and the United Kingdom.

In Canada, the principle of "polluter pays" applies to SNF and RAW, this principle implies that the owners of waste are financially responsible for the proper handling of them. The Government has created mechanisms to ensure that this financial responsibility does not fall on the Canadian public. This mechanism has been documented in the Canadian Government's Policy on Radioactive Waste Management.

In 2016, the Canadian Nuclear Safety Commission issued the document "Disposal of Radioactive Waste and Decommissioning of Nuclear Facilities" (DIS-16-03) in order to receive feedback on it. As a result of these consultations, the specialists of the Nuclear Safety Commission codified the existing regulatory requirements and guidelines and developed a new draft Regulatory Document "Disposal of radioactive waste and Decommissioning of nuclear facilities", based on past revisions of the document, work experience, as well as national and international guidelines and best practices in these areas, taking into account specifics of the Canadian radioactive waste management system.

In this way, the regulatory framework of the Nuclear Safety Commission of Canada was in compliance with international guidelines and best practices, as well as the Policy of the Government of Canada.

8. International cooperation in the field of RAW management

Canada is a party to the Treaty on the Non-Proliferation of Nuclear Weapons. In accordance with this treaty, Canada has also concluded an intergovernmental agreement with the International Atomic Energy Agency on mutual guarantees in connection with participation in this treaty.

The Nuclear Safety Commission of Canada participates in the work of a number of platforms and international groups that exchange information and knowledge about the methods of final disposal of radioactive waste in deep geological repositories, including the work of the Deep Geological Repository Regulatory Forum, aimed at improving the process of phased licensing of deep geological disposal.

The Nuclear Safety Commission of Canada participates in the work of various groups within the Nuclear Energy Agency of the Economic Cooperation Organization to review the strategic and political aspects of the establishment of the deep geological disposal.

The Canadian Nuclear Safety Commission cooperates with the Swiss Federal Nuclear Safety Inspectorate and the French Institute for Radiation Protection and Nuclear Safety in the exchange of information on research work carried out to establish deep geological disposal sites for radioactive waste.

Specialists of the Canadian Nuclear Safety Commission participate in several international joint programs that conduct research at deep geological disposal sites of radioactive waste, including:

DECOVALEX-2023 (development of interconnected models and their approval based on the results of experiments). This project sets researchers the task of experimentally modeling the development of events that may take place in geological repositories;

TENOR - within the framework of this project, experiments are carried out in underground research laboratories on the penetration and circulation of water or gas in bentonite and fractured granitoid rocks. Experiments are also being conducted to study the properties of the host rock using mathematical modeling;

SITEX II is a network of independent technical experts in the field of radioactive waste disposal, which is a forum for regulatory authorities, technical support organizations and civil society groups on the safe management of radioactive waste.

China

Strategy of SNF and RW management

Long-term storage of RW with the intention to build a geological burial site for long-lived ILW and HLW.

RW inventory intended for disposal

Disposal facility (DF)	Generated RW (m³)	Total activity (Bq)
North-west DF for LILW	11408,36	4,81 E+14
Guangdong Bailong DF for LILW	2116,04	1,00 E+14
Total	13524,40	5,81 E+14

Organizational aspects

State government body in the field of SNF and RW management	The China National Nuclear Corporation (CNNC) is a large state–owned enterprise formed in accordance with the decision of the State Council of the People's Republic of China.
Organization responsible for the implementation of the RW disposal project (project development, R&D, licensing, construction, operation)	BRIUG – Beijing Research Institute for Uranium Geology

Main regulators

The body of state regulation in the field of atomic energy safety	China National Nuclear Safety Administration (NNSA)

China is pursuing a strategic policy of "economical, clean and safe" energy, as China is developing energy produced on non-fossil fuels, along with the use of energy generated from fossil fuels. To this end, China is striving to gradually reduce the share of coal consumption and increase the share of natural gas consumption, as well as significantly increase the share of renewable energy consumption, such as wind energy, solar energy, geothermal energy, and nuclear energy.

In the 21st century, the Chinese Government has continued the policy of "active" and "effective" development of nuclear energy ensuring safety. In 2007, the Medium-term Nuclear Energy Development Plan for 2005 – 2020 was published, symbolizing a new stage in the large-scale development of nuclear energy in China.

After the accident at the Fukushima-1 NPP, the State Council held an executive meeting to discuss measures in connection with the emergency situation in Japan, and four decisions were made: to conduct an immediate comprehensive safety inspection at China's nuclear facilities; to adjust and improve the medium- and long-term strategy for the development of nuclear energy; to urgently develop a plan to ensure nuclear safety; and to suspend approval of projects in the field of nuclear energy.

In 2015, the National Energy Administration, the National Nuclear Safety Administration (NNSA) and the State Administration of Science, Technology and Industry for National Defense of the People's Republic of China jointly published a Policy Statement on Nuclear Safety Culture, which outlines the basic attitude to nuclear safety culture and the basic requirements for the development and implementation of a nuclear safety culture. China has integrated nuclear security into the overall national security system and determined the strategic positioning of nuclear security. China has also actively promoted the legislative process regarding the Nuclear Safety Law and the Atomic Energy Law. The draft Law on Atomic Energy was prepared and submitted to the State Council for legislative procedure. The Law on Nuclear Safety was reviewed by the National People's Congress of the People's Republic of China and put into effect on January 1, 2018.

1. General characteristics of atomic energy of China and supervising bodies

As of June 30, 2020, there are 47 operating nuclear power units in China and 11 nuclear power units under construction. In 2019, nuclear power accounted for 4.88% of the total electricity, and in the same year two power units (Yangjiang-6 and Taishan-2) were connected to the grid.

According to China's Eighth National Report under the Convention on Nuclear Safety and the Annual Report on the Operation and Construction of Nuclear Power Facilities for 2019 made for the Chinese Nuclear Energy Association (CNEA), during the period from 2015 to 2019 the share of thermal energy production in China was gradually declining, falling from 74.94% in 2015 to 72.32% in 2019; the share of electricity generated by wind and solar energy increased from 2.99% in 2015 to 6.65% in 2019; and the share of nuclear energy increased from 3.04% in 2015 to 4.88% in 2019.

From 2015 to 2019, 25 nuclear power units were put into operation in China, and construction of 11 nuclear power units began. In 2021, 51 nuclear power units with a total installed capacity of more than 48,759 GW were in commercial operation. Another 10 nuclear power units with a total installed capacity of 11,759 GW were under construction. From 2015 to 2019, the annual combined generating capacity and power grid of Chinese nuclear power plants were growing steadily. In 2015, the annual total electricity generation amounted to 170.79 TWh (3.01%) at operating nuclear power units. In 2016, it amounted to 212.73 TWh (3.60%). In 2017, it amounted to 248.07 TWh (3.95%). In 2018, it amounted to 294.36 TWh (4.33%). In 2019, it amounted to 348.35 TWh (4.88%).

There are four competent government departments overseeing nuclear energy: the China Atomic Energy Administration (CAEA); the National Energy Administration (NEA); the Ministry of Ecology and Environment/National Nuclear Safety Administration (MEE/NNSA); and the National Health Commission.

CAEA is the competent authority of the atomic industry. It is responsible for discussing and developing policies, regulations, strategies, plans and industrial standards for the peaceful use of atomic energy by China. It is responsible for communication and cooperation on nuclear issues with Governments of other countries and international organizations, and is also responsible for planning, supervision, review, and approval in the nuclear fuel cycle industry. It takes a leading role in addressing issues of nuclear emergency response.

NEA is the national governing organization for the entire energy industry. It is responsible for the development and implementation of developed plans, access conditions and technical standards for nuclear energy, preparation of an audit report for major nuclear energy projects, organization of coordination and management of research in the field of nuclear energy and organization of emergency management at nuclear power plants after potential nuclear incidents.

In 2013, the National Energy Administration was reorganized and reconstructed, and the Department of Nuclear Energy was created, which oversees programs, plans and strategies for the development of nuclear energy, as well as the planning of their implementation. The Department of Nuclear Energy also plays a leading role in organizing international cooperation in the field of nuclear energy. The creation of the Department of Nuclear Energy contributes to the integration and improvement of strategic goals, development programs and industrial policy, unification of technological routes of nuclear energy and increase the level of localization and independence of nuclear technological equipment.

MEE/NNSA is Chin's regulatory authority in the field of nuclear safety. It exercises unified supervision over the nuclear safety of China's nuclear power plants. It also supervises and manages environmental protection at China's nuclear power plants by issuing or revoking licenses as one of its main measures, and carries out inspections of nuclear power plants, nuclear materials, and nuclear activities.

MEE/NSA controls the following activities related to the safety of SNF and RW management:

(1) review and approval of programs to ensure high-quality and safe management of SNF and RW, as well as review and approval of safety rules and guidelines;
(2) supervision of the implementation of RW and SNF management programs safety-wise; selective control of storage facilities for RW and SNF;
(3) technical supervision of the main cases of non-compliance with safety rules and for the effective solution of such problems.

Organizations, specializing in the storage, conditioning, and disposal of spent nuclear fuel and radioactive waste, apply to the NSA to obtain a license for the storage of spent nuclear fuel or for the disposal of radioactive waste. If the storage facility is being built together with a nuclear installation for its own SNF or RW, it is not required to apply for each type of license separately.

Another supervisory body in the nuclear energy sector is the National Health Commission. It, together with the relevant authorities, develops laws and regulations on the prevention of occupational diseases related to radioactive substances. It organizes and coordinates national medical response and rescue in emergency situations related to nuclear activities and brings local health departments into proper medical readiness in emergency situations.

The State Labor Protection Administration is responsible for conducting hygienic examinations and participates in decision-making on site selection and project design for newly built, expanded and reconstructed nuclear power projects.

Currently, the three key state-owned enterprises engaged in nuclear energy are CNNC, CGN and SPIC. CNNC and CGN operate most of the nuclear power units. SPIC is mainly engaged in the introduction and implementation, research and development, transfer, application and promotion of third-generation nuclear power technologies.

As for the financing of nuclear energy projects, their owners are large state-owned enterprises. Fundraising for projects in the field of nuclear energy is mainly carried out by the holding company of each project. China allows private and other capital to participate in new projects in the field of nuclear energy as an equity participant. China National Nuclear Corporation (CNNC) and China General Nuclear Power Group (CGN) mainly own and operate nuclear power plants, which have the organizational and legal form of a joint-stock company. In addition, SPIC and the Chinese Huaneng Group are shareholders of some nuclear energy projects or own controlling shares. China Datang Corporation, CHN Energy and China Huadian Corporation are also equity participants in nuclear energy projects.

In China, the costs required annually for the safe operation of nuclear facilities, including spent fuel and radioactive waste management facilities, will be borne by the operators of such nuclear facilities. When a nuclear power plant is put into operation, a certain amount is charged from the income from electricity production each year. Every year, when planning and drawing up the financial budget of a nuclear installation, higher priority is given to a project related to nuclear safety. For radioactive waste disposal facilities that are closed normally, the necessary costs for post-closure maintenance, monitoring and emergency response are covered by fees charged to waste generators.

2. Legislative framework in the field of radioactive waste management

The Law of the People's Republic of China on the Prevention and Control of Radioactive Contamination establishes requirements for the management of radioactive waste, providing legal support for RW management programs. The Law states that in order to prevent and control radioactive contamination, the State exercises strict control, giving priority to safety, thus, creating an effective system for monitoring radioactive contamination. The Administrative Department for Environmental Protection under the State Council supervises and manages the process of protection and prevention of radioactive contamination nationwide. NPP operators apply for radionuclide emissions to the department responsible for environmental impact assessment and report the results of the relevant measurements on the regular basis. Radioactive liquid waste that cannot be released into the environment must be properly disposed of or stored. China's nuclear power plants have sufficient equipment to store waste generated during normal operation and anticipated operational occurrences. When processing waste, the storage of an excessive amount of unconditioned waste is excluded. The record and data of waste inventory are stored in accordance with the relevant laws and regulations. Solid radioactive waste of low and intermediate levels is buried in near-surface disposal facilities ; solid high-level waste should be disposed in a deep geological repository.

Nuclear power plants develop and implement a Waste Management scheme and measures related to the processing, storage and disposal of waste, effective control of releases of radioactive liquids. The scheme approved by MEE/NNSA ensures compliance with operational limits and characteristics for wastewater. The NPP Radioactive Protection Department implements an environmental monitoring program that monitors and assesses the radiological impact of a potential radioactive release on the environment.

In China, the code of laws, regulations, and standards in the field of radioactive waste management includes a wide range of measures to ensure the safety of radioactive waste management in order to achieve the goals of protecting people, society and the environment in the fight against radiological and other hazards.

The Regulation on the Safe Management of Radioactive Waste, adopted in 2012, defines the procedure for the disposal, storage, processing, and management of radioactive waste. It states that the proper management of radioactive waste complies with the principles of reducing the generation of radioactive waste, proper and safe management. The Ministry of Ecology and Environmental Protection is responsible for overseeing the safety and proper management of radioactive waste throughout the country and participates in the creation of a national information system for it together with departments responsible for the nuclear industry and other departments in order to exchange information.

China is also preparing a Guide on minimizing radioactive waste from NPP, at the moment its draft has been completed and is awaiting discussion. This Guide suggests minimizing radioactive waste, which should be focused on waste recycling and disposal processes.

Minimization measures include reducing the amount of RW generation and its possible reprocessing. NPP operators are obliged to ensure control over untreated gas emissions and liquid effluents release generated during normal operation of NPPs, as well as obliged to ensure compliance of radioactive waste, intended for disposal, with the acceptance criteria, provided that the amount of radioactive waste should be as low as reasonably achievable. The guidelines are aimed at reducing the doses of radioactive exposure to people, reducing radioactivity, the volume of generated radioactive materials, and reducing costs during the RW management.

China's nuclear safety program clearly states that its specific goal is to create an advanced and highly efficient waste processing, storage and disposal system adapted to the level of development of the nuclear industry. In fact, it is aimed at the complete final disposal of low- and intermediate-level waste in connection with the development of the nuclear industry. The long-term goal is to eliminate radioactive contamination in all aspects, eliminate all possible physical and nuclear safety risks associated with available radioactive waste, complete the construction of an underground research laboratory, and implement a project for the disposal of high-level waste.

3. Licensing

China has implemented a system of licensing the safety of nuclear facilities. The RW and SNF management without a license is prohibited. MEE/NNSA is responsible for issuing licenses for the nuclear facilities, including the approval of its location. Operators engaged exclusively in the processing, storage and disposal of radioactive waste are required to apply for a license for such activities, and this is handled and approved by MEE/NNSA.

In accordance with the legislation, the operator prepares and submits environmental impact assessment, analytical reports, final safety justification reports, quality control programs for nuclear installations, a commissioning program for nuclear facilities, contingency plans for nuclear accidents and other related documents to the IEE/NNSA prior to the start of construction and operation. Nuclear facility operators carry out scientific assessment of geology, earthquake seismology, meteorology, hydrology, environment and population distribution, and other factors, and provide reports on site safety analysis, meeting the requirements of nuclear safety technology assessment.

Within the framework of licensing legislation, all nuclear facilities, such as on-site SNF storage facilities (i.e. SNF pools and dry storage) and non-reactor SNF storage facilities, built for nuclear power plants and research reactors, undergo scientific demonstration and licensing procedures. Prior to licensing procedures, environmental impact assessment is prepared and submitted to MEE/NNSA for approval. After the reports have been studied and found to meet the requirements of nuclear safety, the operator of the nuclear installation receives a document containing an overview resolution of the nuclear facility location.

MEE/NNSA, together with its regional branches, conduct exercises, regular and unscheduled nuclear safety inspections in order to check whether facilities comply with regulatory requirements for nuclear safety and licensing. After the inspections, acts are drawn up that have instructions to correct the flaws of the work and ensure its compliance with the approved documents and requirements.

Operators of nuclear installations must inform MEE/NNSA about the amount of RW generated, the state of the reprocessing, storage, unloading, acceptance, and delivery of RW for disposal. Radioactive waste management operators must report annually to the relevant agency by March 31.

With regard to license holders who violate the rules and/or licensing conditions, the NNSA has the right to take enforcement measures when necessary: order license holders to make adjustments to their activities and correct the situation or even completely stop activities that threaten national security.

4. SNF management

China's NPPs store spent fuel elements in its storage facilities in strict accordance with nuclear safety regulations to ensure and maintain the integrity and subcritical limits of spent fuel. SNF underwater storage (spent fuel discharged from the reactor should be stored in the SNF pool for about 5-8 years) and water quality correspond to the provided chemical and physical properties. Containers were specially designed for SNF transportation, considering all the aspects of transportation. The NPPs under construction have signed long-term maintenance agreements, including the reception and storage of spent nuclear fuel with the relevant technological service companies.

Non-reactor SNF storage facilities in China meet the design and safety requirements. Operating organizations have developed safe operation plans on a range of issues, including storage, operating procedures, commissioning plans, quality assurance program, personnel training schedules, radiation protection program and emergency preparedness. Operational limits and conditions for facilities were determined, including parameters of subcriticality, radiation safety and residual heat removal.

Operation, maintenance, monitoring, inspection, and testing of temporary dry SNF storage facilities are carried out in accordance with prepared and approved procedures. The above-mentioned plans, regulations, procedures, and requirements include:

- SNF storage plan;
- Operating conditions of the storage module, the position and numbering of the SNF container;
- Checking the container and diving under water;
- Requirements for transportation and lifting;
- Conditions for continuous gamma monitoring;
- Supervision of radiation protection;
- Conditions for the storage module area;
- Conditions for daily inspection and supervision of storage containers, schedule of inspection and maintenance of storage modules, storage containers and shielded work boxes;
- Procedures for maintenance, testing and acceptance of equipment.

5. Policy and practice in the field of RW management

The RW management should be carried out in accordance with the general concept of safety without threatening future generations to satisfy their needs and aspirations.RW generators should ensure the general safety of RW management.

Radioactive waste should be stored in terms of its classification. Radioactive waste resulting from the use of nuclear technologies should be stored in centralized storage facilities at the provincial, municipal, and autonomous regional levels.

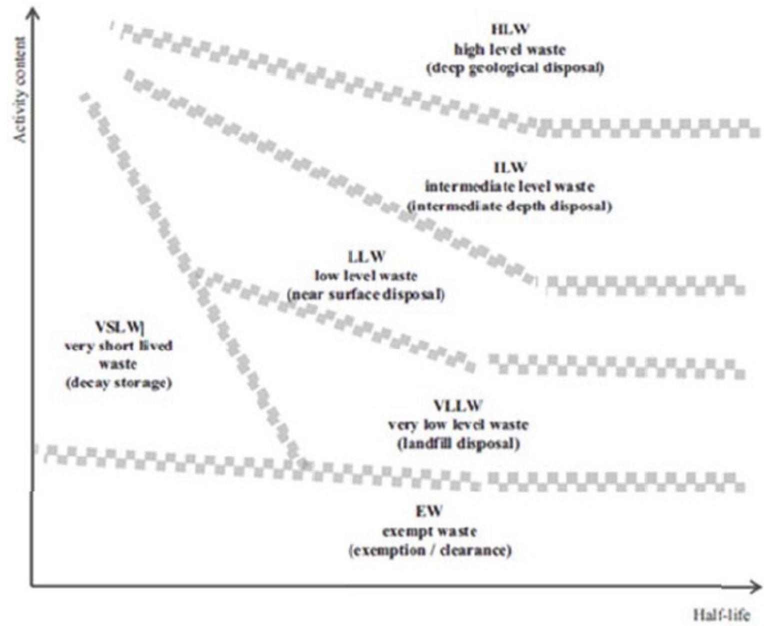
The gaseous and/or liquid waste must be discharged into the environment in accordance with national standards for the prevention of radioactive contamination. Solid radioactive waste is disposed of in accordance with its classification. Low- and intermediate-level waste is disposed of in a near-surface or deepened final isolation facility. High-level waste is centrally disposed of in a deep geological repository.

During the process of the design, construction, operation and decommissioning of nuclear facilities, measures such as source control, recycling and reuse, purification, optimized waste treatment should be taken to maintain efficiency and cost-effectiveness. According to regulatory requirements, auxiliary facilities for radioactive waste management are built by all operators of nuclear facilities. There are programs and procedures for the management of radioactive waste according to the classification at all nuclear facilities where RW is generated.

As a rule, gaseous/liquid radioactive waste is to be processed by nuclear installation operators and maintained at a reasonably achievable low level. Solid radioactive waste and liquid radioactive waste, that are not subject to treatment and release, are placed in stable and standardized waste containers that meet the disposal requirements. Methods of purification of gaseous radioactive waste at nuclear installations include filtration, adsorption and decay storage; methods of treatment liquid radioactive waste include filtration, evaporation, ion exchange, adsorption. Solid waste treatment methods include cementing, solidification/immobilization, super compression, and hot compression.

In China, radioactive waste is generated mainly at nuclear power plants, nuclear fuel cycle research reactors, when using nuclear technologies, as well as in the mining industry and the use of uranium (thorium). On November 30, 2017, CAEA published a public announcement on the classification of radioactive waste in the nuclear industry and the application scope of nuclear technologies.

With reference to the IAEA General Safety Manual: Classification of Radioactive Waste (GSG-1), a new waste classification scheme aimed at the final disposal of radioactive waste in a safe manner. According to the potential hazard of various types of waste and the degree of localization and isolation for disposal, radioactive waste is divided into VSLW (very short-lived), VLLW (very low-level), LLW (low-level), ILW (intermediate-level) and HLW (high-level).



Low- and intermediate-level waste are disposed on an industrial scale at three facilities in China:

• near Yumen, northwest Gansu Province;

• at the Beilong storage facility in Gunagdong Province near the Daya Bay Nuclear Power Plant;

• and in Feifengshan, Sichuan Province.

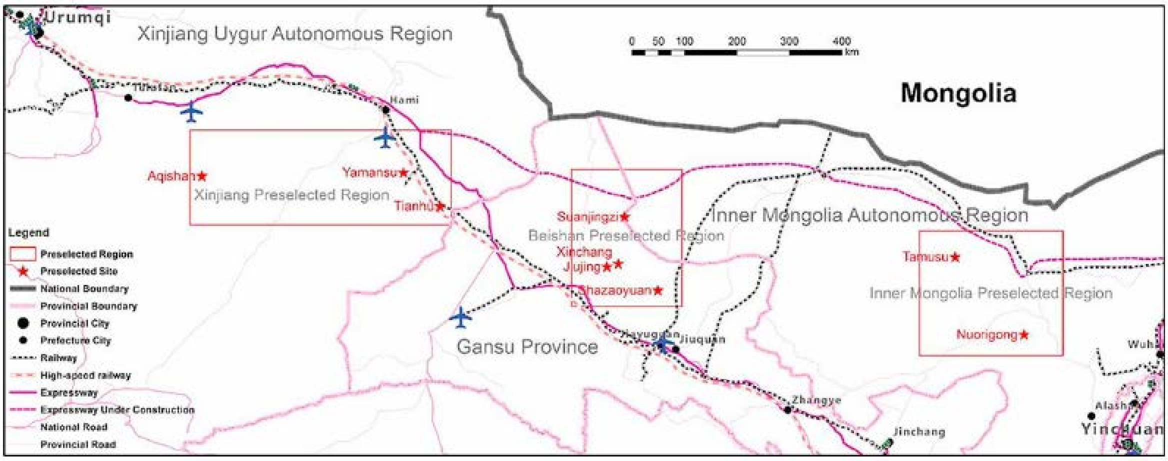
Liquid HLW generated from the processing of SNF should be disposed of in a deep geological formation. Within the framework of legislative and regulatory practice, deep geological repository for HLW must meet the safety requirements for more than 10,000 years after its closure.

Since the last review meeting, the State Council of the Republic of China in February 2017 has approved a document that called for speeding up the study on the HLW disposal. During the 13th five-year plan, the site location was approved for the underground research laboratory (URL) and the subsequent HLW DGR. The Research Institute of Uranium Geology (BRIUG) responsible for the development of the URL and the subsequent DGR made an assessment of the processes, geochemistry and safety of the sites, and the selection of key candidate site was completed. BRIUG developed the principles of geological disposal of high-level waste and, in accordance with them, developed criteria for the selection of possible sites for geological disposal of high-level waste in China.

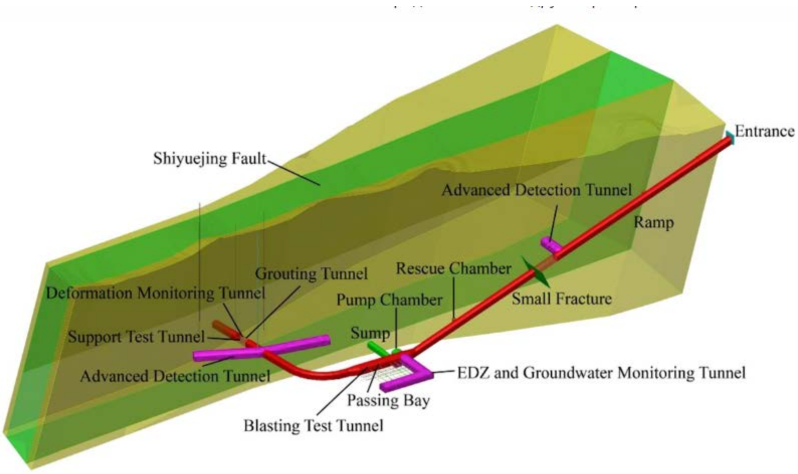
In 2021, China began construction of a large underground laboratory to study possibility of HLW disposal. The laboratory will have to prepare the ground for a future repository that is to safely isolate these materials for several tens of thousands of years.

The laboratory will be located in granite rock massif at a depth of up to 560 meters below the ground level in the Beishan district of Gansu Province. The URL was included in the list of the largest scientific construction projects in China in the 13th five-year plan (2016 – 2020). Its surface area will be 247 hectares, the total area of the premises – 2.39 hectares. The underground complex will have a total structural volume of 514,200 m^2 and 13.4 km of tunnels. The cost of the laboratory is estimated at 2.72 billion yuan ($422 million), and its construction will take seven years. The laboratory is designed to operate for 50 years, and if its research is successful and the site is suitable, a long-term underground storage facility for high-level waste will be built next to the laboratory by 2050.

Due to the fact that the repository must be located far from populated areas, historical or cultural sites, as well as environmental protection zones, but it also needs access to infrastructure so that personnel and materials can be sent there for the construction of the project, hundreds of scientists and engineers in China took 35 years of drilling wells in isolated areas for the whole country to finally choose a place for a laboratory in Gansu province.



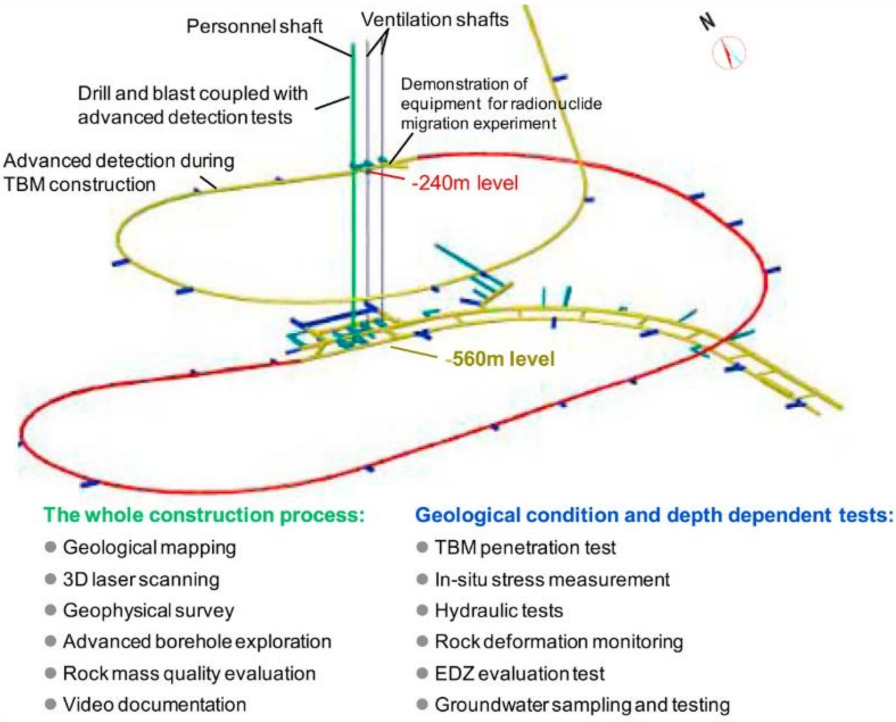
Scientists are required to comprehensively study the environment of the future repository, both on the surface and underground. This includes the study of the geological conditions of the site, the distribution and flow of groundwater, types, location and chemical composition of rocks and many other factors.



As the topic of deep geological disposal of radioactive waste is actively developing in China, the IAEA and the Beijing Research Institute of Uranium Geology (BRIUG), part of CNNC Corporation, signed an agreement on October 12, 2021, defining BRIUG as the "IAEA cooperation center for the deep geological disposal of high-level waste".

The signing ceremony was attended by the heads of the Atomic Energy Administration of China, and, virtually, by IAEA Director General Rafael Grossi and other IAEA officials.

The new cooperation center is the first of its kind. It will promote international academic exchanges and the expansion of joint research and training for R&D in the field of HLW geological disposal, as well as work on the design and construction of underground laboratories necessary for modeling geological storage facilities.



The signing of the agreement marks a new milestone in China's technological cooperation with other countries and is of great importance for ensuring nuclear safety and sustainable development of nuclear energy.

6. Public relations and informing

China attaches great importance to public awareness and communication with stakeholders, ensuring the public's right to know and participate. To this end, the Ministry of Ecology and Environmental Protection published a Scheme for the information dissemination on the regulation of nuclear and radiation safety (for trial implementation) and a Notification on enhancing informing on nuclear and radiation safety, and also published a Scheme of the Ministry's work on informing the public about nuclear and radiation safety and Administrative measures for the information dissemination on the regulation of nuclear and radiation safety, clearly defining the scope of information messages, as well as the content, timing, methods and channels of information dissemination.

The Ministry mainly interacts with the public and the media through the following messages and events:

- The publication of important information on regulatory activities is published on the official website of the Ministry, including the licenses, important review, and inspection activities (and results), reports on the construction and operation of nuclear installations, the results of monitoring of the environment and information on emergency situations.
- Dissemination of knowledge and information related to nuclear and radiation safety on websites, in newspapers, periodicals, on television, in publications and advertising materials.
- Public opinion research, distribution of questionnaires and holding symposiums and public hearings before the publication of important regulatory documents or decisions.

- Inviting media representatives to participate in important events for the exchange of experience in the field of nuclear safety regulation and inviting experts to answer and clarify issues of public concern.

The main content of information on the regulation of nuclear and radiation safety:

- Laws and regulations, standards, policy and planning of the Chinese Government in the field of nuclear and radiation safety;
- The fact of passing through administrative licensing procedures and issuing permits in the field of nuclear and radiation safety;
- Reports of safety supervision inspections and related activities in the field of nuclear and radiation safety;
- General safety status of nuclear installations;
- Results of monitoring of the radioactive environment;
- Contingency plans related to nuclear and radiation threats;
- Important nuclear and radiation occurrences (accidents) and conclusions on their investigation and elimination response.

The public participates in every stage of the environmental assessment, starting with the site selection and ending with the decommissioning of the NPP. The Law of the People's Republic of China on Environmental Impact Assessment states that in relation to projects that may have a negative impact on the environment or on public interests, public hearings, expert consultations, verification and other necessary measures should be taken to obtain the opinions of relevant departments, experts and the general public for drawing up environmental impact analysis before the project proposal is submitted for approval.

The chapter on public participation should be included in the environmental impact analysis during the selection of a nuclear installation site. Builders and operators should consider the proposals of the relevant departments, experts and the public, explanations on the acceptance or rejection of which will be attached to the environmental impact report, which will be sent to the regulator for approval. The Administrative Department for Environmental Protection under the State Council will not accept these environmental impact reports without a chapter on public participation.

At the stage of site selection, construction units, prior to extensive public consultations, disseminate information related to nuclear energy to the local public in a direct and effective way, such as distributing brochures, holding lectures and exhibitions on nuclear energy, and organizing visits to nuclear power plants.

The procedures for public participation in environmental impact assessment when site selecting are as follows:

- Construction departments must publish relevant information about the construction project within seven working days after the appointment of the organization conducting the environmental impact assessment.
- When an organization makes a preliminary conclusion on an environmental impact assessment, the NPP construction division should inform the public about the main content of the conclusion and publish a summary of the document in the media, social networks, local newspapers, magazines, on the Internet, on television, etc.
- After the publication of the environmental impact assessment and a short edition of the assessment in the local media, it is necessary to openly request public opinion through the Internet, a public reception, a survey, discussion meetings or public hearings, etc.

- Operating companies or institutions conducting environmental impact assessments should involve the public and collect proposals from the public and provide timely feedback on a special website or in an environmental impact assessment report.

Nuclear power companies are actively exploring effective means of communication with the public, creating an open and transparent communication system, and allowing the public to understand nuclear energy from a rational and objective point of view. The main ways of communicating with the public include:

- Online information, press conferences and corporate social responsibility reports. Each nuclear power company has created a normalized mechanism for the dissemination of information and a group of representatives. In addition to safe nuclear energy, the information published includes strategic planning, technology development and social responsibility, etc.
- Social networks such as microblogs and WeChat; subsidiaries, employees and experts are encouraged to actively communicate with the public via the Internet.
- Personal communication with the public. Each nuclear power company has established a mechanism for regular dialogue with the public, conducting surveys, forums, dialogues, telephone and online consultations, paying special attention to communication and feedback on various aspects and taking active external observation through dialogue.
- To promote the popularization of nuclear science in schools, CNNC has created a team of nuclear science teachers and organized a nuclear science competition. The Chinese company General Nuclear Power Group Co., Ltd. has developed materials on nuclear power to obtain support from local authorities to include these materials in the local curriculum for junior high school.
- Thanks to active tourism and exhibitions related to nuclear energy, each NPP has created an exhibition hall or auxiliary facilities at the project site and nearby cities. The Chinese company General Nuclear Power Group Co., Ltd. has created ten nuclear science exhibition halls in the country and has been implementing industrial tourism projects for more than ten years. In 2015, the number of visitors reached more than 250,000.

7. International cooperation

China participated in the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), carried out under the leadership of the IAEA. So far, China has appointed specialists to participate and assist INPRO steering committee, seminars, and technical conferences.

China has joined the Generation IV International Forum (GIF). China participated in the work of the HTGRS and sodium-cooled fast reactors steering committees. Several officials and specialists from China became members of the task force of the GIF working group.

China is one of the five founding members of the Global Nuclear Energy Partnership (GNEP). China actively participates in the work of the International Platform for Cooperation in the Field of Nuclear Energy (IFNEC).

CNNC signed a Memorandum of Understanding on Cooperation in the Nuclear Fuel Cycle Production Chain with the Research Institute of the Trnava Nuclear Power Plant (Vuje), Slovakia, in November 2015 at the 4th Meeting of the Leaders of China and Central and Eastern European Countries.

In 2019, China actively participated in international exchanges and cooperation in the peaceful use of atomic energy and reached important achievements within the framework of the “global” strategy in the field of nuclear energy. The cold functional test of the first foreign reactor HPR1000 – Unit 2 of Pakistan's Karachi NPP were completed, the main work on the construction of the nuclear island was largely completed, and the unit fully entered the commissioning phase of the system. China continued to train personnel on the operation and maintenance of power units 2 and 3 of the Karachi NPP.

CNNC signed a General Contract for the 7th and 8th Power Units of the Tianwan NPP and a General Contract for the 3rd and 4th Power Units of the Hudapu NPP with the State Atomic Energy Corporation Rosatom. In addition, CNNC signed an Agreement on strategic cooperation in the field of technical services and a contract for a project to train the technical management of the Turkish Akkuyu NPP with the Rosatom Atomic Energy Corporation. It seeks to expand cooperation in many areas, such as personnel training, technology modernization and transformation, improving equipment reliability and international exchanges.

CNNC signed a memorandum of understanding with Emirates Nuclear Energy to strengthen cooperation in the field of nuclear energy and was ready to create an industry-wide platform for CNNC supply chain management, investment and financing in foreign and global markets in order to jointly study and create a model for the development of China’s nuclear industry (industry + finance + foreign market) under the initiative “Belt and Road”.

In addition, CNNC signed a memorandum of understanding with Hungary, which clearly establishes cooperation in the field of personnel training in the field of nuclear energy, the construction of the second phase of the Paks NPP and the development of a nuclear industrial park.

CGN has signed a Package Agreement on cooperation on new British nuclear energy projects with Électricité de France (EDF) and the UK government for the joint construction of three major nuclear energy projects in the UK and the development of third-party markets. Among them, the Hinkley Point NPP project (using the French third-generation EPR nuclear power technology) went smoothly, and the first concrete unit of the nuclear island was made. For the Bradwell B project (using the Chinese nuclear power technology of the third generation HPR1000), a site survey was conducted.

CGN has signed contracts and memoranda of understanding with 9 companies of the Czech nuclear energy chain for the exchange of engineering construction regimes. CGN also actively monitored the nuclear energy markets in Southeast Asia, Central Asia, Central and Eastern Europe and other regions and maintained close ties and exchanges with government departments and partners in Kazakhstan, Indonesia, Cambodia, Poland, Slovenia, Slovakia and other countries to develop cooperation on new projects in the field of nuclear energy.

In addition, China also exchanges experience internationally in the field of nuclear import and export control, formation of a nuclear safety culture, development of nuclear energy and communication with the public. China actively participates in nuclear energy cooperation with the United Kingdom, the Russian Federation, France, Saudi Arabia, the Islamic Republic of Iran, Argentina, Brazil, Germany, and other countries. It exchanges experiences and information related to “global” nuclear energy strategies, including HPR1000, small reactor, floating power plant, digital nuclear power plants, decommissioning management and other key and research projects.

China continues to develop nuclear research cooperation with the Canadian Nuclear Laboratories (CNL) and the American Electric Power Research Institute (EPRI) and carries out international cooperation with EDF and the British National Nuclear Laboratory on advanced reactor digitization technology.

The project of the Shanghai Center of the World Association of Nuclear Power Operators (WANO) was unanimously approved at the WANO General Meeting on February 21, 2019, and the Shanghai WANO Center was officially launched. The Shanghai Center project is of great importance for the safe and stable operation of newly built nuclear power units in the vast Asian region represented by China. In the next phase, CNNC will collaborate with other nuclear power companies in China to jointly establish the Shanghai WANO Center as an exchange and cooperation platform for regional nuclear power operators with international influence.

A trilateral cooperation agreement was signed in 2020 by the National Operator for Radioactive Waste Management (FSUE NORWM), the Beijing Research Institute of Uranium Geology (BRIUG) and the Institute for the Safe Development of Nuclear Energy of the Russian Academy of Sciences (IBRAE RAS). Within the framework of the agreement, the parties agreed on the exchange of experience and provide consulting support in the issue of research and scientific work. Also, the document provides for the exchange of scientific personnel for internships and training, as well as visits by scientific staff to research facilities. The agreement complements the system of research work within the framework of the underground research laboratory currently under construction in the Nizhnekansk rock massif and the Chinese underground research laboratory in the Beishan district.

USA

SNF management strategy – direct disposal without pre-treatment
Waste Disposal Facilities and Projects
Pilot Plant for Isolation of TRU RAW and DGRDS (New Mexico , Waste Isolation Pilot plant – Geological repository). It has been operating as an object of final isolation of radioactive waste since 1999.
Yucca Mountain – SNF Disposal Facility Project (Yucca mountain nuclear waste repository, Nevada) . Status: In August 2013, the Federal Court of Appeal ordered the Nuclear Regulatory Committee to reopen the application for a license to build a DGR. The project is frozen by a political decision, and legislative contradictions serve as the reason for its stop.

characteristic	WIPP	Yucca Mountain
host rock type	**salt**	**tuff**
burial depth, m	**650**	**300**
Possibility of waste recovery	**eat**	**will**
start R&D	**1965**	**1978**
start of site selection	**1974**	**1983**
project status	**operated since 1999**	**frozen**
commissioning date		
veto power of the local community	**No**	**Yes**[11]
contract for the provision of monetary compensation to the local municipality	**Yes**	**Yes**

Underground research laboratories

	Climax	G- Tunnel	WIPP	Busted Butte
Purpose general / special	general purpose	general purpose	special purpose	special purpose
Host rock type	granite	tuff	salt	tuff
Depth, m	300	420	655	420
Operation period	1973-1983	1979-1990	since 1982	1996-2009

Responsible institutions in the field of radioactive waste management
Ministry Energy (Department of Energy, DOE), US government agency in the field of SNF and RAW management
In the project: operator responsible for waste management and implementation of the SNF and RAW disposal project [12](project development, R&D, licensing, construction and operation)

Regulator	Nuclear Regulatory Commission, NRC
	Environmental Protection Agency EPA

Forecast of HLW and SNF accumulation volumes of the US defense complex by 2048

Site	Waste type	Volume, m^3
"Savannah River"	Vitrified HLW	6 957

[11] However veto state, maybe to be rejected Government USA .

12The creation of such an organization is provided for by the provisions of the Strategy for the Management and Disposal of SNF and HLW, approved by the US Government, but Congress has yet to consider the issue of introducing appropriate amendments to national legislation.

" Hanford "	Vitrified HLW	14 089
	Volume of cesium and strontium from capsules after vitrification	453
	Vitrified HLW from Germany	3
National laboratory in pcs. Idaho	Calcined HLW	3661
	Sodium-containing waste after steam reforming treatment in a fluidized bed system	721
	HLW processed by electrometallurgical method	132
	SNF from naval reactors	4600
Spent nuclear fuel administered by the US Department of Energy	SNF	1800

Abbreviations and abbreviations:

US-DOE - United States Department of Energy.

US-NRC - United States Nuclear Regulatory Commission.

A.E.A. - Atomic Energy Act from1954.

National Environmental Policy Act (NEPA) from 1969.

Nuclear Waste Policy Act from 1982.

CISF (Consolidated Interim Storage Facilities) is a universal storage (project) for intermediate dry storage of SNF. CISF are facilities proposed for the temporary storage of spent fuel prior to final isolation at a deep geological disposal facility. CISFs will be similar to ISFSIs, providing dry storage of waste using safety barrier mechanisms. CISFs will be governed by Title 10 of the Code of Federal Regulations (10 CFR Part 72).

EPRI (Electric power Research Institute) – Electric Power Research Institute.

NNSA (National Nuclear Security Administration) – National Nuclear Security Administration, a division of the Department of Energy.

ESCP (Extended Storage Collaboration Program) is a cooperation program in the field of temporary storage of waste, which is coordinated by the Electric Power Research Institute (EPRI).

EPA (Environmental Protection Agency)

US Clean Air Act, C.A.A.

WIPP (Waste Isolation Pilot Plant – Geologic Repository) –is a pilot plant for the isolation of TRU RAW / DGRW.

NWF - Nuclear Waste Fund (FWF).

WAC (Waste acceptance criteria) – RAW acceptance criteria, technical and administrative requirements that the waste must meet for acceptance into storage, processing or disposal.

NORM (Naturally occuring radioactive material) – radioactive materials of natural origin.

TENORM (Technologically enhanced naturally taking place radioactive materials) –technologically advanced natural radioactive materials.

DU (depleted uranium) – in accordance with the Atomic Energy Agency definition, if depleted uranium is classified as radioactive waste, then it refers to LLW.

GTCC LLW (Greater than Class C Low-Level Radioactive Waste). According to the US Department of Energy classification, GTCC LLW is LLW under its jurisdiction (including non-military transuranic waste) with higher radionuclide activity than class C LLW.

ISFSI (**Independent Spent Fuel Storage Installation**) – a network of autonomous installations for the dry storage of spent nuclear fuel.

TRU RAW – transuranium radioactive waste.

HLW – high-level radioactive waste.

ILW – radioactive waste of medium level of activity.

LLW – low-level radioactive waste.

VLLW – very low-level radioactive waste.

R&D – research and development work.

Nuclear installation, NI – (definition from the EURATOM Directive No. 2014/87) a code-name that can be used to designate: a nuclear power plant, an enrichment plant, a nuclear fuel production plant, a reprocessing plant, a research reactor, a storage facility for spent nuclear fuel, storage facilities for radioactive waste located at the same site with the reactor, and are directly related to the operation of nuclear installations (NI).

Nuclear power USA is the largest in the world in terms of production. The country operates 94 nuclear reactors with a total capacity of ~100 GW and generates 20% of the total produced energy.

1. Policy and discipline of radioactive waste management in the United States of America

Responsibilities of state organizations

Nuclear Regulatory Commission (NRC) is an independent state agency that controls the work of both the commercial sector of the industry and a number of state-owned nuclear power facilities. The Agency supervises the maintenance and use of nuclear materials, the selection of sites for the location of nuclear installations, their construction, operation and closure. The NRC regulates the industry through the enactment of regulations. The Agency authorizes the issuance of licenses for the construction of nuclear facilities (and commercial nuclear reactors in particular), as well as their operation. The NRC approves permits for the possession and use of nuclear materials. The Nuclear Regulatory Commission is responsible for ensuring that facilities holding radioactive materials are protected from the risk of theft and human sabotage. Nuclear specialists Regulatory Commission carry out regular inspections of nuclear facilities for compliance with regulatory requirements. NRC manages the processes associated with the commercial use of radioactive materials, supervises the operation of facilities operating in the nuclear fuel cycle system, oversees the management of isolated sources of ionizing radiation for commercial purposes (including disused ones). Regulation is carried out in relation to three types of commercial nuclear materials: original, used, as well as their byproducts.

US Department of Energy (DOE) is responsible for the development of the nuclear industry, the nuclear weapons production program, oversees work within the framework of the nuclear and radiological non-proliferation program, as well as radioactive waste management and environmental restoration at contaminated sites and facilities. The Department of Energy is empowered to regulate nuclear activities carried out at its own facilities.

Despite the fact that the Nuclear Regulatory Commission and the Ministry of Energy use different systems of radioactive waste management, the work of both departments is coordinated.

US Environmental Protection Agency (EPA) enforces generally applicable environmental standards to protect the environment from harmful effects of toxic substances and radioactive materials. The Agency (EPA) is also authorized to develop and enforce standards for the remediation of contaminated nuclear sites. The EPA is also responsible for the approval of documents certifying the compliance of the DGR at the Waste Isolation Pilot Plant (WIPP) with the requirements applicable to the disposal facilities for transuranium waste, generated as a defense industry byproduct.

Pursuant to the Clean Air Act (CAA) standards of the Environmental Protection Agency define the dose of radionuclides, that is harmless for release into the air by nuclear facilities under the jurisdiction of the Department of Energy.

Commercial sector: radioactive waste management

Owners and operators of nuclear power plants along with other nuclear installations producing waste manage SNF and RAW prior to disposal, as a rule, in accordance with their operating license issued by the Nuclear Regulatory Commission. The management of radioactive waste in the United States is regulated by the Federal Cabinet of Ministers or the Government at the state level. Transfer of waste to state facilities for interim storage or disposal can be carried out at different stages of the RAW management process, depending on their type and volume. During the decommissioning of nuclear installations, waste is generated in both: commercial and public sectors.

Radioactive waste in the United States is classified according to a multi-level and extensive categorization system based on the degree of environmental hazard, origin, production method, and others.

Inventory lists of radioactive waste in the United States contain information about the waste already disposed, and also reflect data on so-called uranium and thorium "tails" – radioactive waste generated as a result of uranium/thorium mining/enrichment processes.

The US Nuclear Regulatory Commission also oversees the handling of certain categories of naturally occurring radioactive materials (NORM) and technologically enhanced naturally occurring radioactive materials (TENORM). The radioactivity level of these two waste types can range from slightly above acceptable levels to very high levels.

A separate category is "Mixed waste" – mixed low-level or transuranic waste, which is a combination of radioactive and other hazardous components of a non-radioactive nature.

New in the field of radioactive waste management:

June 2021. radioactive waste storage of the National Laboratory in Idaho (DOE) accepted last batch of waste, after that work on its closure began. Along with this process, Environmental Protection Agency had been awarded a contract to clean up the area adjacent to the radioactive waste storage facility.

In August 2021. The project of the WIPP equipment with a new ventilation system reached a significant stage, one of the two buildings complex foundation was completed. Highly efficient filtration systems will operate in the new HLW storage facility (5100 m^2) to clean the WIPP storage air discharges from the harmful particles and compounds.

In September 2021. Interim Storage Partners LLC has obtained a license from Nuclear Regulatory Commission for the construction of a radioactive waste disposal facility (in the state of Texas). Interim Storage Partners LLC is joint asset with the Waste Control Specialists LLC and Orano USA. The launch of the RWDF in Texas is scheduled for 2025. By 2048, NRC expects progress in the implementation of the geological disposal project for spent nuclear fuel.

In October 2021, the eighth section of the WIPP disposal facility was put into operation, designed for the disposal of transuranium waste transported from near-reactor storages. In spring of 2022, the eighth section began to be loaded with a new batch of waste.

2. Implementation of SNF and RAW Management Strategies

Owners and operators of nuclear power plants, as well as other nuclear installations that produce radioactive waste, manage SNF and RAW generated as a result of the operation of these installations until they are disposed of.

Since 1977, in the United States SNF processing had been prohibited. Meanwhile spent fuel in the country is classified as HLW, the Government holds responsibility for its final disposal in the DGR. Until such a disposal facility will not be built, SNF generated as a result of NPP operation will be directed to wet and dry storage facilities.

SNF disposal system development plan

The United States is developing a program for deep disposal of spent nuclear fuel, the Department of Energy has assumed the legal and moral obligations of the Federal Government for the proper handling of spent nuclear fuel and HLW produced in the United States, including their reprocessing or final disposal.

Research activities under the auspices of the Government

The US Department of Energy has developed a so-called. "Expanded Program for the Consolidation of Storage Operations" (the so-called " Extended Storage Collaboration Program") as a set of measures to improve the integration of SNF and HLW storage facilities into the overall waste management system, within which R&D is being carried out.

Consolidated Interim Storage Facility for SNF and reactor LLW

In April 2016 Waste control Specialists submitted an application to the Nuclear Regulatory Commission (NRC) for a license to build and operate a facility for the temporary storage of spent nuclear fuel, the so-called. Consolidated Interim Storage Facility, CISF at its site in Andrews County, Texas. The proposed storage system for dry containers at the facility will be above ground. One of the main principles of the implementation of CISF –is the location of the installation on the territory autonomous with respect to the site of the power reactor [13]. In January 2017, the

[13] CISF (Consolidated Interim Storage Facility) –installation of temporary dry container storage of spent nuclear fuel before final isolation at a deep geological disposal facility. The CISF project is similar to the existing stand-alone

Nuclear Regulatory Commission accepted Waste 's application control CISF construction licensing specialists for consideration. Upon receipt of this application, the NRC notified the public that the document had been entered into the register, and also announced the possibility of submitting a request for public hearings on the construction of an interim SNF storage facility. In April 2017 Waste control Specialists asked the Nuclear Regulatory Commission to temporarily suspend the ongoing review of the project's environmental safety, as well as the activities of organizing related public hearings.

In January 2018, the new owner of the project – Interim Storage Partners, requested NRC to reopen the license request, and the technical and environmental reviews of the request were reopened. After the request began to be considered, the NRC received a petition from the Texas public against the planned intervention in the state, the result of the settlement of the collective request has not yet been made public. In May 2020, NRC published a report on the impact of CISF Interim Storage Partners LLC on the environment as part of the implementation of this project for the temporary placement of spent nuclear fuel near the town of Andrews, Texas. The Nuclear Regulatory Commission is in the final stages of conducting studies on the environmental safety of the CISF project.

In parallel with the Texas storage initiative, in March 2017, Holtec International has applied to the Nuclear Regulatory Commission for approval to build and operate a "high-rise" HI-STORE CISF to be located in Lee County, New Mexico. In February 2018, the NRC also accepted and placed the application on the registry. Public response was immediate, with a petition to the NRC opposing the creation of a HLW storage facility in New Mexico. NRC has opened the call for requests to organize public hearings on the HI-STORE CISF project. In March 2020 Holtec's CISF Impact Report was published International on the environment during the implementation of the SNF and HLW storage facility project in Lee County, New Mexico. When reviewing the CISF licensing application in 2021, experts from the Nuclear Regulatory Commission came to the conclusion that the design height of the installation does not correspond to the permissible.

Criteria for categorization of waste as HLW

The US Department of Energy is developing a system for handling waste generated from the reprocessing of spent nuclear fuel, on the same principle as the HLW scheme. The current law on atomic energy (Atomic energy act, 1954) and the Nuclear Waste Policy Act (Nuclear Waste Policy Act, 1982) prescribes that HLW is subject to final disposal at deep geological disposal facilities.

This regulation applies to the entire volume of waste generated as a result of the processing of spent nuclear fuel. At the same time, the conditioning of some categories of waste from among those received from processing, which actually do not have a high level of radioactivity, becomes illegal. This circumstance does not allow timely decisions on the safe disposal of certain waste streams at the level of the Department of Energy, which would significantly reduce the risks to the health of personnel and the environment.

On October 18, 2018, the Department of Energy published a request from the Federal Register to provide the public with data on the criteria for categorizing certain waste groups as high-level. In 2019, the Ministry of Energy published the characteristics, in the presence of which the waste is not classified as HLW:

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spent nuclear fuel facilities (ISFSI), and provides isolation of waste using protective barrier mechanisms. Settings will be regulated by 10 CFR, part 72.

- if the content of radionuclides in the material does not exceed their maximum allowable concentration established for low-level waste in accordance with Section 10 of the Code of Federal Regulations (10 CFR, pp. 61.55);
- if the material, according to its characteristics, does not require isolation in a deep geological repository and meets the technical specifications waste disposal facility.

Thus, radioactive waste that meets these criteria (or one of them) is subject to classification based on its own radiological properties.

The Ministry of Energy's clarification regarding the categorization of waste as HLW has facilitated the management of waste from SNF processing. The amendment also made it possible to place lower-level wastes in RWDFs or specialized intermediate storage facilities, regardless of the

In August 2020, the Department of Energy completed the assessment of the first waste stream under the National Environmental Policy Act (National Environmental Policy Act, NEPA) and an updated HLW categorization concept, proposing scenarios for further actions and methods of handling for each type of waste received.

3. Radioactive waste management in the United States of America

<u>RAW: processing and conditioning</u>

Radioactive waste is processed in order to obtain a form of waste that is stable in its structure, as well as to minimize the volume of releases of radioactive and other hazardous compounds into the environment.

Most of the enterprises licensed in the field of radioactive waste management in the United States of America do not distinguish between the concepts of "processing" and "conditioning" of waste.

<u>Waste processing and immobilization plant " Hanford "</u>

Construction of the Waste Treatment and Immobilization Plant began in 2012 at the site of a former fissile material and nuclear fuel fabrication plant in southeastern Washington State by decision of the US Department of Energy.– Waste treatment and Immobilization Plant. The report of the Accounts Chamber on the quality control mission at the facility in 2012 contained comments on technical malfunctions caused by functional deterioration of the RAW storage facilities at the Hanford site. The government set the task of preventing an accident as a possible consequence of the critical state of the storage facility, in which radioactive waste is placed before the stage of their transfer to vitrification. By 2017, the facility was under the control of the Accounts Chamber, the General Inspectorate, the Security Council for Defense Complex Enterprises, and other US regulators. The estimate for the upcoming work was recalculated, and the project was estimated at $17 billion, subject to completion in 2023. The Defense Enterprise Safety Board in 2019 adopted a report from the Department of Energy on the elimination of critical technical failures of the Hanford radioactive waste storage facility.

The project also bears the alternative name –" Vit Plant " Literally, vitrification plant (English vitrification) RAW, which will use a patented technology tested at the <u>Savannah RAW processing facility River Site</u> and demonstration site for waste treatment and packaging West valley [14]. This method consists of solidifying radioactive waste with a vitrifying chemical mixture, heating the resulting material to 2,100 degrees Fahrenheit (1149 degrees Celsius), pouring the composition into steel containers for subsequent stabilization. Vit Plant", the last stage of construction of which is scheduled for completion in 2023, is today the world's largest enterprise

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[14] West Valley Demonstration Project, US, state of New York, Rock Springs Road.

in the field of radioactive waste management, and is also intended for the conditioning of nuclear waste from the defense industry, stored for decades in 177 underground tanks. The design life of the plant is – 40 years.

First of all, in order to implement the DOE program for the direct transfer of LLW from temporary accommodation points to processing enterprises at «Vit Plant» low-level liquid radioactive waste will be cured. At a later stage of the operation of the enterprise, according to the plan, the conditioning and vitrification of high-level radioactive waste will be carried out.

212,000 m ^{3} of historical radioactive waste, obtained as a result of the plutonium production process, are placed in underground tanks at the enterprise. Most of the waste contained in underground reservoirs is low-level liquid waste.

Bechtel Company National Inc. is the prime contractor for the Department of Energy responsible for the design, construction and operation of the Waste Treatment and Immobilization Plant, with AECOM as its subcontractor.

New waste conditioning units at the Idaho National Laboratory and the "Savannah River site"

The US Department of Energy initiated the construction of installations for conditioning waste accumulated as a result of the work of the National Laboratory in pcs. Idaho and the Savannah River facility.

In underground collectors at the site of the National Laboratory in pcs. Idaho stores materials derived from the reprocessing of historic radioactive waste, most of which is calcine – a thermally evaporated byproduct of spent nuclear fuel reprocessing. At the site of the laboratory, a complex plant for the processing of sodium-containing waste accumulated at the enterprise has been built and is already being put into operation. This is the only plant of this type, according to the envisaged design capabilities, it will process 3.4 million liters of LRW located at the site of the National Laboratory in pcs. Idaho.

At the Savannah River facility, in turn, the conditioning of accumulated radioactive waste continues. Waste in the process of processing here is divided into two fractions: the stream of HLW of a smaller volume and the stream of LLW of a larger volume. The highly active fraction is transported to a plant for the processing of radioactive waste produced at the enterprises of the US defense complex, where it is vitrified and placed in storage until the stage of possible geological disposal begins. The low activity fraction is immobilized on the Savannah River using a cement matrix.

To optimize the RAW conditioning system at the Savannah River facility, in 2021, a Salt Waste Treatment Complex (Salt Waste Processing Facility, SWPF). The Salt Waste Processing Plant has become a critical element of the salt processing system at the Savannah River site, with a design capacity to process ~23,000 m3 of brine per year. SRS currently has ~320,000 m ^{3} of slurry in storage before being transferred to processing, with a forecast of 280,000 m ^{3} of which will be processed at SWPF.

The SWPF plant is equipped with technological tools and equipment developed by specialists from the Argonne and Oak Ridge National Laboratories, the principle of which is to use a system of ring centrifugal contactors. The use of this principle today is the most modern solution for the targeted elimination of cesium-137, strontium-90 and actinides from salt waste. salt Waste Processing Facility decontaminates solutions containing cesium and barium-137 by ~99.998% while removing strontium and actinides.

A number of DOE -operated facilities continue to inventory and characterize accumulated transuranic waste today, such as the TRU waste processing centers at the Argonne, Oak Ridge and Los Alamos National Laboratories, as well as the Hanford and Savannah River facilities. The amount of legacy historical transuranium waste placed in temporary storage is decreasing as a result of their gradual processing and final isolation.

<u>LLW disposal</u>

Industrial LLW in the United States is to be disposed of in near surface final isolation facilities operated under licenses issued by the Nuclear Regulatory Commission.

Four commercial facilities for the LLW disposal were closed as the process of waste reception had been completed:

- "Beatty" (State of Nevada) – in 1993,
- "Maxey Flats" (State of Kentucky) – in 1977,
- “Sheffield” (State of Illinois) – in 1978,
- "West Valley" (State of New York) – in 1975.

After the closure of these facilities, their sites retain a closed status, work on the nuclear facilities decommissioning is carried out in accordance with an individually developed plan approved by the regulator.

There are currently four commercial LLW disposal sites in operation in the country:

- " Energy Solutions " (Barnwell, South Carolina)
  Barnwell Proving Ground accepts for disposal low -level waste of classes A, B and C with a restriction on the disposal of radioactive waste with an activity of more than 0.37 TBq, this criterion allows the enterprise to cut off the reception of a volume flow of sealed sources of ionizing radiation of higher activity.
- Energy Solutions (Clive, Utah)
  Polygon accepts mixed (mixed low-level waste, M LLW) and LLW of class A.
- US Ecology (Richland, Washington)
  Polygon DOE at the Hanford site accepts for disposal LLW of class A, B, and C, radium, naturally occurring radioactive materials, and waste from accelerator operations.
- "Waste Control Specialists " LLC (WCS, Andrews, State Texas)
  landfill accepts A, B, and C class LLW from generators under the Texas Generating Collaboration Program Compact (from Texas and Vermont). LLW from generators in not of the Texas Agreement are accepted for placement in the WCS only on the basis of the signing of an additional agreement. At the WCS waste from commercial and state producers are zoned by separate m tanks.

In the US, the responsibility for acceptance, ownership, storage, and final containment of industrial LLW lies with the Nuclear Regulatory Commission, the Department of Energy, the Environmental Protection Agency, and a number of designated government agencies. Final isolation method prescription for commercial LLW –disposal at one of the four licensed landfills. The Nuclear Regulatory Commission also provides for the coordination of alternative scenarios for the disposal of certain types of LLW at facilities licensed for a different profile (for example, the neutralization of hazardous waste or the processing of industrial non-radioactive waste).

<u>Federal system of LLW management</u>

Six subordinate DOE nuclear facilities operate disposal sites for LLW: Hanford, National Laboratory in pc. Idaho, Nevada Proving Ground National Security Site), Los Alamos National Laboratory, Oak Ridge Test Site, and the Savannah River site. A LLW disposal facility is currently under construction near Portsmouth, New Hampshire, and a license for its operation has also been obtained. Today, a project is being developed for a new disposal facility for LLW as part of the program to clean up and restore the Oak Ridge nuclear test site.

For a long period, only three RWDS were in active operation in the USA: Energy Solutions in Utah, Hanford in Washington State and Barnwell in South Carolina. From the 70s. in the United States, a site was being searched for a new near-surface disposal. Among the candidates were sites in the states of New Jersey, Utah, California, Colorado, Texas and others.

The Andrews Disposal Facility only accepts waste under the jurisdiction of the US Federal Government under the low-level Radioactive Waste Policy Amendment Act (LLWPAA) of 1985. The operating license is valid until September 2024, renewable for 10 years. At the initiative of the Ministry of Energy, an agreement was signed on taking ownership of the Andrews RWDF in order to carry out regulation and long-term maintenance and control of the facility at the decommissioning stage.

2. *Spent nuclear fuel management*

US nuclear facilities generate and store spent fuel from industrial nuclear power plants, defense plants, and research reactors. By 2020, in accordance with the inventory data, ~84,000 MTTM SNF have been produced in the USA, 39,000 of which are placed in dry storage facilities at the reactor sites of nuclear power plants.

Spent fuel administered by the DOE is also stored in pools or in dry storages. DOE pools are primarily held as long-term storage facilities until the final stage of isolation is feasible. Research reactors are also equipped with wet storage facilities, and after the material has cooled down, the spent fuel is transported to a specialized storage facility at the Department of Energy.

Approximately 2,500 MTTM of spent fuel have been stored in wet and dry storage facilities at the Ministry of Energy's subordinate facilities.

Spent nuclear fuel final isolation

In the United States, there are currently no operating facilities for the disposal of spent nuclear fuel. In 2008, the Department of Energy submitted a request to the Nuclear Regulatory Commission for permission to build a geological repository at Yucca Mountain, Nevada, for the disposal of spent fuel and HLW.

The Department of Energy has developed an R&D program for the long-term management of spent nuclear fuel and monitors the implementation of tasks within its framework. The US Department of Energy is also faced with the task of creating alternative methods and technologies to ensure long-term storage, transportation and geological disposal of accumulated and predicted SNF and RAW. Research work focuses on the development of technologies that minimize waste, improve safety, and complement institutional radiation protection measures.

Finland

Strategy of SNF management

Direct disposal of spent nuclear fuel without preliminary processing

Organizational aspects

State government body in the field of SNF and RW management	MEE — Ministry of Labor and Economy (www.tem.fi)
	STM — Ministry of Social Security and Health (www.stm.fi)
Organization responsible for the implementation of the RW disposal project (project development, R&D, licensing, construction, operation)	Posiva** — POSIVA (www.posiva.fi)

Main regulators

The body of state regulation in the field of atomic energy safety	STUK — Radiation and Nuclear Safety Directorate (www.stuk.fi)

RW and SNF inventory

Type	Stored	Disposed
NPP SNF	2261 tHM	0
Research reactors SNF	21,3 kgHM	*
VLLW	204 m^3	**
LLW	1691 m^3	6541 m^3
ILW	1970 m^3	2117 m^3
HLW	0	0

** it is possible to send SNF back to the USA*
*** VLLW is disposed in the DF for LLW and included into inventory of LLW*

1. Overview of nuclear energy sector of Finland

In Finland, two nuclear power plants are operated at the Loviisa and Olkiluoto sites.

Tab.1. Operating nuclear power plants in Finland (June 2022).

NPP	Reactor	Reactor type	Capacity (MW)	Commissio (year)
Loviisa	Loviisa 1	PWR	507	1977
	Loviisa 2	PWR	507	1978
Olkiluoto	Olkiluoto 1	BWR	890	1978
	Olkiluoto 2	BWR	890	1980
	Olkiluoto 3	PWR	1600	2022

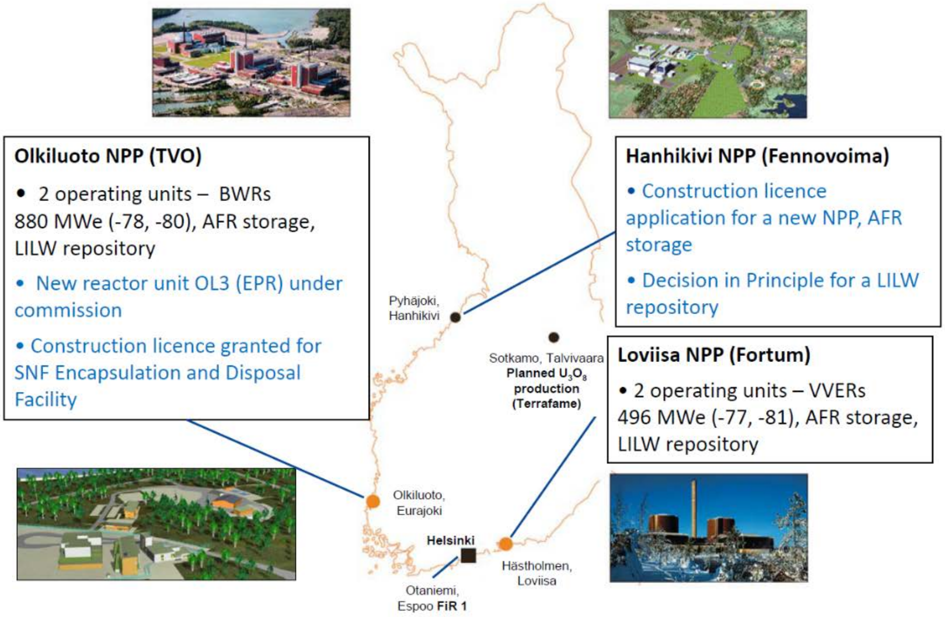
The Finnish Government approved the first principles of the organization of radioactive waste management in 1978:

- each waste generator is responsible for the management of its own SNF and RW generated during the operation of nuclear installations, as well as for the costs associated;
- low- and intermediate-level radioactive waste (LILW) is disposed on the territory of Finland;

- SNF management involves either its permanent return to the United States, or its processing on its own.

In 1983, the Finnish Government introduced the Law on the establishment of a Radiation and Nuclear Safety Operator (STUK) and defined the goals and schedule of R&D in the field of the RW management at existing nuclear power plants. For the first time, a 1983 decision proposed a scenario according to which the country’s energy companies had to consider the possibility of SNF disposal in Finland. The 1983 decision stated that if a national decision on the disposal of spent nuclear fuel is implemented, then measures should be taken no earlier than 2020.

The amendment to the Nuclear Energy Act of 1994 prohibits the import and export of radioactive waste to and from Finland, respectively. Since 1990, the geological repositories for LILW have been operating at Olkiluoto and Loviisa. Fennovoima plans to build its own low- and intermediate-level RW disposal facility at the Hanhikivi site in the 2030s.



Among the many issues of nuclear energy, the Finnish Energy Association has been regularly assessing the level of public support for the project of geological repository of radioactive waste for almost 40 years. In the 2019 survey, the majority of respondents expressed confidence in geological disposal facilities – there were 37% of them, and this was the first time when the opinion of skeptical citizens turned out to be in the minority – there were 36% of them. The slowly but steadily growing trust in geological disposal facilities is seen as the result of long-term systematic work by the parties involved.

2. Nuclear legislation and regulations

Today's Finnish nuclear legislation is based on the Nuclear Energy Act of 1987, as well as on the Auxiliary Decree on Nuclear Energy of 1988. In 1994, a significant amendment to the Nuclear Energy Act was adopted, reflecting a new policy that emphasizes national responsibility for the management of radioactive waste generated in Finland. In general, the export and import of nuclear waste, including spent nuclear fuel, is prohibited in the revised law. A notable exception is allowed for the FIR-1 research reactor. Thus, in accordance with the Law on Nuclear Energy, the provisions prohibiting the export of nuclear waste do not apply to SNF that were generated as a result of the operation of a research reactor in Finland. The legislation in the field of nuclear energy was updated and reformed in 2008 in accordance with the current level of safety requirements and the new Constitution of Finland from 2000. The new Constitution requires that the general principles of protection of citizens be enshrined in legislative acts.

Finland actively participated in the process of developing a proposal for the European Council directive on the management of SNF and RW. In 2013, the Law on Nuclear Energy and the Law on Radiation were amended in order to comply with Directive 2011/70/Euratom of July 19, 2011, establishing a framework for responsible and safe management of spent nuclear fuel and radioactive waste. The Nuclear Energy Law was revised in 2015 to ensure the independence of STUK and to allow the issuance of legally binding regulatory documents. The updated law on radiation was adopted in 2018.

The provisions on the use of nuclear energy in the Law on Nuclear Energy also relate to the management of SNF and RW. The Law provides that the licensee, whose actions lead to the formation of RW, is responsible for all waste management operations and related costs.

3. Licensing activities of RW and SNF management

Licensing of the currently operating radioactive waste disposal sites at the Loviisa and Olkiluoto NPP sites was carried out in accordance with the legislation in force until 1987. The current licensing process is defined in the current legislation.

If the operating license is issued for a longer period than 10 years (or 15 years in the case of nuclear waste disposal facilities), a regular review of the DF safety is required to be submitted to STUK. The regular review of the license terms provides good opportunities for conducting a comprehensive security check of DF.

On the basis of the Nuclear Energy Act, STUK issues secondary licenses for SNF and RW management activities, such as licenses for the operation of near-surface disposal facilities for VLLW, licenses for export, import, transfer and transportation.

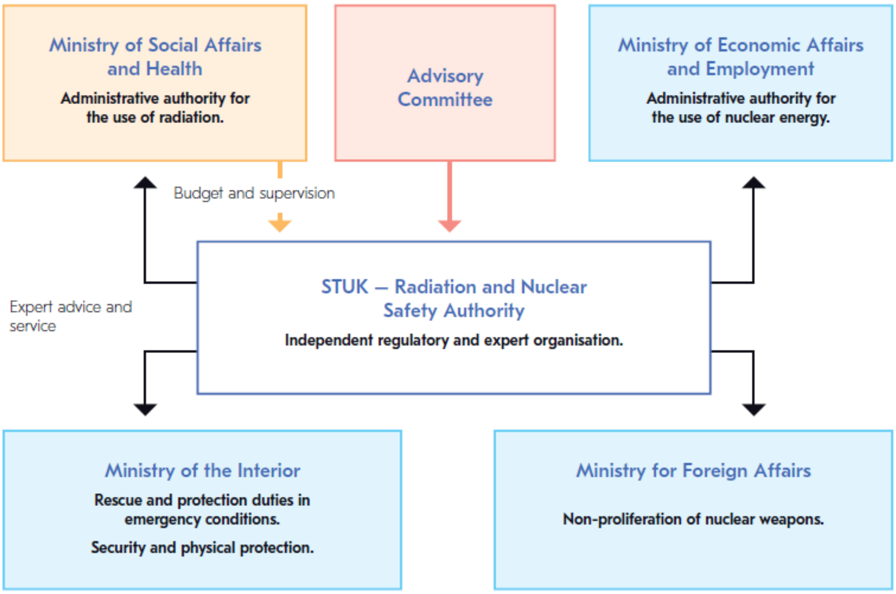
In accordance with the Law on Nuclear Energy, the licensee whose activities lead to the generation or have already led to the generation of radioactive waste is responsible for all measures for the management of nuclear waste and their proper preparation, as well as for the costs incurred.

The Law “On Radiation” provides for the management of radioactive waste of non-nuclear use. The responsible party (i.e. the licensee or any company/organization using ionizing radiation sources in its practice) is obliged to take all necessary measures to ensure the safety of radioactive waste generated as a result of the operation of nuclear power plants. The State, in turn, bears secondary responsibility if the producer of nuclear or non-nuclear radioactive waste is unable to fulfill its obligations to handle them.

4. Regulators

STUK monitors compliance with the Radiation Law and subsequent decrees and regulations. STUK is an independent governmental organization regulating the control of radiation and nuclear safety and nuclear materials. STUK is an administrative unit within the Ministry of Health and Social Welfare. It is important that regulatory control over the safe use of radiation and nuclear energy is carried out by STUK independently. No ministry can make decisions on matters falling within the competence of STUK by law. STUK does not have any duties or obligations that would contradict regulatory control.

The scheme of structural interaction between STUK, ministries, and other involved organizations of the industry



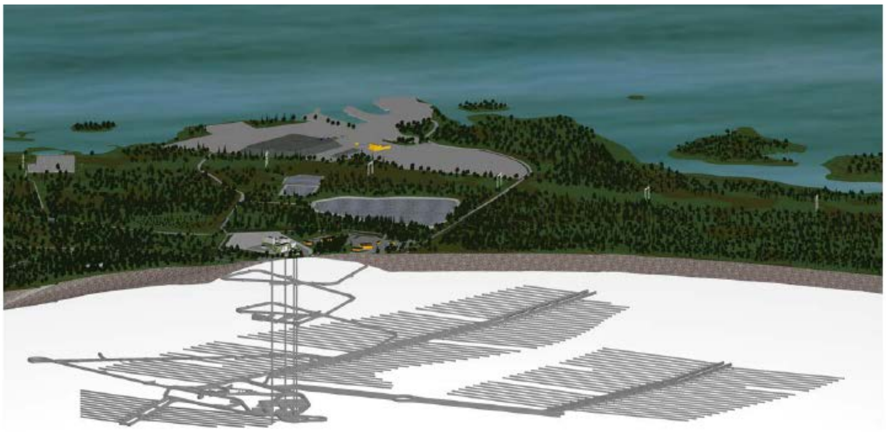
STUK is responsible for communication with the public and the media on radiation and nuclear safety issues. STUK also uses social media platforms for two-way public communication.

5. Practice and plans on RW and SNF management

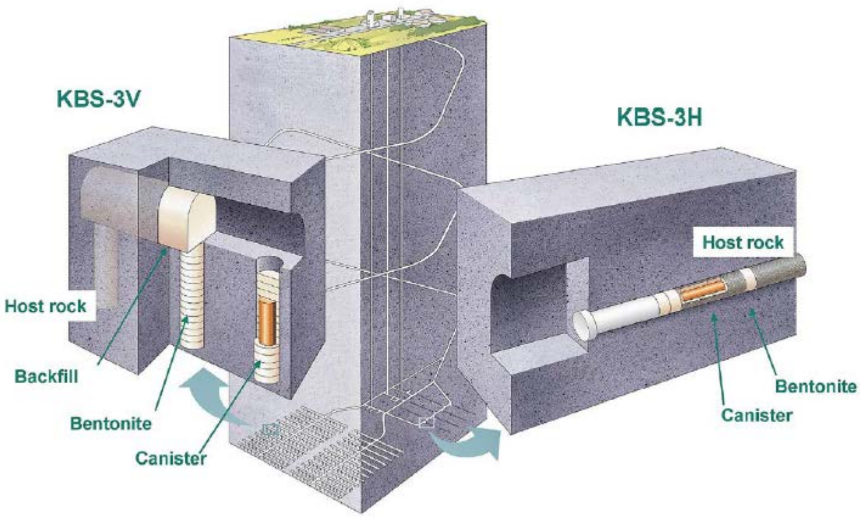
Currently, the main sources of radioactive waste in Finland are waste generated as a result of the operation of two nuclear power plants and one small research reactor. Non-nuclear radioactive waste is generated at several facilities using radioisotopes for medical, research and industrial purposes.

The spent nuclear fuel from the activities of the NPP is stored at the reactor sites until its disposal. Initially, the fuel is cooled for a period of one to five years in the pre-reactor holding pools. Loviisa NPP has a separate integrated storage facility built according to the type of pool. Olkiluoto NPP has a separate storage area for spent nuclear fuel, which is common to all reactor units.

Olkiluoto NPP: project diagram of an underground facility and a network of disposal tunnels for vertical waste disposal



Olkiluoto NPP: tunnel system for placing pennal with vertical (KBS-3V) and horizontal (KBS-3H) radioactive waste



The spent fuel from the FIR-1 research reactor is currently stored at the Otaniemi plant site. The main scenario for handling SNF before dismantling a research reactor is its return to the United States in accordance with the acceptance program “SNF of foreign research reactors of the U.S. Department of Energy (DoE)”. The total volume of this spent fuel is about 340 kg (about 25 kg of uranium).

The treatment of LILW before disposal is currently carried out at the NPP in accordance with their operating licenses and other provisions.

In accordance with the strategy of Finnish NPP operators, low- and intermediate-level waste generated as a result of reactor operation should be disposed of in rocks at power plant sites. At Olkiluoto, the LILW DF operation began in 1992, and at Loviisa – in 1998. The DF of Loviisa is located at a depth of about 110 m in granite rock. Olkiluoto DF is located at a depth of 60 to 95 m in tonalite rock.

Currently, the licensing process of the Olkiluoto LILW DF is being prepared. TVO started these plans at the end of 2018, and the EIA phase of the planned facility was launched in 2020. Also, the LILW DF will be expanded in the 2030s to be able to receive all the LILW of the Olkiluoto NPP during the planned 60 years of its operation. Further expansion of the disposal facility is also planned for waste from the decommissioning of existing NPP units in Olkiluoto.

6. Non-nuclear RW management (including sources)

The two available methods of handling non-nuclear RW are either to return the sources to the supplier/manufacturer, or to transfer them to national long-term storage facilities under the jurisdiction of the STUK nuclear regulator.

Such RW materials are stored in a temporary storage facility at the DF in Olkiluoto. The disposal of sealed sources of ionizing radiation and other non-nuclear radioactive waste is included in the license for the operation of the Olkiluoto LILW DF (2012). The actual LILW disposal began at the end of 2016.

7. DGR project status

The Finnish Policy on Radioactive waste management was formulated in 1983. At this stage, the main principle was agreed upon: licensees should be ready to organize the final disposal of waste in Finland in a safe and environmentally acceptable way if it is impossible to use international storage facilities for this purpose. According to Finnish legislation, radioactive waste generated in the country is subject to permanent disposal in Finland (Nuclear Energy Act 990/1987, Amendment 1994).

The development of the DGR project began with thorough research in 1983, and Posiva Oy, the company responsible for the DGR project, was founded in 1995. In 1999, the site and the Olkiluoto concept (KBS-3) were chosen as the preferred one.

In the 2000s, fundamental decisions were made on the final disposal of RW and SNF, which stated that the SNF of the Olkiluoto 1-3 and Loviisa 1-2 reactors would be disposed in the DGR. The application for a license for the construction of the facility by Posiva was submitted to the Government in 2012, the Government issued a license for the construction of a SNF disposal facility in 2015. The construction of the DGR began in 2016, and the construction of a waste encapsulation point on the surface in 2019. Posiva plans to apply for an operating license to the Government in the near future, and the process of SNF disposal will begin in 2024-2025.

There is no provision on the mandatory recoverability of RW and SNF at the stage after the closure of the DGR in the current Finnish legislation. The reversibility of DGR is not required, but it is not prohibited. Posiva Oy is an independent license holder and a future operator of DGR. It is a private limited liability company owned by Teollisuuden Voima Oyj (TVO - 60%) and Fortum Power and Heat Oy (40%), which are operators and owners of nuclear power plants at two sites in Finland.

The parties responsible for radioactive waste and spent nuclear fuel are obliged to cover all the costs of handling them, including the construction of a storage facility. The Finnish Nuclear Waste Management Fund (VYR) is a guarantee of full coverage of expenses in this area. The Fund operates under the Ministry of Economy and Employment, but its budget is not an integral part of the state. The purpose of this Fund is to collect, store and reliably invest funds that may be required for the management of nuclear waste in the future.

France

SNF management strategy: SNF processing
Organizational aspects:

Government body in the field of SNF and RAW management	Ministry of Comprehensive Environmental Transformation* and its Directorate General for Energy and Climate DGEC ** Since May 2022, there have been 2 equal ministers in the ministry: Minister of Environmental Transformations and Territorial Development** C. Bechu and Minister of Energy Transition*** A. Pannier-Runacher.* ***Ministère de la Transition écologique et de la Cohésion des territoires* ****Ministère de la Transition énergétique*
Organization responsible for the implementation of the radioactive waste disposal project (project development, R&D, licensing, construction, operation)	ANDRA — National agency for the radioactive waste management (Agence nationale pour la gestion des dechets radioactifs)

Main regulatory bodies

State regulatory body in the field of the safety of the nuclear energy	ASN — Nuclear Safety Authority (Autorite de Surete Nucleaire)

1. Review of principles for organizing the nuclear sector in France

France derives about 70% of its electricity from nuclear energy, due to a long-standing policy based on energy security. Government policy, set under a former administration in 2014, aimed to reduce nuclear's share of electricity generation to 50% by 2025. This target was delayed in 2019 to 2035.

In February 2022 France announced plans to build seven new reactors of the EPR2 type with their expected commissioning in 2035.

France is the world's largest net exporter of electricity due to its very low cost of generation, and gains over €3 billion per year from this.

The country has been very active in developing nuclear technology. Reactors and especially fuel products and services have been a significant export.

NPP	Reactor	Reactor type	Capacity (MW)	Put into operation (year)
Belleville	Belleville-1	PWR	1310	1987
	Belleville-2	PWR	1310	1988
Blayais	Blayais-1	PWR	910	1981
	Blayais-2	PWR	910	1982
	Blayais-3	PWR	910	1983
	Blayais-4	PWR	910	1983
Bugey	Bugey-2	PWR	910	1978
	Bugey-3	PWR	910	1978
	Bugey-4	PWR	880	1979
	Bugey-5	PWR	880	1979
Cattenom	Cattenom-1	PWR	1300	1986

	Cattenom-2	PWR	1300	1987
	Cattenom-3	PWR	1300	1990
	Cattenom-4	PWR	1300	1991
Chinon	Chinon B-1	PWR	905	1982
	Chinon B-2	PWR	905	1983
	Chinon B-3	PWR	905	1986
	Chinon B-4	PWR	905	1987
Chooz	Chooz B-1	PWR	1500	1996
	Chooz B-2	PWR	1500	1997
Civaux	Civaux-1	PWR	1495	1997
	Civaux-2	PWR	1495	1999
Cruas	Cruas-1	PWR	915	1983
	Cruas-2	PWR	915	1984
	Cruas-3	PWR	915	1084
	Cruas-4	PWR	915	1984
Dampierre	Dampierre-1	PWR	890	1980
	Dampierre-2	PWR	890	1980
	Dampierre-3	PWR	890	1981
	Dampierre-4	PWR	890	1981
Flamanville	Flamanville-1	PWR	1335	1985
	Flamanville-2	PWR	1335	1986
Golfech	Golfech-1	PWR	1310	1990
	Golfech-2	PWR	1310	1993
Gravelines	Gravelines-1	PWR	910	1980
	Gravelines-2	PWR	910	1980
	Gravelines-3	PWR	910	1890
	Gravelines-4	PWR	910	1981
	Gravelines-5	PWR	910	1984
	Gravelines-6	PWR	910	1985
Nogent	Nogent-1	PWR	1310	1987
	Nogent-2	PWR	1310	1988
Paluel	Paluel-1	PWR	1330	1984
	Paluel-2	PWR	1330	1984
	Paluel-3	PWR	1330	1985
	Paluel-4	PWR	1330	1986
Penly	Penly-1	PWR	1330	1990
	Penly-2	PWR	1330	1992
Saint-Alban	Saint-Alban-1	PWR	1335	1985
	Saint-Alban-2	PWR	1335	1986
Saint-Laurent	Saint-Laurent-1	PWR	915	1981
	Saint-Laurent-2	PWR	915	1981
Tricastin	Tricastin-1	PWR	915	1980
	Tricastin-2	PWR	915	1980
	Tricastin-3	PWR	915	1981
	Tricastin-4	PWR	915	1981

Nuclear activities are governed in France by a range of legislative and regulatory provisions, the objectives of which are public health and safety and protection of the environment.

Depending on the level of radioactivity, a distinction is made between activities regulated by the Public Health Code (medical activities for example), those subject to the regulations for Installations Classified for Protection of the Environment (ICPE), and by the Environment Code, those subject to the regulations for Basic Nuclear Installations (BNI) and Defense related nuclear facilities and activities.

The main principles of the national radioactive materials and waste management policy are based on the following:

- The industrial producers of radioactive waste and spent fuel are responsible for these substances, without prejudice to the liability of those who hold these substances in their role as persons or entities responsible for nuclear activities. They finance the management of radioactive waste and spent fuel as well as the decommissioning of their facilities. The corresponding funds must be secured by the creation of dedicated assets, under the control of the State;
- The quantity and the harmfulness of the radioactive waste must be minimized;
- The disposal in France of radioactive waste from abroad, as well as of radioactive waste resulting from the reprocessing of spent fuels and radioactive waste from abroad, is prohibited[15];
- As this is a subject that concerns society as a whole and which has consequences for future generations, the public must be involved in the decisions on the radioactive materials and waste management.

Implementation of these principles is built around a management framework consisting of three pillars:

- a specific legislative and regulatory framework;
- a public agency devoted to the management of radioactive waste, called ANDRA (French national radioactive waste management agency);
- a National Radioactive Materials and Waste Management Plan (PNGMDR), updated every three years.

The French legislative and regulatory framework in the field of the RM and RW management is based on the European directives and national laws:

Legal Act	Content
Directive 2014/87/Euratom of 8 July 2014 amending Directive 2009/71/Euratom of 25 June 2009	The directive on the nuclear safety of nuclear installations
Directive 2011/70/Euratom of 19 July 2011	The directive on the responsible and safe management of spent fuel and radioactive waste
Directive 2013/59/Euratom of 5 December 2013	The directive on the basic radiation protection safety standards
Act 91-1381 of 30 December 1991	Act set the management principles and the main orientations for research on the management of high level, long-lived radioactive waste (HLW-LL).

15 **Excluding the disposal of radioactive waste from the Principality of Monaco.*

Programme Act 2006-739 of 28 June 2006	The law regulates the issues of the sustainable management of radioactive materials and waste, defining the general framework for radioactive waste management. Act covers all radioactive materials and waste. It sets the orientations and goals for research and development on management solutions for radioactive waste with no operational management solution and specifies how decommissioning and waste management is to be financed. It recalls the ban on the disposal of foreign waste in France, as well as the responsibility of the producers of spent fuels and radioactive waste. It also establishes tools for dialogue with the public. The Act was supplemented by the Ordinance of 10 February 2016, notably with the assessment of the legal and organisational arrangements for the management of radioactive materials and waste, and the organisation of ten-yearly peer reviews of radioactive materials and waste management. The Act also stipulates that the Government is vigilant about improving the legal and organisational arrangements with regard to the management of radioactive materials and waste, taking account of experience feedback, the results of the assessments and technical and scientific developments.
Act 2016-1015 of 25 July 2016	The law specifies the conditions for creating a reversible deep geological repository for high-level and intermediate-level long-lived radioactive waste

The first peer review concerning the French radioactive waste management system was held in France in 2018, within the framework of an ARTEMIS mission organized by the IAEA. The international experts Mission conclusions underlined the fact that France has established a radioactive waste management framework covering all the issues, with numerous strong points, notably in terms of skills and the continuous progress approach.

2. French National operator on the RW management

The **French national radioactive waste management Agency ANDRA**, the national radioactive waste management agency, is a State public institution, created in 1991*.

**The division for radioactive waste management operated until 1991 as part of the Commissariat for Atomic Energy of France (formed by the Decree of General Charles de Gaulle on October 18, 1945) and only since 1991 it became an independent organization. Thus, the real experience of ANDRA activity in the field of radioactive waste management and operation of RWDF dates back to the end of the 50s of the last century, from the project of creation and commissioning (1969) of the CSM disposal facility for LLW and short-lived ILW in the Manche Department.*

The role of ANDRA

ANDRA is an industrial and commercial institution (EPIC) tasked with finding, deploying and guaranteeing safe management solutions for all French radioactive waste in order to protect present and future generations against the risks this waste presents.

The role of ANDRA has been defined by three successive acts:

- the Act of 30 December 1991 relative to research in the management of high-level long-lived radioactive waste (this Act created the Agency as a government-funded institution, entrusting it with research into deep geological disposal of high-level and intermediate-level long-lived radioactive waste);
- the Planning Act of 28 June 2006 relative to the sustainable management of radioactive materials and waste (this Act extends and reinforces the role of the Agency and its areas of activity);
- the Act of 25 July 2016, which details the conditions for creating a reversible deep geological repository for high-level and intermediate-level long-lived waste.

Placed under the authority of the Ministries responsible for energy, the environment and research, the Agency is independent of the radioactive waste producers. In accordance with Article L. 542-12-1 of the Environment Code, ANDRA receives a State subsidy to help fund its assigned missions of general interest. It is the State operator for the implementation of the public policy for radioactive waste management.

ANDRA operates three industrial sites. Two facilities are dedicated to low-level and intermediate-level short-lived waste (LLW/ILW-SL):

- the CSM, which is a disposal facility "undergoing decommissioning", insofar as ANDRA is still scheduling improvement work on the repository cover;
- the CSA, which is a disposal facility in operation and also comprises waste packaging facilities (drum compacting, injection of metal containment structures).

These two facilities come under the system governing basic nuclear installations (BNIs).

ANDRA also operates the **CIRES** (Industrial center for collection, storage and disposal) which comprises:

- treatment and packaging facilities for very low level (VLL) waste;
- a disposal facility for VLL waste;
- a collection building for transit before transfer to the treatment facilities for the waste collected by ANDRA, particularly waste from the medical sector and institutional research ("small producers" waste);
- a treatment building for the waste from the "small producers" in which operations such as the grinding of the tritiated scintillation bottles, separation of the solid part from the liquid part, or preparation by assembly of liquid containers can be carried out. This building was commissioned in 2016 and now enables ANDRA itself to treat waste for which it previously subcontracted the packaging operations;
- storage facilities for the waste collected by Andra which does not yet have an operational disposal route.

ANDRA realizes i.a. the following activities:

- manage the closure of the CSM (Manche waste repository), the first French above-ground disposal facility for low-level and intermediate-level radioactive waste;
- study and devise disposal solutions for the types of waste which do not yet have one, namely low-level long-lived waste (LLW-LL) and high-level and intermediate-level long-lived waste (HLW/ILW-LL): the Cigéo project;
- look for and study solutions to optimise radioactive waste management in order to preserve the radioactive waste disposal facilities, which are a rare resource;
- ensure a public service mission for:

- the collection of old radioactive objects held by individuals (old luminescent watches and clocks, objects containing radium for medical uses, certain minerals, etc.)$
- the clean-out of sites contaminated by radioactivity;
- the drafting every three years of the National Inventory of radioactive materials and waste on French soil (last edition published in 2018 - https://inventaire.andra.fr/).

- informing and communicating with all audiences;
- preserving the memory of its disposal facilities;
- sharing and capitalising on its know-how internationally.

3. Policy of the nuclear regulator ASN

Created by the 13 June 2006 Act on nuclear transparency and security, the nuclear regulator ASN is an independent administrative authority tasked with the regulation and oversight of civil nuclear activities, of nuclear safety and radiation protection to protect people and the environment in France.

ASN's policy is to achieve progress in the safe, consistent and structured management of radioactive materials and waste. To do this, it puts this into practice in its various roles (regulation, authorisation/licensing, oversight, information, monitoring of research). It considers that the methods of drafting the PNGMDR and its recommendations are essential to the implementation of this policy of improvement and is thus fully committed to this. One of the priorities is the existence of safe management routes for each category of radioactive materials and waste, whatever their activity, lifetime, origin, giving preference to definitive management solutions. This implies identifying the foreseeable needs for storage and disposal facilities, ensuring compliance with the requirements of the Environment code and implementing a stepped approach to management methods (reduction at source, recycling, reuse, incineration, disposal).

The aim is to ensure that the BNI licensees and the waste producers assume their radioactive waste management responsibilities.

ASN submits every year the Report on the state of nuclear safety and radiation protection in France to Parliament.

4. National Radioactive Materials and Waste Management Plan

The National Radioactive Materials and Waste Management Plan, enshrined in the "Waste" Act of 28 June 2006, is a central component of national policy oversight, implemented in 2006.

The Environment Code requires that the Government draft a National Radioactive Materials and Waste Management Plan (PNGMDR), every three years. It is then transmitted to the Parliamentary Office for the Evaluation of Scientific and Technological Choices (OPECST) for evaluation, and, after its positive reaction, is made public.

The drafting of the PNGMDR is based on the National inventory of radioactive materials and waste, the first edition of which dates from 2004 and which is revised every three years. All these data are published on France's Open public data platform and on the website of the National Inventory.

This national plan inventories the existing radioactive materials and waste management routes and the technical solutions adopted. It identifies the foreseeable needs for storage or disposal facilities and specifies the capacity necessary for these installations as well as storage durations. It sets the general targets, the main time-frames and the schedules enabling these time-frames to be met while taking into account the priorities it defines. It determines the targets to be achieved for radioactive waste for which there is not yet final management solution. It organizes the implementation of research and studies regarding the management of radioactive materials and waste. It determines the persons responsible for its implementation and the indicators for monitoring the progress of this implementation.

For the first time, pursuant to the provisions of Ordinance 2016-1060 of 5 August 2016 and the decision of the National Public Debates Commission (CNDP), the drafting of the plan was the subject of a public debate. This national public debate prior to the drafting of the fifth edition of the PNGMDR served to clarify the main issues linked to the management of radioactive materials and waste and to involve the public in forthcoming decisions on this subject, which concerns society as a whole. As this is a long-term subject, which concerns society as a whole, as well as future generations, public involvement and transparency are fundamental values of the French PNGMDR.

5. The National Inventory of radioactive materials and waste

Produced by ANDRA in accordance with the provisions of the Environment Code, the National Inventory of radioactive materials and waste aims to meet the following three objectives:

- List the radioactive materials and waste present on French territory as at 31 December of each year, on the basis of the information provided by the holders of the materials and waste;
- Establish forecasts of future radioactive materials and waste production at dates defined by ministerial order and, for the waste, at the end of operation of the waste producing facilities, based on information provided every three years by the holders of the radioactive materials and waste.
- Outline the broad trends for the production of radioactive materials and waste according to several possible scenarios.

ANDRA's 2021 inventory shows that as of the end of 2019 France then had a total of 1.67 million cubic metres of radioactive waste of which 60% was from power generation, 27% from research, 9% from military, 3% from industry and 1% from medical applications.

ANDRA noted that 90% of this volume has a storage and disposal route through its existing facilities, and once the CIGEO deep geologic repository is in operation it will cater for the balance.

6. Radioactive waste management policy

A management policy founded on transparency and democracy

One of the pillars of the radioactive materials and waste management policy consists in ensuring there is a democratic dialogue at all levels:

- locally and continuously, through the setting up of Local Information Committees (CLI) for the treatment and disposal facilities;
- with the general public: the PNGMDR is a key factor in transparency (see § B.1.3);
- at Parliamentary level: the authorisation of a deep geological disposal facility is regulated by law (article L. 542-1-10 of the Environment Code, modified by the 25 July 2016 Act). The main change introduced by this Act concerns the creation of a pilot industrial phase ahead of operation, in order to confirm the facility’s reversibility and its safety case, notably by means of an in-situ test program. The results of this industrial pilot phase shall give rise to a report from ANDRA, an opinion from the national commission tasked with the annual assessment of progress in research and studies relating to the management of radioactive materials and waste, an opinion from ASN and the opinions of the neighbouring regional authorities.

The responsibilities of the nuclear players/licensees

Article L. 542-1 of the Environment Code states that “the producers of spent fuel and radioactive waste are responsible for these substances, without prejudice to the liability of those who hold these substances in their role as persons or entities responsible for nuclear activities”. However, various players are also involved in waste management: the companies tasked with transport, the processing contractors, the managers of storage or disposal centers, the organisations in charge of R&D aiming to optimize this management.

The responsibility of the radioactive waste producer does not exonerate the other players mentioned above from their own responsibility for the safety of their activities. The scope of responsibility of the waste producer includes its financial liability. The fact that a radioactive waste producer has transferred its waste to a storage or disposal facility does not mean that it is no longer financially liable for it.

In accordance with the PNGMDR orientations, the waste producers must continue to aim to limit the volume and activity of their waste, upstream in the design and operation of the facilities and downstream in the management of the waste. Compliance with this goal is ensured both by ASN, through the process to approve the BNI waste studies, and by the cost involved in dealing with this waste, which necessarily encourages the producers to attempt to minimize the quantities. The quality of packaging of the waste must also be guaranteed given the long-term radiation protection and safety implications following disposal.

The radioactive waste management strategies

ASN and ASND (nuclear regulator in the field of defense) periodically assess the strategies implemented by the licensees to ensure that each type of waste has an appropriate management route and that the various routes are mutually coherent. More particularly, ASN and ASND remain attentive to ensuring that the licensees have the necessary treatment or storage capacity to manage their radioactive waste and anticipate sufficiently far in advance the construction of new facilities or renovation work on older facilities.

7. Radioactive waste and materials: improving existing management modes

A long-term management solution now exists for nearly 90% of the volume of radioactive waste. The other waste is stored pending the availability of final management solutions. The majority of the waste is in packages. Some of the radioactive waste is still in bulk or packaged in such a way as to render it incompatible with acceptance in the disposal routes for which it is intended. This mainly concerns legacy waste which must be retrieved and conditioned in fully compatibility with acceptance criteria.

Very low level waste (VLLW)

Management of very low level waste (VLLW) was a specific topic of the public debate held in 2019, in preparation for the fifth edition of the PNGMDR. Following the public debate held in 2019, in preparation for the fifth edition of the PNGMDR, the Ministry responsible for energy and ASN decided on the following orientations for the management of VLL waste:

- continued work to look for additional disposal capacity by identifying a second disposal center and comparison of the advantages and drawbacks of the decentralised disposal facilities close to the production sites, in terms of the protection of human health and safety and of the environment;
- changes to the regulatory framework applicable to the management of very low level waste, in order to introduce a new possibility of targeted exemptions allowing the case-by-case reuse of very low level radioactive metallic waste, after melting and decontamination.

Low and intermediate level, short-lived waste (LILW-SL)

The management of the low and intermediate level, short-lived waste, the technological waste, which accounts for most of the traffic, is:

- either, after pre-compacting on-site in 200-litre metal drums, shipped directly to the CSA press for further compaction and then definitive disposal after concreting in 450-litre metal drums. Certain noncompactable technological waste is packaged in metal containers of 5 m3 or 10 m3. The most highly radioactive is packaged on site in concrete containers and disposed of directly in the CSA;
- or, when incinerable and of low activity, shipped in plastic drums to the CENTRACO incineration unit, while the low-contamination metal scrap is sent to the fusion unit of the same plant in metal containers.

The waste resulting from processing in CENTRACO is dealt with as follows:

- the residual ash and clinkers from incineration are conditioned in 450-litre metal drums and definitively disposed of in the CSA repository;
- the 200-litre ingots resulting from fusion are disposed of definitively in the CSA or Cires, depending on their level of activity. Similarly, depending on their specific activity, the ventilation filters for treatment of the gases and fumes, the slag and the furnace refractory materials produced during the maintenance operations are disposed of in the CSA or Cires.

Low-level, long-lived waste (LLW-LL)

The LLW-LL waste essentially comprises graphite waste from the gas-cooled reactors, radium-bearing waste and bituminized waste from the treatment of radioactive liquid effluents on the Marcoule site. ASN considers it vital to move forward in the setting up of management routes for this waste.

An appropriate disposal solution proportionate to the safety issues represented by this waste must therefore be developed. This solution must address several issues: technical (choice of site, understanding of the waste, disposal concept), consistency with the strategy envisaged by the waste producers for the decommissioning of their facilities and the storage of their waste, as well as ethical and societal questions specific to this waste, which represents a minor hazard but one that persists over long time-scales.

In July 2013 the Municipal Federation of Soulaines hosting the ANDRA's operating RW disposal centers, gave its consent to geological investigations being conducted over a 50 km^2 sector to study the feasibility of a near-surface disposal facility for low-level long-lived waste (LLW-LL). The results as a whole were summarized in the interim report submitted to the government in July 2015.

This first reconnaissance phase identified a zone of about 10 km^2 for the rest of the studies, displaying the most favourable geological characteristics on which to focus continuation of the study of a near-surface disposal facility for LLW-LL waste.

The PNGMDR 2016-2018 therefore asked ANDRA to continue its investigations on this site and evaluate the inventory of LLW-LL waste liable to be emplaced in it, while looking for alternative management solutions for waste which it will not be possible to dispose of there. The PNGMDR 2016-2018 thus recommended continued work to characterize the waste, R&D on reprocessing and the feasibility of the envisaged management scenarios.

The development of an Overall industrial system for management of all the LLW-LL radioactive waste is also expected in near-term outlook. In order to produce this Industrial system, ANDRA carried out additional geological investigations between 2017 and 2018 in the area of interest proposed in 2015. With the waste producers, it is also continuing to conduct studies of the radiological inventory of the waste and its behaviour in a disposal situation. At the same time, ANDRA also examines the possible creation of a disposal area for very low level (VLL) waste in the future center dedicated to LLW-LL waste. Given the predicted volumes of VLL waste to be produced by future decommissioning operations, plans must be made immediately for new disposal capacity and synergy could be created with the existing ANDRA centers in the Aube département. This Overall Industrial system for management of LLW-LL waste is now expected to be ready in coming year.

Reversible RW disposal in deep geological formations (deep geological disposal, DGR)

ANDRA carries our studies in the field of the RW geological disposal and geological storage. These studies are covered by the Waste Act which adopts the following guideline "After storage, ultimate radioactive waste which, for nuclear safety or radiation protection reasons, cannot be disposed of on the surface or at shallow depth, shall require deep geological disposal". The research carried out by ANDRA in the Bure laboratory is contributing more specifically to the study of the feasibility and safety of such a repository.

This disposal project, called the industrial Centre for geological disposal (French acronym Cigéo), provides for underground installations in a layer of clay situated at a depth of about 500 meters and about one hundred meters thick, in the Meuse/Haute-Marne départements.

This disposal project will be designed to take 10,000 cubic metres of HLW, mostly vitrified (from reprocessing 45,000 t used fuel), and 73,000 m^3 of long-lived ILW, of which 15,000 m^3 is metallic parts from spent fuel.

The reversibility issues are defined by the 25 July 2016 Act on the procedures for creating a deep reversible disposal facility for HLW and ILW-LL. In 2015 an amendment to the 2006 Act clarified that for the CIGEO project HLW being 'recoverable' referred to short-term practicality, while 'reversible' meant guaranteeing long-term policy flexibility.

ANDRA has carried out R&D on the base of results of experiments in the Meuse / Haute-Marne underground research laboratory (URL). This URL enables studies of geological environments, in particular at the main level 500m down, designed to evaluate in-situ the thermal, hydraulic, mechanical and chemical properties of the clay host rock and to reproduce the expected interactions between the materials liable to be used in the repository and the host rock.

ANDRA is conducting in-situ tests and using technological demonstrators to examine techniques for building various components of the repository architectures. ANDRA studies the actual behavior of materials in-situ (characteristics in the broad sense, including the behaviour of the radionuclides), the behaviour of the materials interacting with the host rock. ANDRA also develops and tests processes for excavating, observing, monitoring and closing the disposal facility. The studies in the URL were deployed progressively to meet the various milestones of the disposal facility project. More than 1,600 m of drifts have currently been excavated and made available for the scientific and demonstration program. Nearly 14,000 measurement points are installed in the underground laboratory and continuously transmit data on the behaviour of the rock and the structures built.

Several milestones have been reached for the Cigéo deep geological disposal project. In 2016, ANDRA sent ASN a safety options report (DOS) on the Cigéo project, ahead of the facility's creation authorisation application. The review of the file, which began in the spring of 2016, underwent an international peer review under IAEA supervision in November 2016. The ASN opinion of 11 January 2018 concerning the Cigéo DOS is based on the recommendations of the Advisory committee for waste and on the report by the experts of this IAEA mission.

The ASN in its opinion letter underlines the satisfactory technological maturity achieved at the DOS stage and makes a number of recommendations.

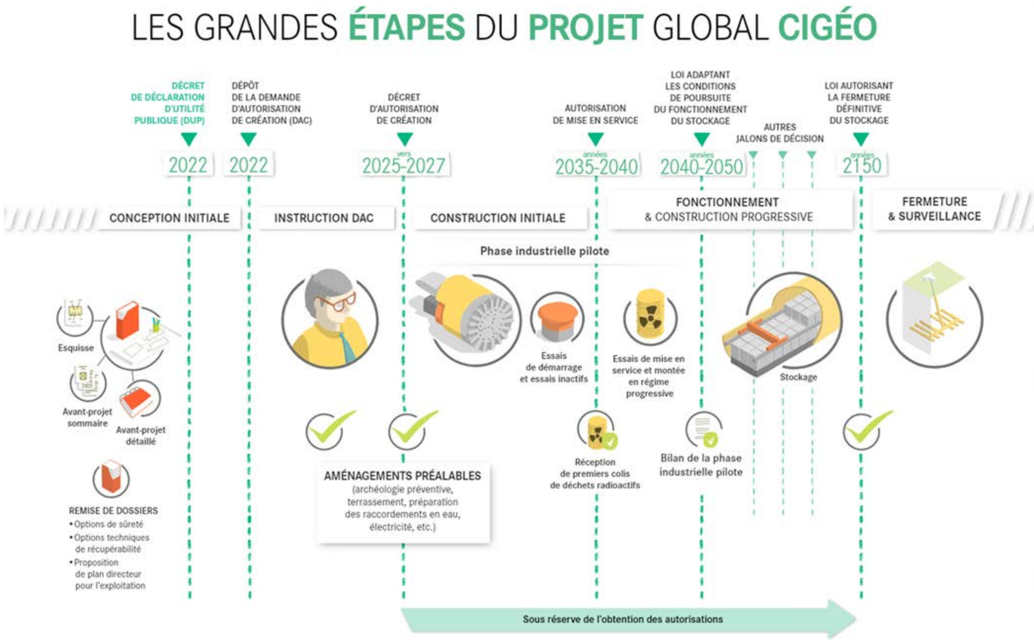
Following the ASN opinion letter, ANDRA consolidated its study program and set up a program concerning the scientific and technical activities aimed at consolidating what had already been achieved and enhancing the justification of the choices made for the DAC dossier (Demande d'Authorisation de Construction), notably in terms of design and sizing. Changes to the configuration of the Cigéo project also enabled optimisations to be made, both in terms of implementation (standardisation, construction site safety) and from the economic standpoint.

ANDRA also undertook work to demonstrate the possibility of emplacing bituminous waste packages through changes to the design of the vaults and management of the corresponding risks, tailored to the identified accident scenarios.

ANDRA also carried out adaptability studies at each of the major steps in the project. These studies' results were regularly updated.

After the French State Council (Conseil d'Etat) had examined the Declaration of Public Utility (DUP) application, the French government signed the decree declaring the public utility of Cigéo on 8 July 2022. The DUP approval will reaffirm the public utility of Cigéo and will also allow for land management on the site of the Cigéo project. This stage precedes the submission of applications for obtaining administrative licenses, in particular those related to the reorganization necessary for the implementation of the project (preventive archeology works, construction of road and rail networks, electricity networks and water supply systems). The DUP approval is also a key stage when applying for a construction license (planned for the end of 2022) in the licensing process of Cigéo project.

ANDRA defines the following **milestones for the implementation of the industrial Centre for geological disposal Cigéo:**



Until 2022	✓ design; ✓ submission of a dossier on safety, technical feasibility of the principle reversibility/re-retrieval and operating plan guidance
2022	Prime-minister decree on approval of the Declaration of Public Utility
2022	applying for a construction license
The following years are indicated as approximate	
2025 - 2027	Decree on approval of the construction license
2027 – 2035	✓ construction of the 1st stage ✓ pilot stage of commercial operation
2035 – 2040	✓ development and adoption of a law defining the conditions for further DGR operation; ✓ operation of the existing DGR and construction of the 2nd stage
2040 – 2050	DGR operation
2050 – 2150	Law on DGR final closure
After 2150	DGR closure and monitoring

8. Secure financing of the costs of managing radioactive waste and spent fuel and decommissioning of nuclear facilities

The system set up by France for financing the decommissioning of BNIs and managing the spent fuel and radioactive waste produced by these installations, is based on the entire financial responsibility of the licensees.

The BNI licensees must make a prudent evaluation of the cost of decommissioning their installations and managing the spent fuels and radioactive waste they produce and must create provisions accordingly in their accounts. These provisions must be covered by financial assets.

The covering assets are included in the licensee's balance sheet and managed by it (internal funds), but are legally separate from the rest of the balance sheet (legal separation): they may only be used to settle long-term nuclear costs, even if the licensee experiences financial difficulties. Article L. 594-3 of the Environment Code thus states that with the exception of the State under its policing powers in this respect, nobody may exercise any right over these assets, including on the basis of book VI of the Code of Commerce. Furthermore, the covering assets must be sufficient in terms of security, diversity and liquidity.

The law makes provision for oversight by the State, along with the power to issue binding requirements and penalties, up to and including seizure of the funds.

Financing of R&D and design studies for the deep geological disposal repository

R&D and design studies on the deep geological disposal repository conducted by ANDRA are financed from taxes and contributions levied on the radioactive waste producers. The "research" tax and the "design" special contribution are used to secure ANDRA's sources of financing. The amounts of this tax and this contribution are calculated as being the product of flat-rate taxation multiplied by a coefficient. On the basis of the current BNIs, ANDRA receives about € 215 M/year.

Financing of long-term nuclear costs

Under the control of the State, radioactive materials and waste management is financed by nuclear licensees, in accordance with the polluter-pays principle. Arrangements to secure the financing of long-term nuclear costs were created by the "Waste" Act. The nuclear licensees are required to assess their long-term costs, including the cost of decommissioning and the costs linked to management of the spent fuels and radioactive waste. They are required to secure future financing of these costs by immediately creating a portfolio of dedicated assets.

Compliance with these regulatory obligations is verified by the Ministries responsible for the economy and for energy. Pursuant to the Environment Code, the licensees send them a report every three years describing the evaluation of the long-term nuclear costs, the corresponding methods and the choices made regarding the composition and management of the assets set up to cover them. Every year, they also send the Ministry responsible for energy a note updating this report and must inform it immediately of any significant change liable to modify the content. They also send it a quarterly inventory of the dedicated assets.

Every year, the ASN and the Defense Nuclear Safety and Radiation Protection Delegate (DSND) analyze the reports and the update notes transmitted, in order to issue an opinion on the consistency of the hypotheses and the data used by the licensees with their strategy for decommissioning and spent fuel and radioactive waste management.

9. Radioactive waste disposal centers of ANDRA: recent changes

Over the past 25 years, considerable progress has been made concerning the quantities of low and intermediate level short-lived waste resulting from nuclear reactor operations. The decisive factors contributing to the drop recorded over the decade 1985-1995 are mainly organizational in nature - reduction of waste at source, shared operating experience feedback, "best practices", and technical - implementation of changes to the liquid effluents treatment process, densification of packaging of certain waste by grouping and/or pre-compacting. These improvements were effective for waste produced directly by operation of the reactors and that from their maintenance.

It is important to underline that this reduction in the production of solid waste was not offset by an increase in liquid discharges. Over this same period, the average activity (excluding tritium) of the liquid effluents discharged into the environment by the NPPs was divided by 50.

ANDRA effectively collects the waste produced by the small and medium-sized industries, research laboratories (apart from those of CEA), universities, hospitals, etc. A collection guide sets out the conditions for acceptance of the waste for which ANDRA has treatment solutions for its elimination or disposal. With regard to waste for which disposal routes are not yet available, the producers address their collection requests to ANDRA, which examines them on a case-by-case basis. A portion of this waste, after passing via the collection building - and possibly via the sorting and treatment building as well - is transferred to the CENTRACO plant for incineration prior to disposal at the CSA.

The Manche repository (CSM)

The assessment of the center's impact is written up in annual reports that are made public and can be consulted on the ANDRA. 2018 was marked by completion of the studies initiated in 2017 for drafting the CSM's periodic safety review report. This report, along with its support studies and supplementary files, were sent to ASN on 9 April 2019. Several studies were finalized with regard to the hydrogeological model, the lightning, electromagnetic, flooding, and earthquake hazards and an inventory of the fauna and flora.

The Aube repository (CSA)

As at 31 December 2019:

- the volume disposed of was about 375,000 m3;
- 148 structures had been closed out of a planned total of about 400.

Given the rate of deliveries, of about 15,000 m^3 per year, whereas the centre was designed for annual traffic of 30,000 m^3, its operation could last beyond 2060. The National Inventory figures show that the CSA should be capable of absorbing the low and intermediate level, short-lived waste produced by the operation and decommissioning of nuclear facilities today authorized.

The flexibility of the CSA's disposal conditions meant that it could accept non-standard waste packages such as large sized waste packages. This option makes it possible to optimize the management of decommissioning waste.

On 13 March 2019, ASN authorized ANDRA to operate the package inspection facility (ICC). This new facility, built in a hall of the waste conditioning unit, allows more in-depth on-site inspection of certain packages, in parallel with the systematic checks performed on all the waste packages when they arrive at the CSA. These inspections may be either destructive (opening of the package to produce an inventory of the waste present, or core sampling of the various components of the package) or non-destructive (measurement of dimensions, weighing, visual inspection, surface and radiological checks, tritium and carbon-14 degassing rate checks, verification of package quality and the absence of any prohibited waste by X-ray scanner). These more in-depth investigations were previously carried out in facilities off the site, not belonging to ANDRA. The fact of being able to conduct them on-site means greater reactivity, avoiding the to-and-fro between external inspection laboratories and CSA, thus increasing the number of inspections.

Industrial Center for collection, storage and disposal of the RW CIRES

The VLL waste repository within the CIRES Center, commissioned in August 2003, has a regulation capacity of 650,000 m^3. Given the total radiological activity it will contain, the repository is not subject to the regulations applicable to BNIs, but to that applicable to ICPEs (installations classified for protection of the environment).

As at 31 December 2019:

- 66.1% of the allowed volume is filled;
- 506 582 RW packages had been placed into the facility;
- 18 disposal cells had been closed.

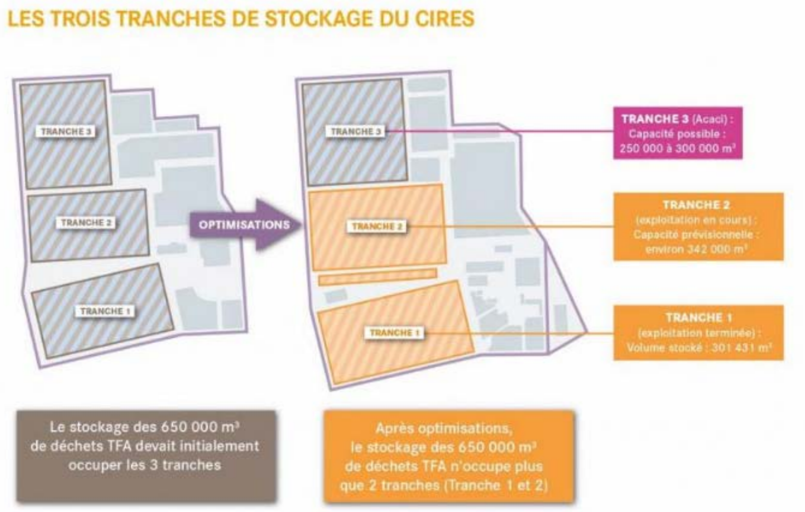
As to the National Inventory-2020 the VLLW volume is estimated as 2 100 000 m^3 for the moment of the CIRES closure. The CIRES center is used to store used sealed sources, radioactive lightning conductors and radium-bearing waste from the clean-out of sites with legacy contamination (radium industry). As at the end of 2019, the quantity of waste of this type was 868 m^3 for a total storage capacity of 4,500 m^3.

The PNGMDR 2016-2018 asked the licensees and ANDRA to thoroughly explore possibilities for the reuse of certain materials and to study the conditions for increasing the CIRES disposal capacity: for the same ground footprint and for creating new disposal capacity (new disposal center, decentralized solutions).

The waste traffic as currently anticipated could lead to early saturation of the regulation capacity of CIRES, the planned service life of which was 30 years. Studies have therefore been initiated to improve the density of the waste emplaced, to optimize the use of the disposal space available and to evaluate the feasibility of a very low level metallic waste recycling solution. This work is being monitored under the terms of the PNGMDR. More specifically thanks to optimized use of the disposal space available, the capacity of CIRES would now appear to be about 40% greater than its regulation capacity which, provided that changes are made to the regulations, would enable its saturation to be postponed to at least 2030, without modifying the perimeter of the facility.

One of explored solutions consists in increasing the allowed capacity of the CIRES storage. This project, called "Acaci" (Augmentation de Capacite de CIRES), aims to increase the disposal capacity by almost 50% through optimization without changing the existing disposal area and maintaining the current level of safety.

The search for overall optimization of waste management led to the development of solutions enabling large components to be accepted, without having to cut them up for packaging in standard packages. These solutions should be deployed taking account of the issues, notably safety, technical, economic, and calendar, of all the phases in waste management.



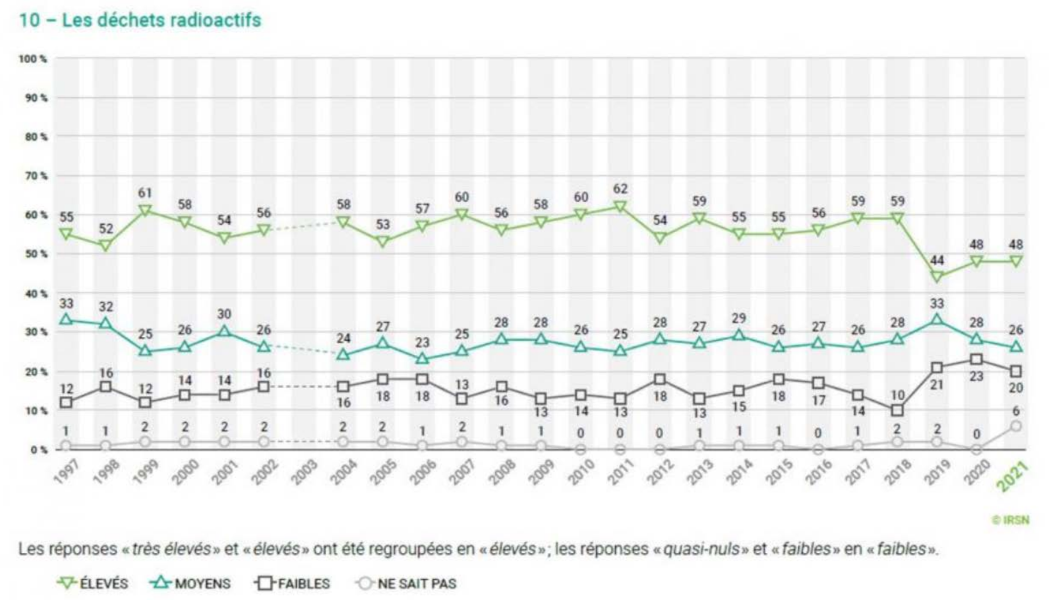
RWDF for 650,000 m^3 for VLLW is designed for 3 stages. As a result of optimization, 650 000 m^3 of VLLW will be occupied by 2 stages: Stage #1 for 301 431 m^3 is filled; Stage #2 for 342 000 m^3 is in the process of being filled; Stage #3 (highlighted in crimson area) corresponds to the implementation of the Acaci project, the planned amount is from 250 000 m^3 to 300 000 m^3.

Baromètre IRSN* 2022 : French attitude towards radioactive waste

At the end of August 2022, IRSN presented a snapshot of public opinion regarding the perception of risks and security by the French. The Institute has been conducting its research (IRSN Barometer) for 30 years. Barometer 2022 presents changes in public perceptions of risk and safety in 4 main areas: the main issues of great concern to the French; the French view of science and expertise; the attitude of the French towards risks and the opinion of the French about nuclear energy. In the last block of the study, IRSN is constantly reassessing the attitude of the French to radioactive waste and its management. Below is a summary of the main results (extract from the IRSN 2022 Barometer Policy Brief):

“The level of risks associated with nuclear installations has been assessed as historically low over the past 3 years. In 2021, as in the previous year, the topic of radioactive waste is mentioned as having a high degree of risk by 48% of respondents. This is 9% less than the average value recorded for the period 1997-2018. It is also the second (after 2019) historical low on this topic.”

Évolution des résultats - 1997-2021



**IRSN - Institut de radioprotection et de sûreté nucléaire*
The Institute for Radiation Protection and Nuclear Safety provides technical expertise for the nuclear regulator ASN and the Parliamentary Office for the Evaluation of Scientific and Technological Choice OPECST.

Czech Republic

Strategy of SNF management

Direct disposal of spent nuclear fuel without preliminary processing.

Organizational aspects

Governmental body in the field of SNF and RW management	MPO — Ministry of Industry and Trade (www.mpo.cz)
	MCP — Ministry of Environmental Protection (www.mcp.cz)
Organization responsible for the implementation of the RW disposal project (project development, R&D, licensing, construction, operation)	SÚRAO — Department for the Disposal of Radioactive Waste (www.surao.cz)

Main regulators

The body of state regulation in the field of atomic energy safety	SUJB — State Administration for Nuclear Safety (www.sujb.cz)
	Czech Mining Office(www.cbusbs.cz)

RW inventory

Object	*Type*	*Volume, m³*
Dukovany NPP	LRW storage	804
Temelin NPP	LRW storage	148
Ryszard DF	Stored RW	8 201
Bratrstvi DF	Stored RW	954
Dukovany DF	Stored RW	12 565
Řež	Temporary LRW storage	17,5
Řež	Temporary LRW storage	19,5

1. Nuclear energy in Czech Republic

The era of nuclear power in the former Czechoslovakia began in the 1950s. Currently, there are six nuclear power reactors operating in the Czech Republic, which accounted for 37.3% of electricity production in 2020.

2. Energy policy and law regulations

May 18, 2015, The Czech Government has approved an updated version of the State Energy Policy of the Czech Republic, prepared by the Ministry of Industry and Trade, with a schedule until 2040. Energy policy defines a comprehensive set of priorities and long-term goals, considering energy, environmental, economic, and social interests.

The outlined strategic objectives are based on the energy strategy of the European Union and are aimed at the goals of the State Energy Policy to implement the long-term vision of the energy sector of the Czech Republic. The main strategic objectives are:

(1) security of energy supply;

(2) competitiveness of the energy sector and social acceptability;

(3) sustainable development.

The Czech Republic’s energy policy is clearly determined by factors related to international energy policy and the world market on which the Czech economy depends on gas and oil imports.

3. General energy policy and RW management law

The legislative framework in the energy sector is based on the following legislative acts:

• Law No. 458/2000 (Collection of Laws) on business conditions and public administration in the energy sector (Energy Law) establishes a new regime for regulating business in this sector. According to the Law on Energy, the production, distribution, transmission, and trade of electricity are subject to licensing.

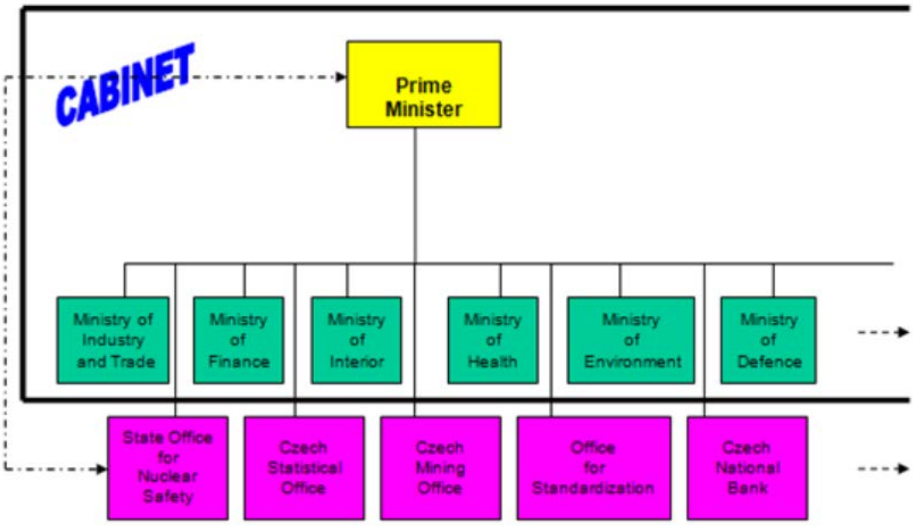
• Law No. 406/2000 on energy management stipulates the rights and obligations of individuals and legal entities in the field of energy management, in particular electricity and thermal energy, as well as gas and other fuels.

Requirements for the management of radioactive waste (radioactive waste from nuclear installations and institutional radioactive waste) are defined in the Law on Atomic Energy and in Resolution No. 377/2016 “On requirements for the safe Management of radioactive waste and Decommissioning of nuclear installations category III or IV”. Czech legislation in this area includes, by reference in the Atomic Energy Act and other regulations, international treaties to which the Czech Republic (or the former Czechoslovak Republic) has acceded. In addition to the above-mentioned international instruments, the Czech Republic has signed the Comprehensive Nuclear-Test-Ban Treaty, but it has not yet entered into force. The Czech Republic is also an active member of the IRS, INES and ENATOM within the framework of the IAEA systems.

The obligation to inform about significant events affecting nuclear safety is also established in bilateral agreements concluded by the Czech Republic or its predecessors in the past.

4. Regulator(s)

The structure of Czech government is drawn below:



The Ministry of Industry and Trade is the ministry primarily responsible for the overall policy in the energy sector and the support of individual areas.

The Federal Agency for Nuclear Safety (SÚJB) belongs to a group of regulatory government agencies along with the Czech Mining Office (these institutions have their own budget, not related to the ministry). The heads of these organizations are appointed by the Cabinet of Ministers on a professional basis.

The SÚJB was established as the national regulatory body of the Czech Republic for the supervision of nuclear safety and radiation protection on January 1, 1993, by Law No. 21/1992. The legal basis for the activities of SÚJB is provided by Law No. 263/2016, the Law on Atomic Energy.

In accordance with the Atomic Energy Act, the duties of the SÚJB include, inter alia:

a) the issuance of licenses for activities, registration and receipt of notification of activities;

b) approval of the type of packages for transportation, storage or disposal of radioactive or fissile materials, sources of ionizing radiation and other nuclear materials;

c) issuance of a permit to carry out activities of particular importance for nuclear safety and radiation protection;

d) approval of documentation for licensed activities;

e) monitoring and assessment of exposure, regulation of exposure of individuals, including exposure from natural sources of radiation;

f) making decisions on the management of nuclear materials, ionizing radiation sources or radioactive waste in cases where they are managed in contradiction with the legislation;

g) submission of an opinion on the territorial development policy and territorial planning documentation from the point of view of nuclear safety, radiation protection, technical safety, monitoring of the radiation situation, management of emergency radiation events and safety of activities related to the use of nuclear energy and activities in irradiation situations;

h) provision of information in the field of radioactive waste and spent fuel management;

i) making mandatory conclusions on territorial planning decisions concerning construction on the land where the closed disposal facilities (DF) are located; mandatory opinions should indicate whether the proposed plan is acceptable from the point of view of radiation protection and monitoring of the radiation situation, and set out the conditions for ensuring radiation protection and monitoring of the radiation situation related to this plan;

j) management and monitoring of the radiation situation on the territory of the Czech Republic, including comparative measurements organized by the European Commission, evaluation of results, communication of radiation monitoring data to the European Commission.

5. RW management

In January 2016, the Czech government decided to decommission the uranium mine at the Rozhna deposit by the end of 2017. The GEAM Dolní Rožínka branch of the state enterprise DIAMO eliminates the consequences of uranium mining activities, including the purification of mine waters in settlements where the mines were stopped. An underground research laboratory in Bukovina was built on the site of the Rozhna I mine.

Spent fuel storage is provided by its generators: CEZ (from nuclear power plants) and the Rež Research Center (from research reactors). Spent nuclear fuel extracted from reactors is stored in holding pools (approximately 7-10 years), and then in dry storage (approximately 40-60 years), which are located at the sites of power plants.

The construction of a deep geological repository is stated in the Policy for the Management of Radioactive Waste and Spent Nuclear Fuel in the Czech Republic, prepared by SÚRAO. The policy complies with the requirements of the Council Directive 2011/70/Euratom. In accordance with the recommendation contained in these directives and recommendations submitted by the Working Group of the European Nuclear Energy Forum (Information and Transparency), the issue of implementing a national legislative framework in the site selection process is currently being discussed. Based on the preliminary schedule, the selection of the final and reserve end sites is planned based on a government decision for 2030; the construction of a deep geological repository is planned for 2050-2064; the commissioning of the storage facility is planned for 2065. At the end of 2020, the government agreed on a short list of 4 sites for the placement of a deep geological repository.

The capacity of DGR may amount to about 10,000 tons of TM, according to current estimates. It is expected that the DGR will house:

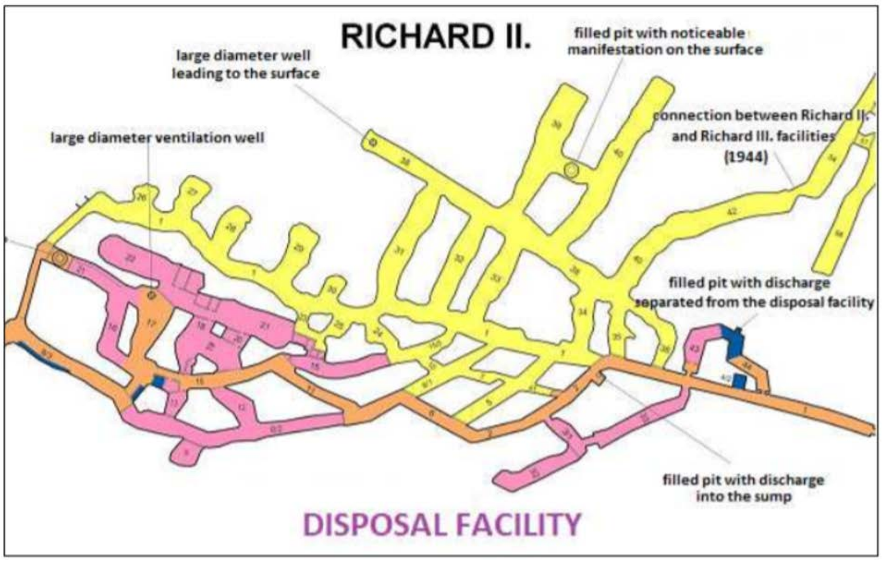
- all RW materials that cannot be disposed in near-surface DF,
- SNF declared as RW,
- if necessary, also HLW from the potential reprocessing of SNF from the Dukovany and Temelin NPPs,
- as well as SNF and HLW from other nuclear installations.

The ground-based radioactive waste disposal facility is operated by SÚRAO on the territory of the Dukovany NPP. It is designed to accommodate all future low-level radioactive waste from both the Dukovany NPP and the Temelin NPP.

The disposal site for low- and intermediate-level radioactive waste generated from medical and industrial applications is located in the abandoned limestone mine Ryszard, near Litomerice in the north of the Czech Republic. It started functioning in 1964. Another facility, Fraternity, for waste containing only natural radionuclides, is located near Jachimov in the northwestern part of the Czech Republic and has been operating since 1974. DF Hostim, near Beroun, was closed in 1997 and is currently controlled by SÚRAO.

Ryszard DF

This DF is mainly used for the disposal of institutional radioactive waste containing artificial radionuclides. Basically, these RW materials include sealed sources with radionuclides, sources with radionuclides from fire detectors and nuclear materials.



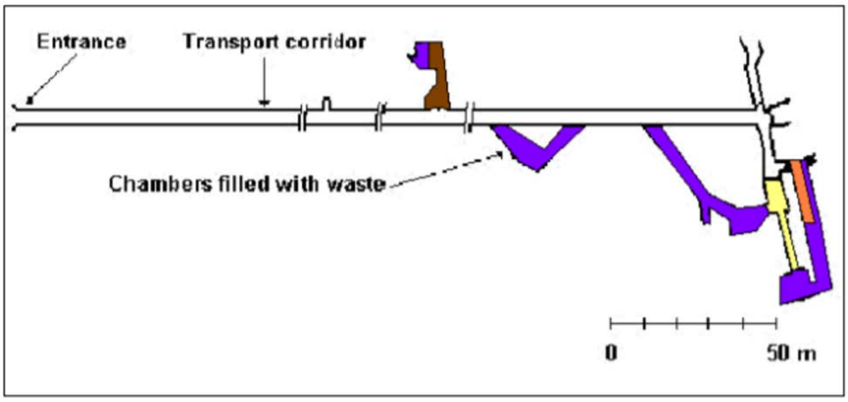
In 2016, a revision of the justification and safety analysis was prepared in order to confirm the required DF capacity and update the assessment of the already proposed method of closure and decommissioning. In 2019, a revision of the safety justification was prepared, including a revision of the hydrogeological model, and the question of a possible expansion of the disposal areas to previously unused premises in the northern part of the facility was raised. In 2018, a project was prepared for the comprehensive reconstruction of the underground and ground part of the facility.

The second phase of reconstruction of the Richard DF, which will provide sufficient capacity of the DF, will be started after the completion of the first phase of reconstruction. The second phase of reconstruction will include the modernization of the ground-based RAW reception complex.

The method of DF closure is provided for in the decommissioning and closure plan, and the last plan was approved by the SÚJB in January 2020. It is expected that the disposal chambers and access tunnels will be filled with a mixture based on cement or clay sealing material. Institutional control is expected within 120 years after decommissioning is completed. A monitoring program for the post-closure period has not yet been proposed.

Bratrstvi DF

The DF is intended for the disposal of radioactive waste containing natural radionuclides.

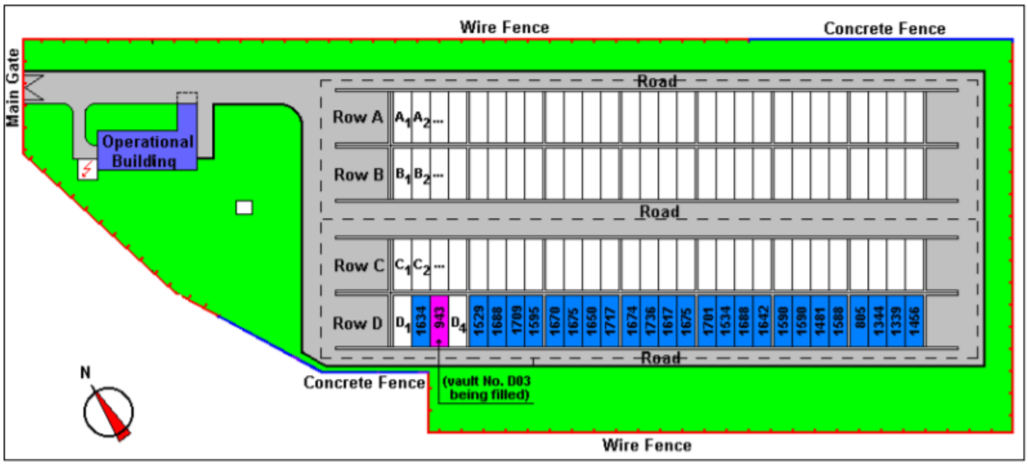


In 2019, a revision of the safety justification was also prepared for this DF, including a revision of the hydrogeological model. It was decided to extend the operation of the Bratrstvi DF for several more years. The DF closure is planned for the period after 2025.

The method of DF cloure is presented in the decommissioning plan, and the last plan was approved by the SÚJB back in 2013. It is expected that the disposal chambers and access tunnels will be filled with a mixture based on bentonite or cement. Institutional control is expected within 120 years after the end of operation. A monitoring program for the post-closure period has not yet been proposed.

Dukovany DF

The DF is used for the disposal of low- and intermediate-level waste from both nuclear power plants in the Czech Republic and a limited number of institutional RW.



The safety report was updated in 2016. In 2019, a revision of the safety justification was prepared, including a revision of the hydrogeological model. In 2019, the reconstruction of the Dukovany DF was started. In 2020, a study was conducted on the further development of DF.

The method of DF closure is provided for in the decommissioning and closure plan, and the last plan was approved by the SÚJB in January 2020. Closure is assumed by applying layers of sealing materials. Institutional control is expected within 300 years after decommissioning. A monitoring program for the post-closure period has not yet been proposed.

6. International cooperation and initiatives

The Czech Republic maintains fruitful international cooperation with a number of international nuclear organizations and is a member of a number of international nuclear organizations and associations, such as the IAEA, the Nuclear Energy Agency of the Organization for Economic Cooperation and Development (OECD/NEA), the World Association of Nuclear

Plant Operators, the Western European Association of Nuclear Regulators, the VVER Forum (established by the regulatory authorities of countries operating Soviet-style reactors), the Association of Countries with Small Nuclear Programs.

7. Informing and public relations

The interaction of State institutions with the public is carried out on the basis of openness and transparency. Although this activity is regulated by Law No. 106/1999 on free Access to information and Law No. 500/2004 on administration, in practice interaction is realized using Internet services.

8. Future developments

The updated State Energy Policy of the Czech Republic considers nuclear energy as a possible and desirable option. Within the framework of the State Energy Policy, a number of issues are outlined for consideration for the future, including:

(1) support for the development of nuclear energy, including the achievement of the goal, which involves increasing the share of nuclear energy to 50% of the volume of electricity generated and heat supplies from nuclear power plants;

(2) support and acceleration of the process of negotiations, preparation and implementation of new nuclear installations at existing NPP sites with a total capacity of up to 2500 MW or an annual capacity of about 20 TWh by 2030-2035;

(3) creating conditions for extending the service life of the Dukovany NPP to 50 or 60 years, taking into account existing technologies, safety and security regulations, economics and the rules of the European Union;

(4) planning for the potential construction of a new unit at existing NPP sites in accordance with the expected decommissioning of the Dukovany NPP (i.e. after 2035);

(5) deciding on the disposal of radioactive waste by 2025.

In addition, the policy recommends wider use of thermal energy obtained from nuclear sources for heating large urban agglomerations. If nuclear energy is to be used for a long period of time, it will also be necessary to study and prepare, as necessary, sites for future additional nuclear power plants after 2040.

Switzerland

SNF management strategy

Direct disposal without preliminary processing.

Organizations

State governmental bodies in the field of SNF and RW management	DETEC — Federal Department of the Environment, Transport, Energy and Communications	
	SFOE — Swiss Federal Office of Energy (www.sfoe.admin.ch)	
Organization responsible for SNF and RW disposal (project development, R&D, licensing, construction, operation)	Nagra — National cooperative of Radioactive Waste (www.nagra.ch)	

Main regulation bodies

State regulation bodies for nuclear safety	ENSI — Swiss Federal Nuclear Safety Inspectorate (www.ensi.ch)
	NSC — Federal Nuclear Safety Commission
State regulation body for environmental protection	FOEN — Federal Office for the Environment (www.bafu.admin.ch)
State regulation body for radiation protection	FOPH — Federal Office for Public Health (www.bag.admin.ch)
State regulation body for spatial planning	ARE — Federal Office for Spatial Development (www.are.admin.ch)

1. Atomic energy overview of Switzerland

Nuclear power in Switzerland generates 35.2% of the total electricity volume in the country[16]. It is worth mentioning that earlier this figure was 40%, but the share of NPP participation in the national electricity production decreased due to the decommissioning of the NPP in the municipality of Muehleberg, canton of Bern, in 2019. At the moment, Switzerland has 3 operating nuclear power plants:

- Beznau NPP – 2 identical PWR units (pressurized water reactors),
- Goesgen NPP – 1 PWR unit,
- Laibstadt NPP – 1 BWR unit (boiling water reactor).

After the tragedy at the Japanese Fukushima-1 NPP in 2011, the Swiss authorities decided to reduce the use of nuclear energy and phase it out. In accordance with the Nuclear Energy Act, revised in 2018 (Nuclear Energy Act[17], 2003), the construction and commissioning of new nuclear

[16] According to the official data for the end of 2020 provided by Swiss Federal Office of Energy of Federal Department of the Environment, Transport, Energy and Communications, URL: [https://energeiaplus.com/2021/02/19/schweizer-elektrizitaetsbilanz-2020-pandemie-laesst-stromverbrauch-sinken/?translateto=en].

[17] Nuclear Energy Act, URL: [https://www.fedlex.admin.ch/eli/cc/2004/723/de].

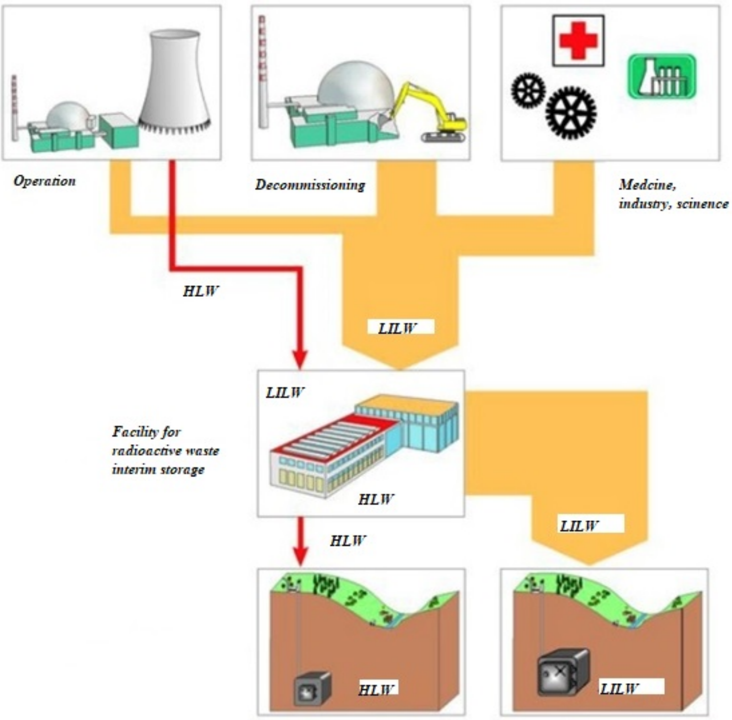
power plants is prohibited, while existing operating nuclear power plants can continue operating as long as they comply with safe operation standards[18].

The new version of the Nuclear Energy Act has also cleared the issue of the spent nuclear fuel export for reprocessing. Previously, Swedish SNF reprocessing was carried out outside the national territories – mainly, in France and the UK. Plutonium and uranium, obtained through reprocessing, were used for the production of nuclear fuel, and were fully returned together with the radioactive waste, generated as a result of this process, to Switzerland. However, in the early 2000s this practice was interrupted by the moratorium on the SNF export for reprocessing. Ultimately, the modern version of the Nuclear Energy Act has established a full-fledged ban on the SNF export for reprocessing[19]. Thus, at the moment all SNF is classified as radioactive waste and is subject to final isolation at the deep geological repository.

The modern Swiss concept of disposal of radioactive waste provides for the creation of two disposal facilities for high-level waste and for low- and intermediate-level waste separately, but within the same site. It is worth noting that the implementation of the project of the combined geological disposal site is at the stage of site selection[20]. Thus, at the moment, all Swiss radioactive materials are located in interim centralized storage facilities. In addition, each NPP has facilities for the treatment and conditioning of radioactive waste.

2. Classification and register of RW

The main source of radioactive waste in Switzerland is nuclear power plants. RW is formed both during the NPP regular operation and during its decommissioning, as well as during the reprocessing of spent nuclear fuel. Partially radioactive waste may result from the use of radionuclides in the medical, industrial and scientific areas. As Switzerland has no uranium mines and facilities for the enrichment, production or reprocessing of fuel, so there are no other sources of radioactive waste than those listed above.



[18] Art.12a, Nuclear Energy Act.

[19] Art. 9, Nuclear Energy Act

[20] «Guiding principles of waste management», Nagra’s Annual Report 2020, p. 7.

The main sources of RW in Switzerland[21]

In contrast to the generally accepted IAEA classification of radioactive waste, the Swiss system provides for a more simplified approach and divides radioactive waste into only three types[22]:

- **High level waste –** this includes SNF (fuel elements (fuel rods) and fuel assemblies of NPP nuclear reactors).
- **Alpha-toxic waste –** LILW with a high content of alpha emitters (more than 20,000 Bq/g)[23] and a long half-life.
- **Low and intermediate level waste –** all other radioactive waste (industrial waste of NPP operation, such as contaminated protective equipment and its parts, cleaning materials, tools, concentrated wastewater, ion exchange resins and filters of purification systems; in addition, LILW also includes radioactive waste obtained from medical, scientific and other sources).

In order to generalize and systematize information about all accumulated radioactive waste in Switzerland, Swiss NPPs, radioactive waste management enterprises, as well as the National cooperative of Radioactive Waste (Nagra) have agreed to create a common electronic database on accumulated radioactive waste. The Swiss register of radioactive waste was named the Information System for Radioactive Materials (ISRAM). ISRAM constantly stores and updates data on the number of different types of RW materials and on the types of waste packages, tracks untreated waste in nuclear power plant storage facilities, keeps records of SNF at nuclear power plants and in interim storage facilities. The Information System for Radioactive Materials provides waste owners and Nagra with a complete and detailed report on the radioactive waste existing in Switzerland. In addition, ENSI regularly gets information about the inventory of waste in accordance with the regulations and provisions of atomic energy legislation.

3. Entities responsible for RW management

In accordance with the international principle of "polluter pays", waste producers are responsible for radioactive waste disposal and covering the costs associated with it. Thus, waste producers should ensure radioactive materials management in such a way as to minimize the formation of radioactive waste, as well as to implement its safe disposal. The advising legal provisions are included in the Nuclear Energy Act and the Nuclear Energy Ordinance of Switzerland and are based on the principles of protecting the lives of residents and the environment.

Since nuclear power plants are the main source of radioactive waste in Switzerland, it is the operators of nuclear installations who are responsible for the management of spent nuclear fuel and radioactive waste. They are obliged to prepare spent nuclear fuel and radioactive waste for transportation, to store it until the geological disposal facility is put into operation, and to dispose radioactive waste safely at the expense of the operators of nuclear installations.

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[21] «Implementation of the Obligations of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management», 7th National Report of Switzerland according with Article 32 of the Convention, October 2020.

[22] "Types of Radioactive Waste", Official website of the National operator for radioactive waste management of Switzerland NAGRA, URL: [https://www.nagra.ch/en/types-of-radioactive-waste].

[23] Nuclear Energy Ordinance.

The State bears full responsibility for the safe management of radioactive waste resulting from the use of radioisotopes in the medical, industrial and scientific area.

4. Regulatory bodies in the field of RW management

The Parties of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management of 1997 are bound by the obligation to create and maintain a regulatory framework for ensuring safety in the field of radioactive waste management. The legislative and regulatory framework includes the introduction of national requirements in relation to nuclear safety, the licensing system and the responsibilities of the parties involved, as well as clear delineation of the responsibilities and functions of bodies dealing with separate stages of the management of SNF and RW[24]. In Switzerland, the regulatory body established pursuant to the above provision of the Convention is represented by several institutions and organizations at once.

The Federal Council issues a general license, in fact, a political decision on the construction of an object, which must be approved by the Parliament and is subject to a facultative referendum. The Federal Council is also responsible for issuing orders on the closure of waste disposal facilities.

The Federal Department of the Environment, Transport, Energy and Communications (DETEC) is the licensing authority for the construction and operation of nuclear installations. In addition, DETEC issues licenses for geological researches carried out during the disposal of radioactive waste.

The Federal Office of Energy (FOE) is also the licensing authority for obtaining all other types of licenses in the field of SNF and RW management. In accordance with the Nuclear Energy Act, these include licenses for transportation, trade, import and export of nuclear fuel, etc. FOE can also perform the functions of DETEC, licensing nuclear facilities on behalf of the latter. The Federal Office of Energy is the competent authority for the supervision of nuclear installations and its safety, it also manages the site selection process.

The Federal Nuclear Safety Inspectorate (ENSI) is the competent authority that supevises nuclear installations in terms of compliance with radiation protection and nuclear safety requirements at all stages of its life cycle. The Inspectorate is responsible for the safety assessment during the site selection process. Since 2008 ENSI has been performing three main functions:

- specifying the safety requirements established in regulatory legal acts,
- considering applications for licenses and
- supervising nuclear installations, preparing radioactive waste for the disposal and transporting radioactive materials from and to nuclear facilities.

The Federal Office for Public Health (FOPH) is also involved in the process of site selection for the construction of waste disposal facilities. FOPH supervises the radioactive materials management in medical and research institutions and is the main licensing authority for the management of radioactive materials that is not subject to the Nuclear Energy Act.

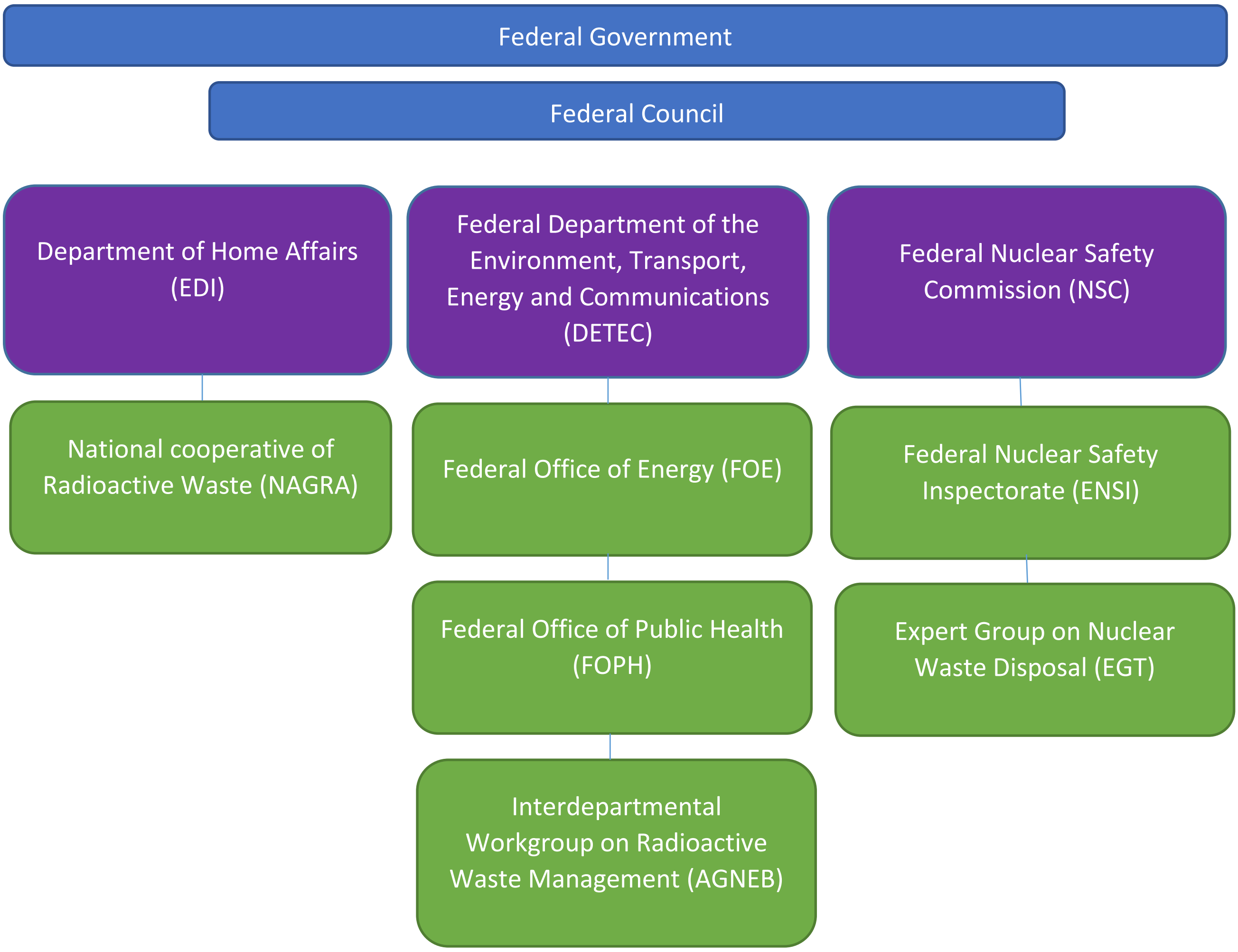
[24] Art. 19-20, Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, September 5, 1997, URL: [https://www.iaea.org/sites/default/files/infcirc546_rus.pdf].

The Swiss National Accident Insurance Fund (Suva) supervises the production practices of workers at nuclear power plants.

The National Emergency Operations Center (NEOC), part of the Swiss Federal Department of Defense, Civil Protection and Sport, is responsible for all emergencies, including those arising from nuclear power plant activities and related to the protection of the population and the environment.

In addition to the above-mentioned organizations, advisory bodies for the management of SNF and RW have been established in Switzerland. These include **the Federal Nuclear Safety Commission (NSC)**, which handles fundamental issues in the field of nuclear safety and provides consultations, comments and its own conclusions to the Federal Council, DETEC and ENSI. **The Interdepartmental Working Group on the Radioactive Waste Management (AGNEB)** prepares documents to support government decisions on the management of radioactive waste (mainly submission of technical reports to the Federal Department and the Federal Council). **The Expert Group on Nuclear Waste Disposal (EGT)** provides advice and recommendations to ENSI on geological engineering and technical aspects of radioactive waste disposal.

Also it is necessary to mention **the National Cooperative Society for the Disposal of Radioactive Waste (Nagra)** in this section. This organization was established jointly by the operators of nuclear power plants and the Federal Government to implement projects for the disposal of radioactive waste, including the development of a concept for the disposal of all



categories of radioactive waste.

Interested parties in the field of RW management in Switzerland

5. SNF storage facilities in Switzerland

In addition to spent fuel pools in nuclear reactor power units at four nuclear power plant sites, the following spent fuel management facilities exist in Switzerland:

- **ZZL** is a centralized temporary storage facility in the municipality of Würenlingen owned by Zwilag. ZZL is a dry storage facility for SNF and vitrified HLW, accommodating 200 transportation and storage containers suitable for both activities. The storage facility started functioning in 2001.
- **ZWIBEZ** is a temporary storage facility located at the Beznau NPP site. ZWIBEZ has been operating since 2008 and has a capacity of 48 transportation and storage containers for SNF and vitrified HLW.
- **Nasslager** is a wet SNF storage facility based on the Goesgen NPP. The Nasslager is an external pool designed for 1008 spent fuel cells of nuclear power plants. The storage was put into operation in 2008, since then it has been filled by 50% percent; in the future it is planned to use more compact structures for the installation of fuel assemblies, in order to increase the capacity of the point to 1206 SFAs.

Disposal facility	Number of SFA	Total weight, tHM	Total level of activity, Bq
NPP Beznau (incl. ZWIBEZ)	1056	341,7	$7,3*10^{18}$
NPP Muehleberg	178	31,2	$1,2*10^{18}$
NPP Goesgen (incl. Nasslager)	696	281,1	$10,0*10^{18}$
NPP Leibstadt	1553	262,2	$7,6*10^{18}$
ZZL	3561	590,7	$7,8*10^{18}$

Register of SNF in Swiss storage facilities (status as of December 2019)

6. RW storage facilities in Switzerland

Currently there are the following facilities for the RW management in Switzerland:

- **NPP** – each Swiss nuclear power plant is equipped with its own on-site RW reprocessing and conditioning installation, as well as LILW storage facilities. The main method used is the cementation of RW materials, however, bituminization method (Goesgen NPP) or the use of polystyrene (Beznau NPP) is also present.
- **ZZL** – centralized temporary storage facility. In addition to the room for SNF dry storage and vitrified HLW (see above), it houses storage facilities for HLW with a capacity of 4000 m3 16500 m³. ZZL is equipped with auxiliary facilities for sorting and disinfection of materials, as well as conditioning of radioactive waste. An important conditioning equipment is a plasma generator for LLW burning. The repository began to operate actively in June 2001. It should be noted that the room intended for the LILW storage was used only for the storage of conventional non-radioactive materials until 2018. Only in June 2020, ENSI approved the full operation of ZZL for the storage of low- and intermediate-level waste.
- **ZWIBEZ** is a temporary storage facility at the Beznau NPP, operating since 1994, which combines both a storage site for SNF (see above) and a storage facility for LLW with a capacity of 6000 m³.

- **PSI** is the Paul Scherrer Institute, where the National Center for the collection of radioactive waste generated apart from NPP activities is located, that is, from the medicine, industry or science field. The Swiss Federal Interim Storage Facility (BZL) is also located there, which holds up to 2,100 m³ of waste. At the moment, PSI intends to increase the storage capacity to ensure sufficient safe storage space for radioactive waste before the commissioning of the deep geological repository of radioactive waste.

Storage facilities	RW class	Volume, m^3.	Total level of activity alpha, Bq	Total level of activity beta/gamma, Bq
NPP Beznau (incl. ZWIBEZ)	LILW, cond.	1199	$8,5*10^{10}$	$5,1*10^{14}$
	LILW, non-cond.	28	$1,1*10^{9}$	$5,8*10^{11}$
NPP Muehleberg	LILW, cond.	797	$1,6*10^{12}$	$1,6*10^{15}$
	LILW, non-cond.	62	$1,6*10^{8}$	$7,4*10^{11}$
NPP Goesgen	LILW, cond.	109	$7,5*10^{9}$	$1,2*10^{14}$
	LILW, non-cond.	18	$1,8*10^{9}$	$1,4*10^{12}$
NPP Leibstadt	LILW, cond.	1401	$6,0*10^{10}$	$2,5*10^{14}$
	LILW, non-cond.	5	$3,8*10^{7}$	$2,0*10^{10}$
ZZL	HLW, cond.	115	$1,0*10^{17}$	$7,2*10^{18}$
	α-toxic, cond.	99	$2,8*10^{14}$	$3,7*10^{16}$
	LILW, cond.	2253	$1,6*10^{11}$	$1,6*10^{15}$
	LILW, non-cond.	391	$2,2*10^{11}$	$8,8*10^{12}$
PSI	α-toxic, cond.	68	$2,2*10^{13}$	$5,4*10^{14}$
	α-toxic, non-cond.	15	$1,2*10^{13}$	$1,6*10^{14}$
	LILW, cond.	1555	$7,8*10^{11}$	$1,2*10^{16}$
	LILW, non-cond.	549	$3,5*10^{10}$	$8,7*10^{13}$

Register of RW in Swiss storage facilities (status as of December 2019)

7. The project of the deep geological repository for radioactive waste in Switzerland

Switzerland does not yet have operational disposal facilities for radioactive waste. Producers of radioactive waste, i.e. NPP operators and the Swiss Confederation (as the responsible entity for the management of radioactive waste generated in the field of medicine, industry and science) have created the National Cooperative of Radioactive Waste (Nagra), which is responsible for the development and implementation of solutions for the disposal of all categories of radioactive waste. Nagra must also assess and confirm if each type of packaging produced is suitable for disposal, and monitor the process of RW conditioning.

The concept of RW disposal provides for the construction of two deep geological disposal facilities: one for low- and intermediate-level waste, and the second is for high-level waste (including spent nuclear fuel), separately. In addition, it is important to note an interesting detail of the Swiss project: it is assumed that both disposal facilities will be located on the same site, that is, a combined storage facility will be created for both HLW and LILW.

In accordance with the atomic energy legislation, the construction of separate deep disposal facilities for various types of radioactive waste on one site is possible if this site has all necessary guarantees of safe and permanent waste disposal. Thus, this project is possible and allowed in Switzerland, the only thing that remain is its implementation. It is important to note that the LILW disposal technology itself was presented back in 1985 as part of the Gewähr project and was accordingly approved by the Federal Council. In 2006, the Federal Council approved the project "Opalinus Clay" ("Opaline Clay") presented by Nagra, which displayed a feasibility study of the concept of HLW disposal[25].

As for the initiative to combine two RW disposal facilities on one site, Swiss experts highlight a number of advantages here. The environmental and socio-economic consequences of operating a deep geological repository are concentrated in one region, and the cumulative impact of such DGR is significantly lower compared to two separate disposal facilities. In addition, the labor requirements in the combined storage are lower than in the two, and on-site employees can be hired for a longer period of work. A combined DGR requires only about a half of the surface area that would be occupied by two separate facilities. A smaller amount of ground infrastructure units, a smaller amount of material recovered during construction, as well as lower consumption of resources and energy, and lower CO2 emissions also indicate in favor of a combined RW disposal facility. There are also advantages in terms of costs: the combined disposal facility costs about 1.5 billion Swiss francs less than two disposal facilities separately for the HLW and LILW[26].

The basis of the Swiss concept of deep geological repository for radioactive waste is the use of a system of multiple barriers for passive radioactive safety. The most important barrier is the clay-rich rocks where the repository will eventually be located. These include opaline clay (host rock), which has very low permeability, and limiting geological formations located above and below it, which have equally low permeability (for example, the so-called Brauner Dogger and Effingen Member). Compared with opaline clay, these geological formations are heterogeneous in composition and have a slightly different composition. Both mainly consist of marl, which is a mixture of clay and limestone, contain sand, limestone or iron oolites (iron ore).

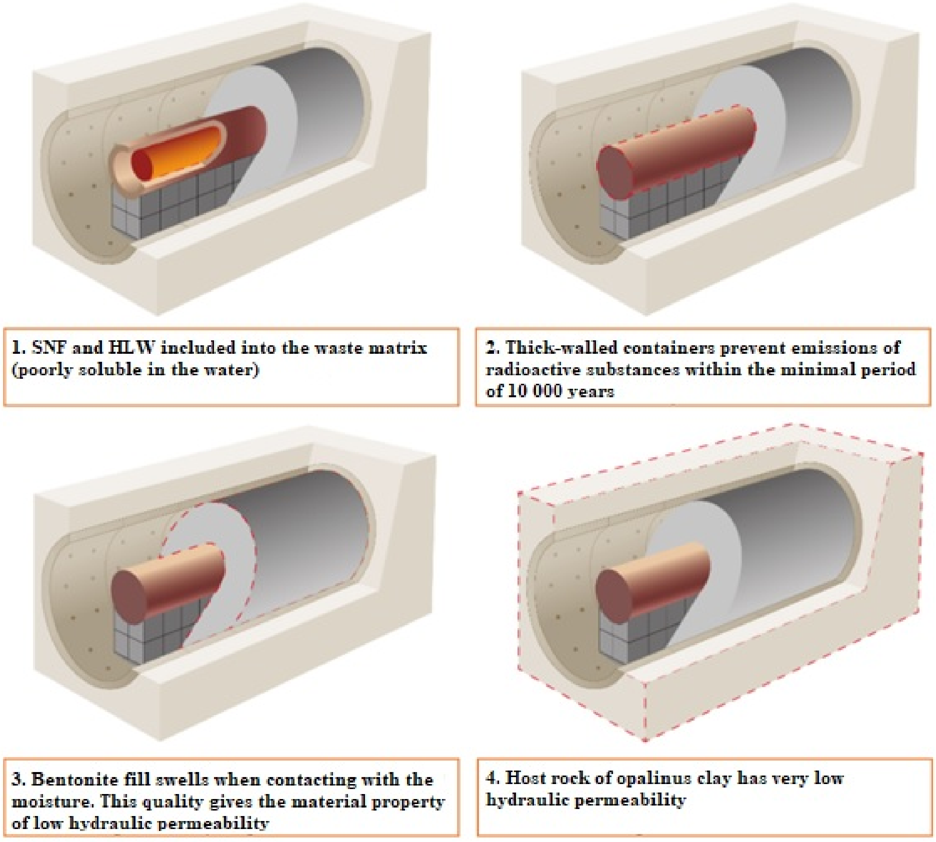
In addition, the barrier system also includes anthropogenic components. Thick-walled steel containers, fuel pellets made of uranium oxide, granulated bentonite and protective structures made of it are used for the disposal of high level waste.

Switzerland has two underground laboratories that allow scientists conducting experiments directly in the most realistic conditions. Researchers study the rock and its performance and analyze how the designed protective barriers work. They also evaluate the behavior of toxic substances during transportation process inside protective barriers and rocks. All these experiments provide important information for the construction of the DGR and its long-term safety. Nagra has its own laboratory – the Grimsel test site in the canton of Bern, built at a depth

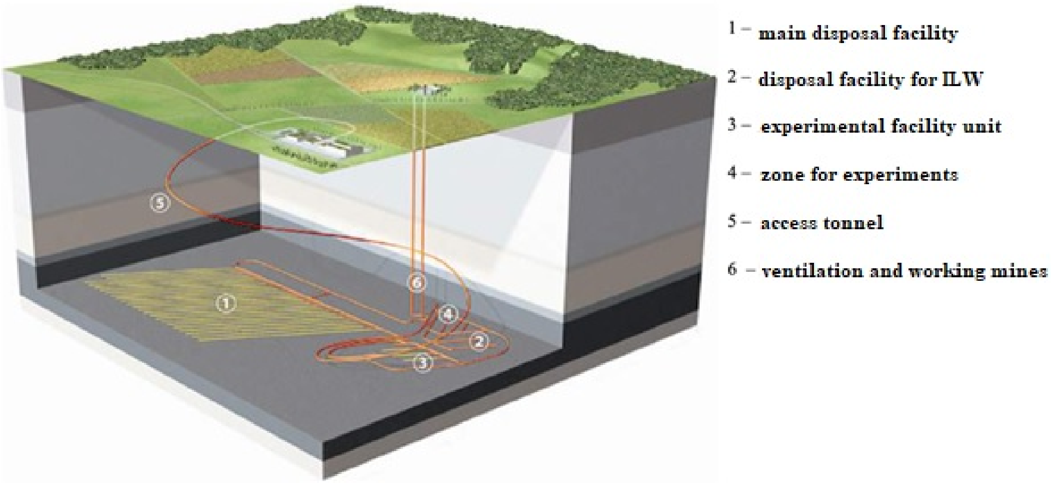
[25] «Implementation of the Obligations of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management», 7th National Report of Switzerland in Accordance with Article 32 of the Convention, October 2020, p.12.

[26] Nagra work report NAB 19-15: "Site-independent comparison of a combined repository with two individual repositories with regard to construction and operating procedures as well as the environment".

of 450 m in the granite host rocks. Nagra also conducts its research at the Mont-Terri State Laboratory in the Canton of Jura at a depth of 250-320 m in clay formations.

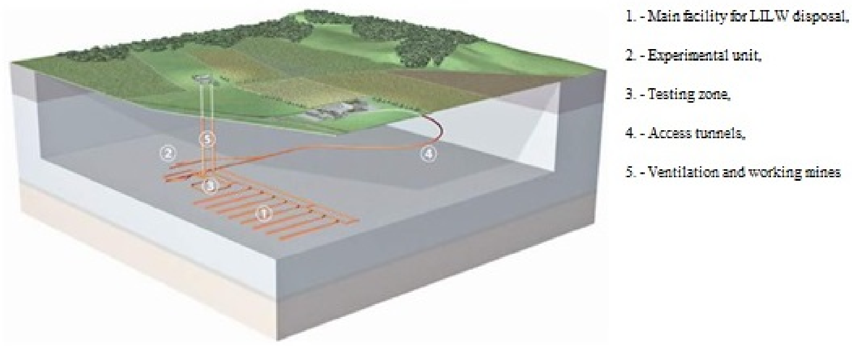


Configuration of protective barriers during the disposal of spent nuclear fuel and HLW



The DGR facility for SNF and HLW

Configuration of protective barriers during the disposal of LILW



The DGR facility for LILW

Site selection for a deep geological repository of radioactive waste

The project for the construction of a deep geological repository for radioactive waste in Switzerland is at the stage of selecting a suitable site. The Federal Government is leading the process of site selection for the DGR, focusing on the fundamental principle of the safety of radioactive waste management. Nagra is conducting a large-scale study of the proposed sites for the construction of the DGR, and by 2022 it is planned to officially present the most suitable territory for this purpose.

The process of site selection for a deep geological repository is carried out in accordance with the "Sectoral plan of deep geological repositories" established by the Federal Government. Rock formations, such as opaline clay, are crucial for safer waste storage. Opaline clay lies at a depth of several hundred meters and will serve as a host rock for waste.

Currently, two proposed regions are being considered for the construction of the deep geological repository. These include: Jura-Ost, Zürcher Nordost and Nördlich Lägern.

Under the leadership of the Federal Department of Energy, the federal authorities developed a concept of the procedure for the DGR site selection, which was the subject of extensive public discussions in 2007, covering the whole of Switzerland, as well as neighboring countries. After all the discussions, the final concept of site selection was approved in 2008[27].

The conceptual part of the procedure for the DGR site selection is determined by the safety of RW management, land use and socio-economic aspects in the region. The program for the DGR site selection includes 3 stages, each one provides for significant involvement of public opinion and wraps up with the approval of the Federal Council.

Stage 1. The beginning of the first stage is considered to be the approval of the site selection plan for the DGR by the Federal Council in 2008. The main purpose of this stage was to determine suitable geological location areas for both types of disposal facilities for HLW and LILW separately. It was during this stage when Nagra proposed three potential location regions for the HLW geological repository and six for the LILW facility. ENSI studied the documentation and agreed to all the proposed geological location areas. The Swiss Federal Nuclear Safety Commission (NSC) commented on the inspection results and also agreed to the proposed regions. At the end of 2010, public discussions on the suitability of the regions were completed, and in 2011 the Federal Council approved potential location regions, thereby completing the 1st stage of the site selection process. The proposed location areas were only clay-rich host rocks at this stage, meeting the safety requirements of Switzerland.

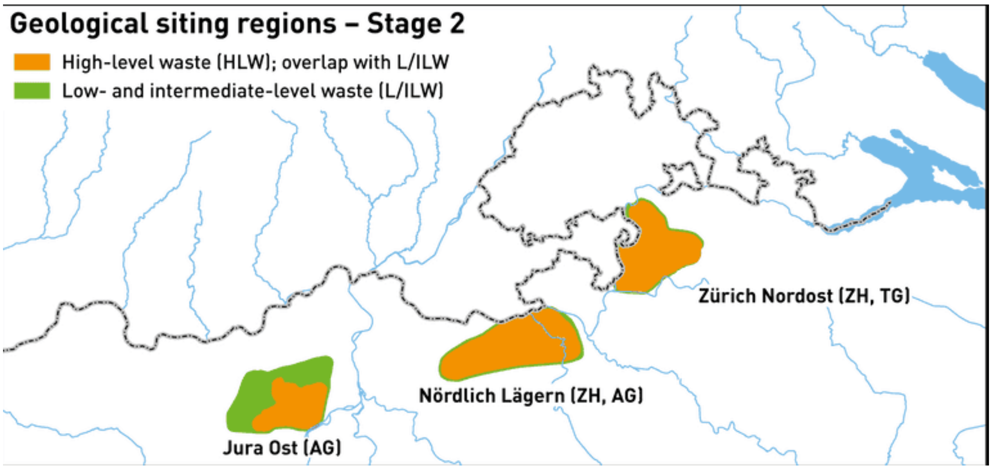
Stage 2. At Stage 2, Nagra re-evaluated the proposed regions in order to identify the need for additional geological studies. As a result, a 2D seismic campaign was carried out, including 300 km of seismic profiles measured in the winter of 2011/12. As a result, Nagra proposed two DGR location areas for the HLW, LILW: Jura-Ost, Zürcher Nordost. It is proposed to use opaline clay as a host rock in these areas.

However, the Federal Council decided in November 2018 that the three location regions – Jura-Ost, Zürcher Nordost and Nördlich Lägern – should be included in the list of regions for further detailed examination of suitability in the next stage.

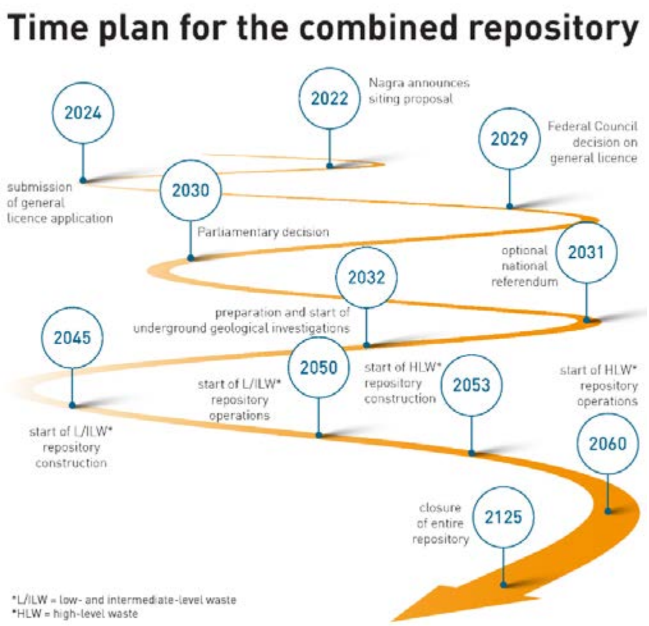
27 «Sectoral Part for Deep Geological Repositories: Conceptual Part», URL: [http://www.radioactivewaste.ch].

Stage 3. In preparation for Stage 3, ENSI clarified its safety requirements for the site selection process and documentation for the last stage of the Sectoral Plan. The comparison of sites is based on the geological situation in the location areas, the facility layout developed for a specific site, safety analysis and a qualitative assessment of 13 safety criteria. Due to the stricter requirements for geological barriers and a longer period of time to assess the HLW disposal facility, first of all, a location for the HLW disposal should be selected, and only then – a location for the LILW disposal.

In 2022, Nagra should submit a report on the most suitable location region for deep geological repository. Further, according to the Swiss policy, it will be necessary to obtain a general license for the DGR construction on this territory. Swiss government reckons that the decision on the location of construction site of the future DGR should be made in 2029-2030 by the Federal Council and authorized organizations. As soon as a certain location is confirmed, Nagra will begin construction of the first deep geological repository for radioactive waste in Switzerland.



Three candidate regions for the construction of a combined DGR for HLW, LILW in Switzerland (at the beginning of 2022)



Timeline of the implementation of the deep geological repository in Switzerland (source: Nagra)

South Korea

Organizational aspects

State governmental body for SNF and RW management	KORAD – Agency for Radioactive Waste Management of the Republic of Korea
Organization responsible for the implementation of the SNF and RW disposal project	KORAD – Agency for Radioactive Waste Management of the Republic of Korea KAERI – Research Institute of Atomic Energy of the Republic of Korea

Main regulators

The body of state regulation in the field of atomic energy safety	NSSC – Committee on Nuclear Safety (Safety regulation issues) MOTIE – Ministry of Trade, Industry and Energy (SNF and RW Management Policy)
The authority issuing licenses for the construction and operation of disposal facilities (DF)	NSSC – Nuclear Safety Commission (the body that issues the license and permit for the construction of DF) KINS – Institute of Nuclear Safety of the Republic of Korea (conducts a safety assessment of the planned MANPADS, on the basis of which the NSSC issues a license)

Inventory of SNF (storage at nuclear power plants) (as of March 31, 2020)

Site	*Reactor type*	*Storage type*	*MTU*
Kori	PWR	Wet	2 636,63
Saeul	PWR	Wet	81,61
Hanbit	PWR	Wet	2 682,89
Hanul	PWR	Wet	2 493,27
Wolson	PWR	Wet	214,83
	PWR	Wet	2 712,46
		Dry	6 098,91

Inventory of SNF in storage basins of research facilities (as of March 31, 2020)

Science and Research facility	*Inventory volume (MTU)*
HANARO (multipurpose research reactor)	0,904
Storage area for irradiated SNF	3,320

Инвентарное количество РАО (на 31 марта 2020)

Site	*Number (drums of 200 l)*	*Main radionuclides*
RW stored at NPP		
Kori	42 622	^{3}H, ^{60}Co, ^{137}Cs, ^{14}C and etc
Saeul	247	^{3}H, ^{60}Co, ^{137}Cs, ^{14}C and etc
Hanbit	20 969	^{3}H, ^{60}Co, ^{137}Cs, ^{14}C and etc
Hanul	16 010	^{3}H, ^{60}Co, ^{137}Cs, ^{14}C and etc
Wolson	10 770	^{3}H, ^{60}Co, ^{137}Cs, ^{14}C and etc
RW stored at KAERI		
1 storage	8 799	^{60}Co, ^{137}Cs, ^{238}U and etc
2 Storage	895	^{60}Co, ^{137}Cs, ^{238}U and etc
Storage for the processing of flammable waste	11 491	^{60}Co, ^{137}Cs, natural uranium and etc
RW stored at the production site for the nuclear fuel		
Production site storage	9 016	^{234}U, ^{235}U, ^{238}U
Inventory number of radiation sources in KORAD		

Storage for used sources	372 (unsealed)	^{125}I, ^{99}Tc and etc
	189 (sealed)	^{60}Co, ^{137}Cs, ^{241}Am and etc
Volume of RW at the disposal site of LILW		
Receipt area/Storage	2 969	^{60}Co, ^{137}Cs etc.
	45 (sealed sources	^{60}Co, ^{137}Cs, ^{241}Am and etc.
Building for RW	209 (unsealed sources)	^{3}H, ^{14}C, ^{125}I, ^{99}Tc and etc.
	60 (sealed sources)	^{60}Co, ^{137}Cs, ^{241}Am and etc.
	1 496 (asphalt-concrete)	
Silo	19 050	^{60}Co, ^{137}Cs, ^{59}Ni and etc
Other sites		
Taekwang Industrial (Ulsang)	8 635	
Taegutec Co (Daegu)	52	

The project of creating a disposal facility for LILW, Wolsong (WLCD)

RW type for disposal	LILW
Hosting rock	Crystalline rocks
Location region	Gyeongju
Population density	211,5 p/km^2
WLCD area	2 060 000 m^2
Number of blocks/facilities	3
Start of the construction of the 1 facility	July 2007
Commissioning of the 1 facility	December 2014
DF type of the 1 facility	Underground type, shaft storage
Capacity	100 000 drums of 200 l
Start of the construction of the 2 facility	December 2015
Commissioning of the 2 facility	2022 (at the moment, the construction permit and the license are being considered by the authorities)
DF type of the 2 facility	Ground type, engineering storage
Capacity	125 000 drums of 200 l
Start of the construction of the 3 facility	January 2019
Commissioning of the 3 facility	Unknown at the moment, preparation for the project is underway
DF type of the 3 facility	Near-surface type, trench storage

KURT Underground Research Laboratory

KURT is a universal underground research laboratory (tunnel) with a total length of 551 m with six research modules. The maximum depth of the tunnel is about 120 m from the surface. Granite is used as a host rock, which is considered as a potential type of host rock for the burial of HLW in Korea. Various on-site tests and experiments have been conducted since 2007. The research experience gained with KURT provides important information to confirm the safety and feasibility of a deep geological burial system.

1. Historical background

Since the beginning of commercial operation of the Kori Power unit No. 1 in April 1978, Korea has continued the construction and operation of nuclear power plants (NPP) and as of March 31, 2020, operates 24 power units.

Kori Unit No. 1 and Wolsong Unit No. 1 have been stopped and are in preparation for decommissioning.

After the accident at Japan's Fukushima-1 nuclear power plant in 2011, the Korean Government established the Presidential Nuclear Safety Commission to increase the independence and transparency of nuclear safety regulation. In March 2013, the Commission was transferred to the Office of the Prime Minister.

In March 2008, the Radioactive Waste Management Act (RWMA) was adopted for the Safe and Effective management of Radioactive waste, and in January 2009, the South Korea Radioactive Waste Management Corporation (KRMC) was established, renamed in July 2013 as the South Korea Radioactive Waste Management Agency (KORAD). Since December 2014, after passing the pre-operational inspection of the regulatory body, the KORAD Agency began to operate the 1st stage of the rock-cavern type disposal facility for low- and intermediate-level radioactive waste (LILW). In December 2015, the KORAD agency also submitted to the NSSC an application for a construction permit and a license for the operation of the 2nd stage of the engineering storage of the waste disposal facility, which is currently under consideration by regulatory authorities.

In November 2012, the Korean Government held the 2nd meeting of the Atomic Energy Promotion Committee (AEPC) and approved a draft Plan for the Management of Spent Nuclear Fuel for activities to attract public attention to the issues of spent fuel management. Based on the recommendations of the Commission for Public Relations on the Management of SNF, at the end of July 2016, the Government developed a Basic Plan for the Management of High-activity Radioactive Waste. In May 2019 A Committee was established to review the SNF management policy, in particular, on taking into account the opinions of the public and residents of settlements located in close proximity to nuclear energy facilities.

Nuclear SNF is stored in wet or dry storage facilities. The LILW generated at nuclear power plants are firstly placed in local storage facilities and then transported to the KORAD disposal site after an on-site inspection by the agency.

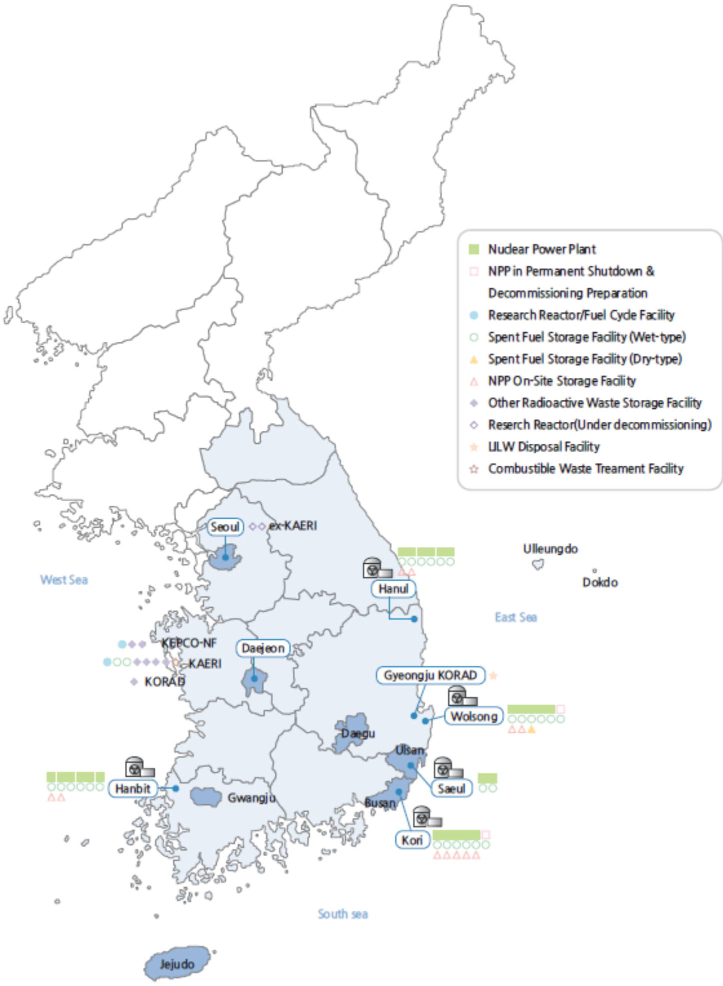
The LILW, obtained as a result of the operation of the research high-flow reactor of an improved design using 30 MW neutrons (HANARO) of the Korean Atomic Energy Research Institute (KAERI) in Daejeon, were either stored on site or transported to the KORAD disposal site. The SNF of this research reactor was stored in the pre-reactor holding pool. Two other research reactors, the Korean Research Reactors 1 and 2 (KRR-1 and 2), located at the former KAERI site in Seoul, are currently being decommissioned by KAERI after a final shutdown.

A permit was issued for the construction of a 15 MWT research reactor in Gijang-Gun (Busan) for the production of radioactive isotopes of medical and industrial purposes, as well as power semiconductor devices in May 2019.

Nuclear fuel for nuclear power plants is produced by the Korean Electric Power Corporation (KEPCO NF) in Daejeon, and the radioactive waste generated during its manufacture is stored in a warehouse for KEPCO NF raw materials.

The number of users of radioisotope (RI) and radio generating devices in the medical, research and industrial fields is steadily growing and as of March 2020 is about 8,800 users generating various types of radioactive waste. Radioisotope waste was stored at the KORAD nuclear waste management facility in Daejeon until June 2015 and has been transported to the KORAD LILW disposal facility in Gyeongju since July 2015.

Location and operational status of nuclear facilities and radioactive waste management facilities (as of March 2020)



2. Law regulation

The national laws of South Korea on the management of spent nuclear fuel and radioactive waste are: the Nuclear Safety Act (NSA), the Radioactive Waste Management Act (RWMA), the Environmental Impact Assessment Act and other by-laws. The NSA was adopted as the basic law concerning the safety rules for the handling of SNF and RW.

A more substantive regulation of the issues of SNF and RW management is contained in the Law on Radioactive Waste Management (RWMA). The latter is divided into 4 levels:

1. RWMA – establishes a basic system of standards for the management of radioactive waste and defines the main issues of the sale and effective management of radioactive waste,

2. Decree on the Enforcement of RWMA - establishes procedures and administrative issues of radioactive waste management,

3. The Resolution on the application of the RWMA – provides detailed rules on the treatment of SNF and RW, expands the RWMA and the Decree on the enforcement of the RWMA,

4. Notification of the Ministry of Trade, Industry and Energy – defines the detailed regulation of aspects related to technical standards and administrative procedures.

3. Regulating bodies

Nuclear Safety Commission (hereinafter - NSSC)

The Government established the NSSC under the jurisdiction of the Prime Minister in order to protect people from radiation hazards associated with the production and use of nuclear energy, as well as to promote public safety and environmental protection, in accordance with the Law on the Establishment and Functioning of the Nuclear Safety Commission. Among the general tasks of the NSSC related to nuclear safety management is the regulation of the safety of nuclear energy facilities, including radioactive waste management facilities, research activities and international cooperation.

NSSC regional offices located in the immediate vicinity of nuclear facilities are responsible for regulating safety at the locations of nuclear reactors, nuclear fuel cycle facilities, radioactive waste management facilities, as well as for working with residents and authorities.

The Department of Radioactive Waste Safety was established at the Bureau of Emergency Radiation Situations in February 2017. The responsibilities include the development of a policy on RW and SNF, systems for the management of these wastes, regulation of storage, transportation and disposal of RW and SNF, as well as safety regulation and research projects related to the development of methods of storage, treatment and disposal of RW, as well as SNF temporary storage.

The responsibility for regulating the decommissioning of nuclear power reactors lies with the Nuclear Safety Department, and the responsibility for standardizing permits/licenses for radioactive waste management facilities lies with the Safety Standards Department, while regulation in the locations of RW management facilities lies with the Regional Bureaus (Wolsong and Hanbit).

Institute of Nuclear Safety of the Republic of Korea (KINS)

The Institute of Nuclear Safety of the Republic of Korea (hereinafter - KINS) was established in February 1990 as an expert organization for the regulation of nuclear safety, in accordance with the Law on the Establishment of KINS. The Institute performs the tasks of regulating the nuclear safety system assigned to the NSSC in accordance with the legislation, which includes safety checks in connection with licensing and permits for the operation of nuclear energy facilities, and safety inspections in connection with the project design, construction and operation of nuclear energy facilities.

KINS opened the International School of Nuclear Safety (INSS), which also functioned as the Asian training center of the IAEA (since the moment of signing the relevant Agreement on Cooperation in the Field of Nuclear Safety with the International Atomic Energy Agency).

South Korea Institute for Control and Non-proliferation of Nuclear Technologies (hereinafter – KINAC)

KINAC was founded in June 2006 and is active in the field of protection of facilities related to nuclear energy, as well as in the field of creating protective measures for working with radioactive materials and import and export control, including in the field of physical protection and R&D.

4. RW classification

The Law on Nuclear Safety defines “radioactive waste, including spent nuclear fuel” as radioactive materials or materials contaminated with radioactive substances that are subject to specialized treatment. The Executive Decree of the Law on Nuclear Safety defines HLW as radioactive waste, the concentration of radioactive substances and the rate of heat release of which exceed the levels prescribed by the NSSC. LILW are low- and intermediate-level radioactive waste that are not included in the previous two categories. HLW must meet both the criteria of radioactivity and the rate of heat release specified in the NSSC Standards for Radiation Protection, etc.:

- Radioactivity concentration > 4000 Bq/g for alpha-emitting radionuclides having a half-life longer than 20 years;
- Heat generation rate > 2 kW/m^3.

LILW is classified according to the criteria of radioactivity concentration and is divided into three categories: very low level radioactive waste (VLLW), low level radioactive waste (LLW) and intermediate level radioactive waste (ILW). This system of classification of LILW and maximum concentrations of radioactivity was developed taking into account the features of the existing radioactive waste management system in Korea, the development plan for radioactive waste disposal facilities and the IAEA Safety Standards Series No. GSG-1 (Classification of Radioactive Waste), published in 2009.

Overview Matrix for RW and SNF

Type of Liability	Long-term Management Policy	Funding of Liabilities	Practice/Facilities	Planned Facilities
Spent Fuel	- Plan to deveop a plan based on opinions collected by the review committee - Onsite storage until operation of an interim storage facility	Generators' pay (Generators bear the expenses for management of spent fuel which are deposited to the Radioactive Waste Management Fund)	- Stored in the onsite wet storage facility for each nuclear power plant - However, spent fuel from PHWR is also stored in the on-site dry storage facility	- Plan to deveop a plan based on opinions collected by the review committee - Onsite storage until operation of an interim storage facility
Nuclear Fuel Cycle Wastes	Disposal at the LILW disposal facility	Generators' pay (Generators bear the expenses for management of radioactive waste which are deposited to the Radioactive Waste Management Fund)	Waste generated from Nuclear Fuel Cycle is treated and stored, and then disposed of at the LILW disposal facility	CP and OL for the 2nd phase LILW disposal facility under regulatory review (engineered vault type)
Application Waste	Disposal at the LILW disposal facility	Generators' pay (Generators bear the expenses for management of radioactive waste which are deposited to the Radioactive Waste Management Fund)	- RI Waste (including disused unsealed sources) in Daejeon is received at the LILW disposal facility - Waste from KAERI is treated and stored, and then disposed of at the LILW disposal facility	CP and OL for the 2nd phase LILW disposal facility under regulatory review (engineered vault type)
Decommissioning	Immediate dismantling of NPP	- Decommissioning cost of NPPs is accumulated by KHNP every year - Decommissioning cost for research reactors is funded by the government	- KRR 1 and 2 under decommissioning since 1997 - Decommissioning of KAERI's UCF completed in 2012 and license was terminated	- Kori Unit 1 permanently shut down and under preparation for decommissioning - Wolsong Unit 1 permanently shut down and under preparation for decommissioning
Disused Sealed Sources	Research on management policy and options underway	Generators' pay (Generators bear the expenses for management of radioactive waste which are deposited to the Radioactive Waste Management Fund)	- Disused sealed sources are stored in the RI waste storage facility in Daejeon - Stored in the disposal facility in Gyeongju from July 2015	CP and OL for the 2nd phase LILW disposal facility under regulatory review (engineered vault type)

5. National Agency for radioactive waste management PAO KORAD

KORAD consists of the head office (Quality and Safety Department, Administrative Department, Project Department), the LILW Disposal Center, the Radioactive Waste Research Institute and the Fund Management Center, which is responsible for the Radioactive Waste Management Fund.

KORAD employs a total of 316 employees. The main responsibility of the LILW Disposal Center is the operation of the disposal facility. The Facility Operation Department manages the general processes at the DF – from transportation, acceptance and inspection to waste disposal. The department is also responsible for radiation safety management, environmental assessment, emergency preparedness exercises, etc.

The Head office carries out activities related to management, administrative support, public awareness, and quality control. In accordance with the Law on the Management of Radioactive Waste, generators of radioactive waste, including sources of ionizing radiation, pay the costs incurred in management these radioactive waste upon their acceptance. The expenses are paid by the state fund, thus KORAD receives the budget necessary to ensure its own activities. As of 2020, 160.79 billion won (approximately 160 million US dollars) were allocated for the management of DF and the management of radioactive materials, 1.93 billion won (approximately 1.9 million US dollars) for the management of spent fuel and 1.32 billion won (approximately 1 million US dollars) for technology development.

6. Existing disposal facilities (DF)

Nuclear energy facilities in Korea, including radioactive waste management facilities, are built and operated after passing a proper safety assessment and obtaining a permit in accordance with the Nuclear Safety Act and its by-laws. Technical inspection of these facilities is done on the continuous basis, in accordance with the conditions of the regulator. When reviewing previously approved operating conditions for a particular facility, legal procedures must be followed in accordance with the Nuclear Safety Act and its by-laws, such as authorization for significant changes or notification of minor changes.

When planning the construction and operation of a DF, it is necessary to conduct a safety assessment in accordance with the provisions of the Law on Nuclear Safety, including a preliminary and detailed study of the project of the facility. Based on the assessment data, a report on the radiation situation and the study of the object is compiled and submitted to the NSSC together with an application for preliminary permission.

Currently, the decision on the site selection for the construction of facilities for new projects has not been approved, except for the disposal site of the LILW in Gyeongju. Prior to the approval of this site in Gyeongju, the Korean authorities had been trying to find a suitable disposal site for 19 years. 9 sites were considered. The government decided to hold public hearings and a local referendum, and only after that the site in Gyeongju was approved for the DF construction.

Gyeongju was chosen, among other things, based on the highest level of consent of the local population (89.5%) compared to other candidate territories - Gusan (84.4%), Yengbok (79.3%), Pohang (67.5%). The level of agreement was influenced by the following pleasant conceptual decisions:

- exclusion of SNF from the list of waste disposed of at the site;
- adoption of legislative acts that increase the interest of administrative-territorial units in placing a DF site on their territory;
- increasing the transparency of the policy on the RW materials management and mandatory voting of local residents.

The permit for the construction and operation of the 1st facility for LILW disposal site was issued on July 31, 2008. The operation of the 1st facility started after all the conditions specified in the construction permit and operating license were fulfilled. In order to solve the problem of the lack of space and volume of RW storage facilities at the reactor sites of the NPP during the construction, KORAD received the approval of the regulator and implemented a plan for the preliminary use (partial operation) of several ground facilities, including the receipt and temporary storage building until the final completion of the construction of the 1st facility. Since the start of operation of the 1st facility of the complex, radioactive waste, stored in the building of the receipt and storage area, has been isolated after checking if it meets waste acceptance criteria. As of March 2020, the volume of LILW stored in the receipt and storage area amounted to 3,929 drums (200 liters), and 19,050 drums (200 liters) were disposed of in the silos.

The Regulation on the operation of the 1st building of the final disposal facility contains requirements for regular inspection, inspection of the disposal facility, quality control inspection, as well as a special inspection for accounting and control of nuclear materials. Regular inspections are carried out annually for 28 aspects, including structural integrity, disposal inspection – for 4 parameters, including the impact of RW disposal on the environment. Quality control is done for 18 parameters, including the quality control organization itself and the quality assurance program. Special inspections on accounting and control of nuclear materials are carried out annually to check compliance with the approved accounting and control rules.

KORAD continues to monitor the characteristics of the facility (geological, meteorological, hydrological, etc.), which are expected to change during operation and after the closure of the disposal facility.

LILW from the Hanul, Hanbit and Kori nuclear power plants are transported to DF by sea. The transport vessel for LILW is designed, built, and approved by the Ministry of Oceans and Fisheries in accordance with standards set by international organizations such as the IAEA and the International Maritime Organization, as well as Korean standards such as the Ship Safety Law and the Nuclear Safety Law. The safety of the vessel was checked by the Korean Register of Shipping, and the radiation safety of the vessel, including the procedure for its operation, was checked during the KINS inspections.

LILW from facilities in the center of the country, including the Wolsong NPP and KAERI, where sea transportation is impossible, are transported to the DF by motor transport. When transporting LILW with a volume of more than 1.6 m^3, the safety of the transport container and the operational procedures are checked by means of a transport declaration and compliance with technical standards defined by laws and regulations related to nuclear safety. If a LILW transport container is subject to licensing, all such containers must pass project approval and verification before it will be used for LILW transportation.

7. Responsibility for nuclear safety

In accordance with the Law on the Management of Radioactive Waste, the operator for the management of radioactive waste must cooperate with the regulatory body to ensure safe and efficient operations. In accordance with the Nuclear Safety Act, NSSC assumes the responsibility to verify, through inspections, that the operator of a nuclear installation complies with licensing or licensing conditions during construction or during its entire service life. If a violation occurs, the NSSC immediately orders the responsible organization/operator to take additional measures to ensure the safety of the RW disposal facility. In case of non-fulfillment of the conditions of the permit or license by the operator of the DF, the NSSC may order the revocation of the permit/license or the suspension of the operation of the installation for a certain period. If the DF performance characteristics do not meet technical standards, the NSSC may order the operator to strengthen security measures.

In accordance with the law, the operator of a nuclear installation is responsible for the safe management of SNF and RW until they are moved to a storage, processing, or disposal facility. The operator of the RW management is responsible for receiving it from manufacturers, processing (except for SNF), storage and safe disposal.

The Korean Government took responsibility for the management of radioactive waste because it needs to be handled safely in the long term. The final responsibility for the safe SNF and RW management is borne by the State.

Japan

Spent fuel management strategy – processing		
RAW inventory as of 2020		
RAW categoty		Volume of wastes
High-level waste (HLW)		2,492 casks of vitrified HLW; 576 m^3 of liquid radioactive waste
Radioactive waste acquired from Nuclear Power Palants	Elements and sections of the nuclear reactor cores (intermediatl-level wastes with rather high heat emission rate)	Adjusting rods – 11,437; Other elements – 75,041
	Low-level wastes (LLW, waste with rather low heat emission rate)	700,000 of 200-l drums at the reactor sites; 310,000 of 200-l drums at the long-term repository and processing facilities of JAEA and JNFL
	VLLW (very low-level waste)	1,670 t disposed at the Tokai repository
Radioactive wastes (spent fuel) containing uranium		19,183 t
Research plants RAW		25,139 casks of solidified wastesми отходами; 82 m^3 of liquid radioactive waste

Underground research facility				
Title	Mizunami	Horonobe	Tono	Kamaishi
Type	utility type	utility type	utility type	utility type
Hosting rock	granite	sedimentary neptunic rocks	sedimentary neptunic rocks	granite
Depth, m	300	250	130	700
In commission	from 2004	from 2005	1986-2002	1988 – 1998

Agency of state administration in the field of spent fuel and radioactive waste	METI – Ministry of Economy, Trade and Industry (www.meti.go.jp)
Organization, responsible for SF and RAW disposal project implementation (project development, R&D, licensing, construction and operation)	NUMO – The Nuclear Waste Management Organization of Japan (www.numo.or.jp)
Main National Regulatory Authority in the field of radioactive waste and spent fuel	
National Regulatory Authority on the safety and security in the field of nuclear energy	NRA – Nuclear Regulation Authority (www.nsr.go.jp)
	JAEC – Japan Atomic Energy Commission (www.aec.go.jp)

	MOE – Ministry of the Environment

Abbreviations and acronyms, legal acts descriptions:

Near-surface disposal facilities (NSDF) in Japan can be of two types: trench-type and pit-type **Nuclear Emergency Act** – is an Act on Special Measures Concerning Nuclear Emergency Preparedness.

Radiation Hazards Prevention Act – is an Act on Prevention of Radiation Hazard by Radioisotopes (was renamed to the RI Regulation Act in 2019).

The Nuclear Reprocessing Organization of Japan was established in 2016 as a consequence of publishing **the Spent Nuclear Fuel Reprocessing Implementation Act**. by this statute was established a scheme for the steady and efficient spent fuel reprocessing. In 2016, Japan amended the Spent Nuclear Fuel Reprocessing Fund Act. The Law establishes the scheme of funds securing, related to spent fuel reprocessing, is also stipulates an implementation body, responsible for reprocessing, which has to be authorized by the Minister of Economy, Trade and Industry as well. Basing on that, **the Nuclear Reprocessing Organization of Japan** was established as an authorized corporation on October the 3rd, 2016. Organization's main activities include the development of a master plan of overall nuclear reprocessing projects, collection of the expenses paid by electric power utilities, and commission of the reprocessing activities of spent fuels to a private entity – Japan Nuclear Fuel Limited, JNFL.

The Reactor Regulation Act aims to protect people's lives, health, property and preserve the environment through necessary regulation in accordance with the spirit of the Atomic Energy Basic Act. Its objective includes ensuring public safety by preventing hazards, that can be caused by radioactive materials, sealed radioactive sources, nuclear fuel material and nuclear reactors. Thus, **the Reactor Regulation Act** stipulates necessary requirements so that individuals, society and the environment are appropriately protected by its implementing. **The Reactor Regulation Act**, earlier had been named as **Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors**. This Act is aimed to promoting protection of life, health and people's property, alongside with the environment preservation by ensuring safety, based on established international standards.

The Final Disposal Act, enacted in May 2000, provides systematic and secure disposal works execution on HLW, generated from the spent fuel reprocessing ("Designated Radioactive Wastes").

Spent Nuclear Fuel Reprocessing Implementation Act (amended in 2016 the Spent Nuclear Fuel Reprocessing Fund Act). It establishes a scheme for securing funds, as well as an implementing body responsible for reprocessing authorized by the Minister of Economy, Trade and Industry. Nuclear Reprocessing Organization of Japan was established in 2016, its main activities include the development of a master plan of overall nuclear reprocessing projects, accumulating the fees, paid by electric power utilities, and substitution of spent fuel reprocessing activities to a private entity – Japan Nuclear Fuel Limited.

1. Brief History of Japanese nuclear industry development

Since 1973 nuclear power appeared to be Japan's national strategic priority, as a country within reason relying on fuel imports. Since the moment of the first NPP construction, there had been ascertainable concerns expressed about the plants' capacity to resist high seismic activity.

Before the Fukushima-1 NPP meltdown, which occurred in March 2011, there were 54 operating nuclear reactors in Japan, the country ranked at the third place in the world in terms of nuclear energy development after France and the United States, among the countries of the Asian region – at the first place. Japan's nuclear power plants produced about 30% of the country's total electricity.

Consequent the 2011 Fukushima-I NPP meltdown, which was acknowledged to be the worst crisis, generality of nuclear reactors in Japan had been shut down for the safety inspections on the back of widespread public censure over the safety of outdated plants.

By the end of 2017 Japan generated only 3.61% of electricity by force of the nuclear power. Meanwhile 34 nuclear reactors are formally classified by the IAEA and the Japanese Government as operational, only 9 of them generated electricity in 2018, the rest of the reactors were temporarily shut down.

Despite the dire consequences of the 2011 meltdown, Japan's lack of minerals and the unreliability of energy sources such as sun and wind, forces the country to import 90% of its electricity consumption, which adversely affects country's economy. Thuswise, Japan is gradually with new security measures returns to nuclear energy after its replacement attempt didn't work out in the island state. Up to date, only 10 reactors of the existing and ready-to-operate 30 nuclear reactors acquired operation licenses (as it is shown in the table below).

NPP	Reactor title	Reactor type	Capacity (MW)	Commission date (year)	Reboot (year)
Sendai	Sendai-1	PWR	890	1984	2015
	Sendai-2	PWR	890	1985	2015
Takahama	Takahama-3	PWR	870	1985	2016
	Takahama-4	PWR	870	1985	2016
Ikata	Ikata-3	PWR	890	1994	2016
Genkai	Genkai-3	PWR	1180	1994	2018
	Genkai-4	PWR	1180	1997	2018
Ohi	Ohi-3	PWR	1180	1991	2018
	Ohi-4	PWR	1180	1993	2018
Mihama	Mihama -3	PWR	826	1976	2021

Table 1. Nuclear reactors in operation in Japan as on the end of 2021

2. Legislative system in the field of RAW and SNF management

In Japanese legal frame, concerning regulation in the nuclear field, the "Basic Law on Atomic Energy," adopted in 1955, is the most important enactment of legislation and it defines the main principles of the nuclear energy use.

In accordance with this enactment, to ensure the safety of nuclear energy use the following statues were adopted: the law "On the establishment of the Nuclear Regulation Directorate (NRC)", the law "On the regulation of reactors" and the law "On the regulation of radiation" – to prevent radiation hazards.

In order to optimize spent fuel and radioactive waste management in the course of taking measures to create an advanced waste processing system and create an infrastructure for the production of nuclear energy, the Law on the Implementation of Spent Nuclear Fuel Processing was put into force. The Law on the Final Radioactive Waste Disposal was introduced to take the necessary measures to ensure the systematic and safe implementation of the final radioactive waste disposal subject to geological disposal (such as vitrified HLW, resulting from the spent nuclear fuel reprocessing).

The other necessary legislation had also been enacted, such as the Law on Special Measures of the Nuclear Emergency Preparedness, hereinafter referred to as the Law on Nuclear Emergencies, which subsists full range of measures of response to nuclear disasters.

After the Reactor Regulation Act revision in 2012, the IAEA IRRS mission in January 2016 recognized the need to improve the inspection system during the operation phase and confirmed the importance of a number of issues, identified by the NRA directly. In April 2017, NUMO amended the legislation, including the Reactor Regulation Act. Revising the inspection system, Nuclear Waste Management Organization amended the requirement on demanding the consideration on decommissioning at the early stage of design, radioactive waste (generated as a consequence of reactors decommissioning) disposal monitoring system.

The inspection system has been revised in order to increase the security level by virtue of the inspection system flexibility, covering all aspects of the licensee's activities, related to the process of safety insurance. The new inspection program is being systematically operated since 2020.

Essential changes in the legislative system in regard of RAW and SNF management for the recent 5-year period (updated in the end of 2020)

6 nuclear fuel processing facilities and 1 temporary SF storage had obtained operational permits, one of 2 licensed reprocessing facilities is at the stage of decommissioning after the reception of a relevant plan approval. 2 temporary RAW storages and 3 disposal facilities had also been licensed. 209 facilities, working with certain uranium or other nuclear fuel material amounts, were given licenses on operating with those materials.

At the same time as the amendment of the Reactor Regulation Act in 2017 mentioned in E2-2, the Radiation Hazards Prevention Act was also amended in 2017 (renamed to the RI Regulation Act in 2019). In this amendment, special cases concerning the disposal of radioisotopes and radioactive contaminants were added. When licensees and registrants under the RI Regulation Act entrust disposal to disposal licensees under the Reactor Regulation Act, such radioisotopes and radioactive contaminants can be regarded as radioactive waste under the Reactor Regulation Act. Thus, the NRA is able to regulate waste disposal in waste disposal facility installed under the Reactor Regulation Act integrally and reasonably.

Renewed requirements:

• The required performance parameters of waste treatment facilities and waste packages are being reconciled. For the reference, the requirements had been changed from previously prescribed criteria, according to specification, based on the performance exponent. Licensees are obliged to define Waste Acceptance Criteria for producers to meet the characteristics of waste packages.

• Safety scenarios were outlined in the baseline scenario (dose criterion: 0.01 mSv/year) and in the alternative one (dose limit: 0.3 mSv/year) in the previous regulation version; in the newly revised regulation, the scenarios are divided into "natural event scenarios" and "human invasion scenarios". As for the "natural event scenario", the scientific assessment, resulted to the most conservative parameters should not exceed the dose limit of 0.3 mSv/year, coincidently the result with the most conceivable figures should not exceed the criterion dose of 0.01 mSv/year. As ditch repository is unaccommodated of physical resistance engineering barrier against human intrusion, the dose standard for the "human intrusion scenario" amounts to 0.3 mSv/year, which is aligned with the naturally occurring event scenario.

• Waste, generated at the MOX processing plants, radioisotopes and a number of other substance categories have to be managed by applying the pit or ditch disposal methods. However, these two NSD methods exclude the uranium waste ingestion.

• In order of radionuclides leakage reduction at the ditch repository site, it should be equipped with an inbuilt underground covered structure to avoid ground- and rain water penetration, as for the pit repository method, there should be a concrete engineering barrier installed to restrict water flows and persist soil layers movement.

In December 2019, the Nuclear Regulation Authority revised the regulatory requirements, regarding RAW (of Category 2) repositories, engineered to be disposed in a pit or ditch

Enactment of the law "On the processing of spent nuclear fuel"

In 2016, Japan amended the Law on the Spent Nuclear Fuel Reprocessing Fund. The amendments introduced a program for the reprocessing of spent nuclear fuel and the body, responsible for its implementation had been appointed. In October 2016, the National Organization for the Processing of Nuclear Waste (The Nuclear Reprocessing Organization of Japan - NuRO) was established, which main activities included the development of a Master Plan draft of RAW processing and the creation of appropriate funds, based on contributions from companies in the fuel and energy sector of Japan. Responsibility for SNF processing, according to the concept of this project, will be transferred to a private corporation - Japan Nuclear Fuel Limited (JNFL).

3. Safety of RAW and SNF management

Based on the recommendations and proposals made by the International Emergency Agency's Integrated Regulatory Review Service (IRRS/IAEA) mission in January 2016, Nuclear Regulation Authority (NRA) revised the Law on Reactors Regulation and the Law on the Prevention of Radiation Hazards. As a result of these changes, the following improvements were made to the regulatory system:

- a reform of the control system for nuclear facilities was carried out;
- a requirement was introduced to consider the issue of decommissioning the facility at an earlier design stage;
- proposal to limit activities, including geological surveys at intermediate depths and geological disposal;
- streamlining the radioactive waste contaminated by different types of radioactive hazards and radioisotopes.

A new inspection system for SNF and RW management facilities had been implemented in April 2020.

4. Nuclear regulation of radioactive waste management

The Nuclear Regulation Authority (NRA) is the main institution that controls the field of nuclear energy, as well as radioactive waste management in Japan. NRA had been established in 2012 to ensure the radiation safety of the population and the environment. The Nuclear Regulation Authority is an external bureau of the Ministry of the Environment, its the chairman and general officials are appointed by the Prime Minister of the country on agreement with the Parliament of the country. NRA has the right to issue permits for the construction of such nuclear installations as: temporary storage facility, disposal facilities and some other types of professional activities in the field of RAW management.

SNF and radioactive waste producers in Japan carry out all their activities in accordance with the Reactor Regulation Act, and therefore the occurrence of unidentified spent nuclear fuel or radioactive waste in the country is unlikely.

5. Radioactive waste classification and register

The Japanese RAW classification system provides its division on two main categories, depending on the level of its activity: high and low. The Reactor Regulation Act (on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors) represents the upper limits of radionuclides concentration, that can possibly be containing in the radioactive waste.

High-level waste (HLW) is a radioactive substance, that is formed, resulting to spent fuel processing. HLW category further includes the vitrified waste, obtained as a consequence of liquid radioactive waste (LRW) solidification, and it contains a significant amount of fission material and actinides.

Low-level radioactive wastes (LLW), according to the customary system, are being divided into four categories:

1. **LLW,** resulted from the NPP operation;

2. long-lived heat-emitting **LLW (transuranium wastes)** are formed as a result of spent fuel processing and MOX-fuel production, which contains radionuclides of the atomic numbers above 92 (like neptunium, plutonium, americium, etc.);

3. uranium containing **LLW** is generated at nuclear fuel production and uranium enrichment facilities, and it contains long-lived uranium radionuclides with its decay products;

4. **LLW** obtained from the research facilities.

RAW produced at NPPs are divided into three categories:

1.RAW of reactor core constructions with sufficiently high heat emission level – HLW;

2. RAW with sufficiently low level of heat generation – LLW;

3. RAW of very low activity level (**VLLW**), its disposal is customary allowed in near-surface trench-type facilities, engineering safety barrier or RAW preliminary encapsulation are uncovenanted for the design of a VLLW-special repository type.

6. Japanese RAW inventory

Japanese electric power utilities contracted with the United Kingdom and French companies on reprocessing of 7,100 MTU of spent fuel (5,600 from LWR and 1,500 from GCR) between 1969 and 2001. In return Japan got nuclear fuel decontaminated from SF residuals and vitrified HLW. Containers with the vitrified waste had been returned to the country and subsequently stored at the specialized Facilities for storing returned vitrified waste, belonging to the JNFL reprocessing facility as per the contracts agreements. By the end of March 2020, 1,830 canisters of vitrified RAW had been returned back to Japan (between 1995 and March 2020). The return shipment of 1,310 vitrified waste containers from France began in 1995 and ended in 2007. The return shipments of vitrified waste containers from the UK began in 2010, approximately 380 remaining vitrified waste containers will be returned to Japan within several iterations in about three years. As Rokkasho (Aomori Prefecture) reprocessing plant had been at the construction process from 1993, there were no contract on SF processing with the United Kingdom or French companies after 2002. Now Rokkasho Reprocessing Plant of JNFL keeps 346 vitrified canisters, obtained resulting to the active test operation execution.

High-level liquid wastes, generated at the Tokai Reprocessing Plant of JAEA, were stored in tanks within the territory of Tokai plant site and had been solidified at the vitrification facility, that began operating in January of 1995. By March 2020, there were about 365 m^3 of LRW and 316 vitrified waste casks in the storage. Vitrified waste casks are customarily subjected to deep geological disposal isolation method in accordance with the Final Disposal Act.

As of the end of March 2020, the waste remaining deposited at the NPP sites in the RAW interim storage facilities comprised of appr. 700,000 LLW casks (200 l each), 35 disused steam generators, disused control rods, channel boxes, dumped ion-exchange resin. Beyond that, the certain volume of break-stone, trimmed trees, dumped protective clothing (and RAW of some other nature, generated after the accident) amounted to 472,500 m^3 total. The waste obtained from the contaminated water treatment summed up to 4,713 of cesium absorber columns and 597 m^3 of sludge, deposited at the TEPCO Fukushima Daiichi NPP interim storage. 2,492 containers with vitrified HLW and about 576 m^3 of high-level liquid waste are located at the waste storage and processing facilities.

3. Practices of radioactive waste and spent fuel management. Radioactive waste management facilities

There is a number of RAW repositories in Japan along with the storage facilities for the wastes to be temporarily stored till the moment of its disposal. Apart from the RAW repositories and storages engineered in Japan, there is a number of near-surface disposal facilities (NSDF) of trench- and pit-type built in the country.

VLLW is customary disposed into the trench-type facilities. The solidified cement-packaged wastes or homogeneously covered wastes are disposed in casks to the pit-type disposal facilities.

In 1992, LLW, located at the RAW storages at the reactor sites, had been placed under control of

Japan Nuclear Fuel Ltd. (JNFL) to be disposed in a deep vault.

JNFL specializing in RAW disposal accepted for final isolation appr. 310,000 drums (200 l each) by of the end of March 2020. Approximately 1,670 t of concrete structures (VLLW), obtained resulting to the dismantling of demonstration power reactor belonged to the Nuclear Research Institute, were disposed by the Japan Atomic Energy Agency (JAEA) through the trench method.

Wastes subjected to disposal under active control

Operators, responsible for the RAW management, perform its duties regarding waste, generated at their own facilities, in accordance with the Reactor Regulation Act, Radiation Hazards Prevention Act and other relevant regulations.

Disposals, subjected to the active control in Japan, are categorized into three following types: “near surface trench disposal”, “near surface pit disposal”, and “disposal at the intermediate depth”. Low-level radioactive wastes, generated at the NPP and subjected to the near surface trench or pit disposal are already being managed with this method.

Method of deep geological RAW disposal in the hosting rocks

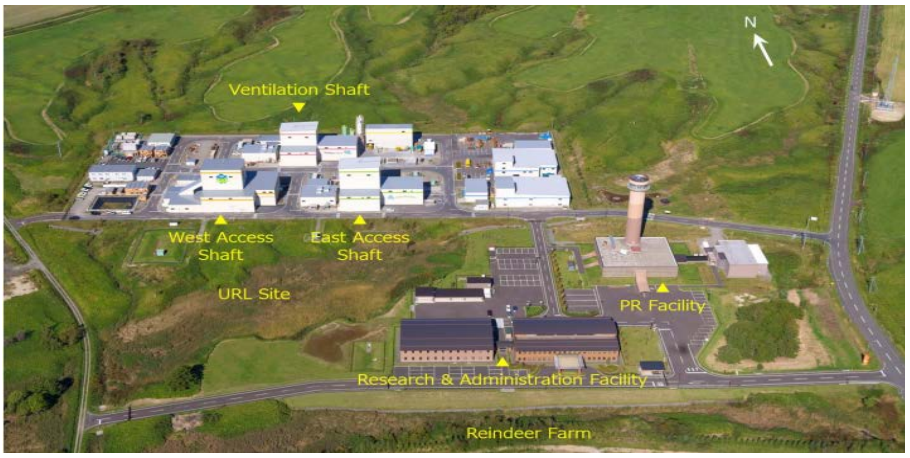
In Japan, a site for geological disposal of HLW is determined through three selection steps: “choosing a preliminary investigation area”, “choosing a detailed investigation area” and “choosing a construction site for the final disposal facility”, in accordance with the Final Disposal Act established in May 2003.

During search for alternative disposal options, the technical reliability of the geological method of RAW disposal was assessed. The Government, involved into the development of this project, is considering the matter of regional consensus, which is being formed by the sum of the inhabitant’s opinions in the region, where DGR is planned to be construction, along with the unique factors inherent to a particular region.

The Nuclear Waste Management Organization of Japan (NUMO) was established in 2000 as an organization, responsible for implementation of RAW final disposal. All the nuclear field enterprises deposited financial contributions to the NUMO reserve fund on creation of DGR. NUMO addressed to the public announcing the site selecting process beginning for defining a region-candidate to carry-out the studies on estimation of the possibility to build there a DGR. The study has not been begun yet.

Under these circumstances, the Japanese Government revised fundamental policy based on the Final Disposal Act in May, 2015. In the new policy it was decided that Japan should take the initiative to solve the problem of high-level radioactive waste.

In order to ensure a deeper public concern and understanding of the DGR project, Government is supposed to indicate an area, having highest suitability from a scientific perspective. The Japanese Government published the “Nationwide Map of Scientific features for Geological Disposal” in July, 2017. While making efforts on the assumption of geological disposal, it is ensured that the future generation will be able to select the best disposal method (reversibility and retrievability). The technical reliability of geological disposal will be evaluated while proceeding with parallel surveys and research of alternative disposal options. In addition, structure of regional consensus building for citizens of various positions to participate in and supportive measures toward the sustainable development of communities to accept final disposal site will be considered.



Horonobe URL Site plan

Horonobe URL Site underground outline

4. Public outreach

To clarify the discussions, taken in the framework of decontamination and waste management processes, the Nuclear Regulation Authority issued the "Operational Transparency Policy", which is centered on the following basic principles:

1) establishing an information-disclosure system, that will eliminate periodic disclosure requests;

2) holding of fully-fledged public discussion;

3) timely execution of comprehensive administrative arrangements, conforming to the pertinent statutory enactments (and/ or documents).

In accordance with the Policy, the NRA decided to convene a commission to approve information disclosure and transparency principle in regard to research results and minutes of meetings, where the experts and public representatives are rendering the decisions in regard to the RAW management. In compliance with this Policy the NRA is required to prepare summaries of all the meetings, attended by 3 or more Commissioners. NRA is obliged to publish the rundowns of interviews, held between the representatives of nuclear installation licensees and NRA Commissioners or Secretariat officials, later providing the full-text versions of this meetings to public attention.

The NRA conducts the committee sessions and other training meetings openly in accordance with its "Operational Transparency Policy" and "Operational Guidelines for Conducting Commission Meetings". The Authority streams the committee sessions, trainings and seminars live on the YouTube, and publishes abridged episodes of the meetings, that had not been broadcasted live. The total time of video materials, released on YouTube platform by NRA in 2019 amounted to more than 900 hours.

Additionally, background materials used at the commission meetings, compliance review meetings, and research group meetings are posted on the NRA official website. The minutes of the commission meetings are published the next day, and other various sessions minutes, such as compliance meetings and research group meetings, are published in about 1 week after its holding.

The Technical Information Committee, examining whether the latest findings require a certain response, often uses non-disclosure material from international regulators, that is the reason, this meeting itself is held in private. The NRA is pursuing this policy since June 2018.

The NRA invited external experts to join the research team, and also held public hearings with the licensees participating. Regarding meetings with licensees or the consecutive area professionals, the NRA held it successfully in compliance with information transparency principle, as a higher communication density contributes to the acquisition of domestic and international knowledge jointly with the regulation understanding alongside with building of liaising for rapid response in emergency situations.

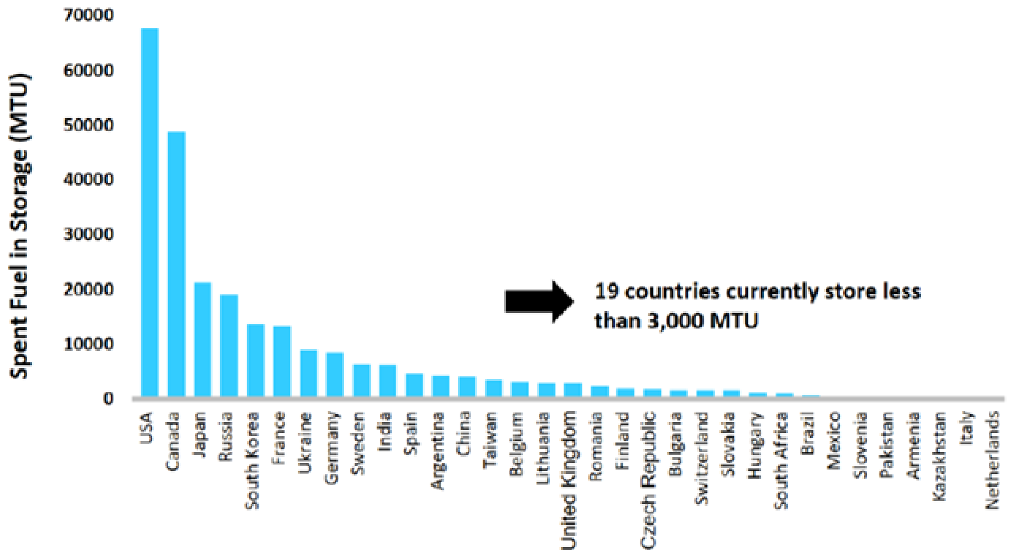
Multinational Repository (MNR)

At present is a clear understanding that every country bears ethical and legal responsibility for radioactive waste (RW) generated on its territory[28]. The major position is that all radioactive waste will be disposed of in each of the approximately 50 concerned countries. Radioactive waste is managed basing on national strategies that certainly implement international principles, including such aspects as collection, processing, temporary storage, and final isolation (disposal) of radioactive waste. Cross-border cooperation of the countries in this area is significantly hampered due to the focus exclusively on national strategies and practices of the RW management. This matter is quite influenced by the internal policy for the nuclear energy and related issues.

According to the generally accepted approach, a country, benefiting from peaceful atom developments and nuclear technologies, should bear full responsibility for the management of the generated radioactive waste. Most of the high-level waste is generated in the nuclear reactors producing electricity in more than 30 countries around the world. However, there are countries with volumes of generated radioactive waste that hardly justify the creation of a separate national disposal facility, or these countries do not have economic resources or suitable natural conditions for the disposal of radioactive waste. In such cases, it is reasonable to participate in the creation of a multinational repository (hereinafter – MNR), in order to dispose all RW generated on the territory of the country, thus, fulfilling its obligations for the safe management of radioactive waste.

1. Background of multinational repository projects

Many countries currently have small nuclear power programs that generate relatively small amounts of spent nuclear fuel and/or high-level radioactive waste. The number of countries adding nuclear power generation to their energy mix is expected to increase over time, and this will likewise increase the number of nuclear power programs generating relatively small amounts of spent nuclear fuel.



The long timescale over which some radioactive waste remain hazardous has led to the concept of disposing waste in deep underground repositories in stable geological formations. Waste isolation is ensured by a combination of engineered and natural barriers (rock, salt, clay), and no obligations to actively maintain the facility is passed on to future generations. Deep geological repository (DGR) disposal is the preferred option for nuclear waste management in several countries, including Australia, Argentina, Belgium, Great Britain, Hungary, Spain,

[28] IAEA, Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, URL: https://www.iaea.org/sites/default/files/infcirc546.pdf; and IAEA: Nuclear series. Policy and strategy in the field of radioactive waste management, URL: https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1396_web.pdf

Canada, the Republic of Korea, the Netherlands, Russia, Finland, France, the Czech Republic, Switzerland, Sweden, Japan, and the USA[29].

2. Multinational repositories – historical background of the multinational approach to the RAW management

In November 2003, Mohamed El Baradei, Director-General of the UN's International Atomic Energy Agency (IAEA), said to the 58th Session of the UN General Assembly that countries should consider multinational approaches to the management and disposal of spent fuel and radioactive waste. He noted that over 50 countries currently had spent fuel stored in temporary locations, awaiting reprocessing or disposal. Not all countries have the appropriate geological conditions for such disposal – and, for many countries with small nuclear programmes, the financial and human resources required for the construction and operation of a geological disposal facility are daunting. A year later, some arguments were again presented at the Annual Symposium of the World Nuclear Association that the international community should take concrete steps to expedite credible proposals for shared repositories[30].

The IAEA put forward three concepts for multinational repositories:

- Incremental addition to a large national programme
- A supranational facility with international management and control
- Collaborative partnering among countries for a multinational repository

A specific decision on the practical development of one of the above proposals for the multinational disposal facility was not taken at that time, though there was a broad consensus that geological disposal is the only way of ensuring adequate safety and security in the long-term management of spent fuel, which is treated as waste, and of separated high-level radioactive waste.

The multinational radioactive waste disposal facility should operate in accordance with the Treaty on the Non-Proliferation of Nuclear Weapons (NPT)[31]. The trustworthiness and standing of the host country is fundamental to the project's acceptability to NPT states, which comprise virtually every country but India, Pakistan, Israel, and North Korea. Also, the international treaty produced by the IAEA and signed by most nations of the world in 1997 covering the management and disposal of used fuel and high-level waste requires that the host facility or system meets the highest national and international standards[32]. Even countries with no nuclear power have a need for secure disposal of long-lived radioactive waste from their research reactors, medical or industrial installations.

The multinational repository of radioactive waste again became an issue in mid-2019. This was mentioned in the presentation of the International Framework for Nuclear Energy Cooperation. IFNEC made a report Development *of Multinational Repository Concept: Exploring Alternative Approaches to Financing Multinational Repository*[33] with the specification of the phased profile of the costs of MNR. IFNEC concluded however that multinational repository development was not yet timely, though the concept had potential and should continue to be studied.

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[29] International Nuclear Fuel Cycle Evaluation (INFCE), URL: https://www.iaea.org/sites/default/files/22204883033_ru.pdf>

[30] «Nuclear Fuel Cycle Centers – an Old and New Idea", Charles McCombie, Neil Chapman, Annual Symposium of the World Nuclear Association (2004), URL: http://www.arius-world.org/pdfs_pub/WNA-%20Fuel%20Cycle%20Centres-04%20NAC%20CMcC.pdf>

[31] The Treaty on the Non-Proliferation of Nuclear Weapons, approved by UN General Assembly resolution 2373 (XXII) of June 12, 1968, URL: https://www.un.org/ru/documents/decl_conv/conventions/npt.shtml.

[32] Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, adopted on September 5, 1997 by a Diplomatic Conference convened by the IAEA, URL: <chrome-extension://oemmndcbldboiebfnladdacbdfmadadm/https://www.iaea.org/sites/default/files/infcirc546_rus.pdf>.

[33] Development of Multinational Repository concept: Exploring Alternative Approaches to Financing Multinational Repository, IFNEC, International Conference on Spent Fuel Management of Nuclear Power Reactors, June 24-28, 2019, Vienna, Austria, URL: https://www.ifnec.org/ifnec/jcms/g_12434/iaea-cn272-id120-zagar-ppt.

3. Modern initiatives of multinational SNF and RW repositories

3.1. MNR project in South Australia

In May 2016 the South Australian Nuclear Fuel Cycle Royal Commission[34] reported that there is a need and possibility to create a facility for the disposal of international spent nuclear fuel and intermediate-level waste accumulated in some countries.

The World Nuclear Association said that the report had fundamentally changed the nature of the global nuclear waste discourse, and a multinational waste facility based in South Australia would provide a welcome option for countries operating nuclear facilities today[35].

The timeline for establishing an interim storage facility and associated transport infrastructure, including harbour, port and railway would be 11 years after project commencement. Transferring spent fuel and ILW from surface storage to underground repository would begin at 28 years. Although, legislative changes would be necessary at state and federal levels.

3.2. ARIUS

Early in 2002 a new, non-commercial body to promote the concept of regional and international facilities for storage and disposal of all types of long-lived nuclear waste was set up. This is ARIUS – the Association for Regional and International Underground Storage[36]. A key objective is to explore ways of providing shared radioactive waste management approaches and facilities, in particular storage and disposal facilities for smaller users. Membership is open and comprises countries with small nuclear programmes as well as industrial organisations with relevant interests.

A 2003 European Commission proposed directive said that geological disposal of radioactive waste was preferred and an approach, involving two or more countries, could also offer advantages especially to countries that have no or limited nuclear programmes, insofar as it would provide a safe and less costly solution for all parties involved[37].

In September 2006 the EC-funded SAPIERR II (Strategic Action Plan for Implementation of European Regional Repositories) project was commenced to assess the feasibility of European regional waste repositories. This indicates a recognition in the EU that implementing 25 national repositories is not optimal economically or for safety and security. The project was in line with proposals from the International Atomic Energy Agency (IAEA), Russia and the USA (with the Global Nuclear Energy Partnership, now IFNEC) for multilateral cooperation in the fuel cycle in order to enhance global security. Shared repositories for high-level nuclear waste are an important element of this. The main outcome of this was that the European Repository Development Organisation (ERDO) was set up. As of April 2020, ERDO consisted of Austria, Croatia, Denmark, Italy, the Netherlands, Norway, Poland, and Slovenia.

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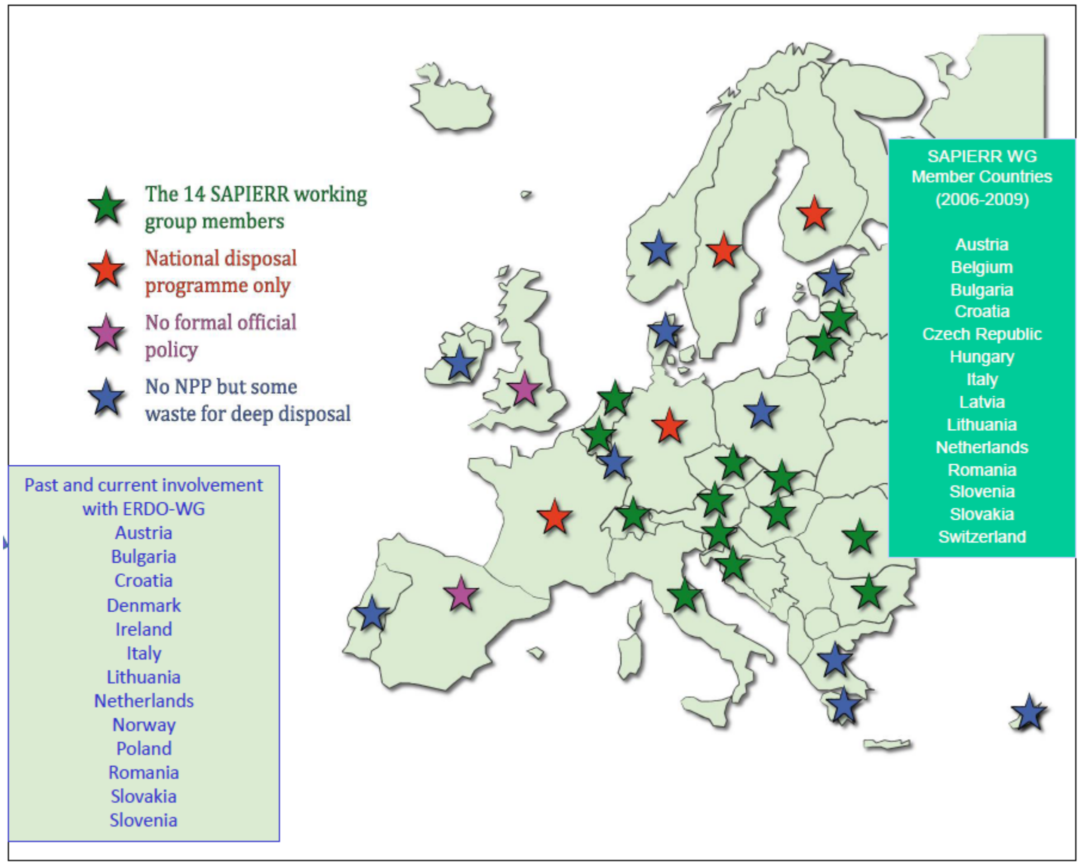
[34] Official website of the Nuclear Fuel Cycle Royal Commission, URL: http://nuclearrc.sa.gov.au.

[35] Royal Commission's conclusions create middle-ground in the nuclear waste discourse, World Nuclear Association report (9.05.2016), URL: https://www.world-nuclear.org/press/press-statements/royal-commission%E2%80%99s-conclusions-create-middle-groun.aspx.

[36] Official website of Arius project, URL: http://www.arius-world.org/index.html.

[37] Commission of the European Communities, Proposal for a Council Directive (Euratom) on the management of spent nuclear fuel and radioactive waste (30.01.2003), URL: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52003PC0032(02)&from=EN.

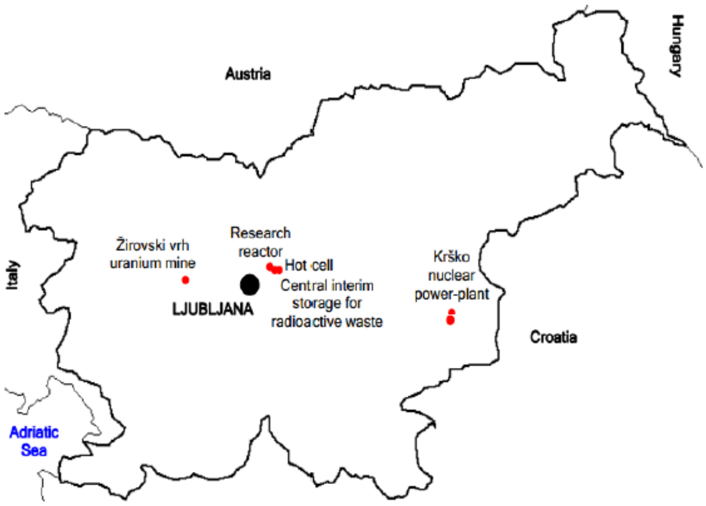


A multinational or "dual-track" approach in the field of radioactive waste management, involving the combination of a national program for the storage and disposal of radioactive waste and options for regional cooperation, has already been included in the strategies of some countries that develop nuclear power programme, in accordance with the Waste Directive – for example, the Netherlands and Slovenia.

Arius makes its research, evaluating whether similar, regional shared solutions would be appropriate for and of interest to emerging nuclear power programmes in the Persian Gulf, Middle East, and North Africa (MENA) region and also southeast Asia. The overall aim is to assess the interest within each region of working towards regional repository development organizations (RDOs) similar to the Europe's ERDO.

Since 2012, meetings have regularly been held in the region with the participation of an expanded group of Persian Gulf countries and the support of the IAEA. In the six countries of the region where the Gulf Cooperation Council operates, the possibility of launching a project on joint radioactive waste management and disposal is also being considered. The UAE and Saudi Arabia, which have rapidly developed nuclear energy programs, are among these countries.

Arius estimated that the cost of such a shared regional repository in the Middle East might be $4 billion but would offer a large payback in the form of regional security. It would not be needed before about 2080.



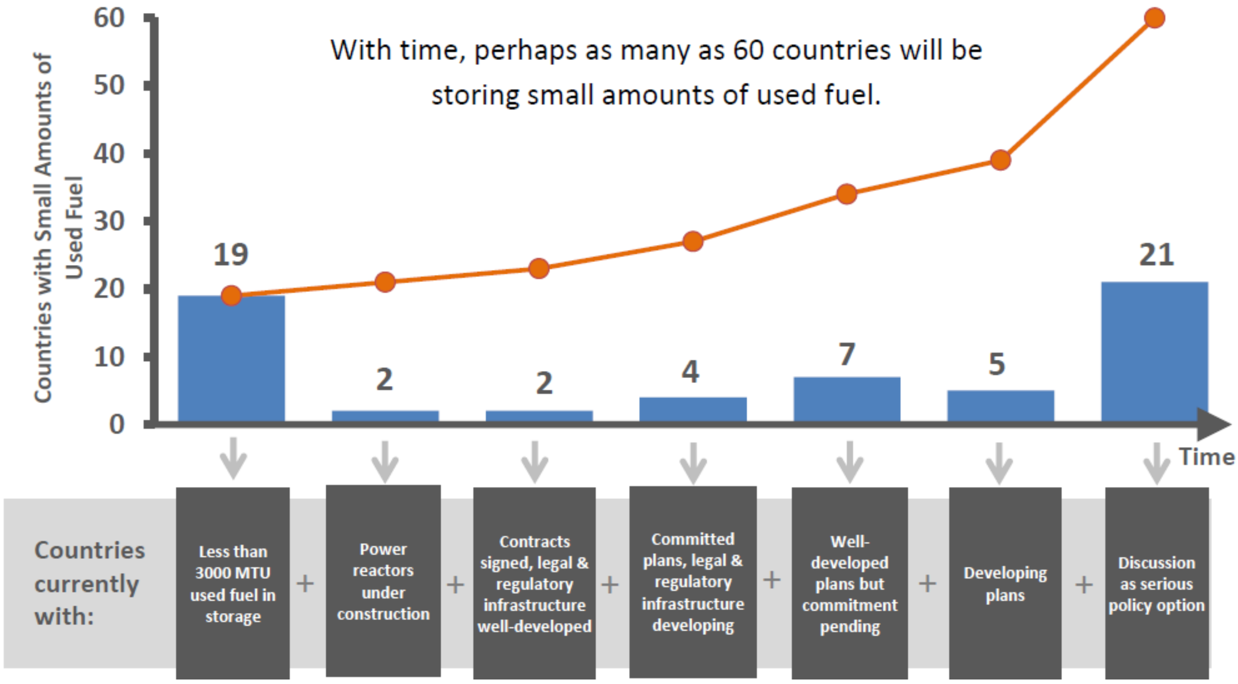
4. Financing the MNR project

For the past decade the International Framework for Nuclear Energy Cooperation (IFNEC) has worked to advance the Multinational Repository (MNR) Concept. The concept has been discussed and developed in a number of IAEA publications going as far back as 1998[38].

One of the key problems of the MNR concept is financing. As part of the IFNEC work on the MNR concept, a workshop was held in Paris in December 2018 [39] to begin a dialogue on the various approaches that might be used to finance an MNR. The work on the MNR concept development is being continued as the interest to the shared solutions of RW management is growing.

[38] Technical, institutional and economic factors important for the creation of a multinational repository of radioactive waste, IAEA-TECDOC-1021, IAEA, Vienna (1998); Development of multinational radioactive waste storage facilities: infrastructure framework and scenarios of cooperation, IAEA-TECDOC-1413, IAEA, Vienna (2004); Technical, economic and institutional aspects of regional spent fuel storage facilities, IAEA-TECDOC-1482, IAEA, Vienna (2005).

[39] International Framework for Cooperation in the Nuclear Field, Seminar: Financing Multinational Repositories, "Approaches to financing multinational repositories – problems and alternative approaches", IFNEC, Paris (2018), URL: <chrome-extension://oemmndcbldboiebfnladdacbdfmadadm/https://www.ifnec.org/ifnec/upload/docs/application/pdf/2019-10/74820_ifnec_rnfswg_workshop_on_approaches_to_financing_web.pdf>.



5. International legal obligations and consequences of the establishment of a multinational RAW disposal facility.

Long timelines of underground disposal repository require the forecasting of several “what ifs” regarding the future global political landscape and its nuclear risks[40]. It will particularly focus on potential scenarios where safeguards agreements may no longer apply, but also how they may be shifted, and the potential for the current (and future) nuclear non-proliferation regime to respond.

MNR projects could be specifically designed, sited and constructed to create high levels of security that would benefit the host country, partner countries, and international security.

5.1. Nuclear cooperation agreements

Nuclear cooperation agreements (NCA) are generally bilaterally negotiated agreements that are additional to IAEA safeguards agreements, and which provide further assurances of peaceful uses for items transferred pursuant to the agreement as well as items derived from transferred items. Given IAEA safeguards are generally not concerned with origin attribution.

The establishment of MNR would not likely require a revision of these provisions, but it could be expected that they would need to be more expressly clarified and strengthened. Objectively, a separate discussion of the framework and risks associated with the MNR project will be required in the nuclear-weapon states.

In order to take into account the possible course of events, it would be possible to strengthen the legal framework of the MNR project, supplementing it with the obligations of the host country, as well as partner countries, aimed at providing reliable guarantees of the use of nuclear material for peaceful purposes and any other undeclared actions. These measures can be supported by the financial and logistical support of the host country with the participation of all partner countries.

6. Conclusion and recommendations

[40] C. Vestergaard, J. Casterton, “Back-end to the Future: Some Safeguards Considerations for Multinational Geological Repositories”, Technology&Trade, Stimson Center (2020), URL: https://www.stimson.org/2020/back-end-to-the-future-some-safeguards-considerations-for-multinational-geological-repositories/.

Multinational repositories can play a positive role in improving global security by providing a wider range of countries with the opportunity to dispose radioactive waste in a timely manner. For some IAEA member states, multinational repositories are a necessity if the safe and reliable disposal of long-lived radioactive waste is to replace indefinite storage at ground facilities.

The global advantages of multinational repositories are obvious, and the benefits can be significant for each of the parties if they are distributed on an equitable basis. For individual countries, the balance of advantages and disadvantages arising from participating in the project as a host or partner should be weighed by the relevant national decision-making bodies.

The creation of MNR is a difficult task. There are already several possible scenarios for the development of the MNR system.

It's noticeable that, despite the independent development, there are related areas in the presented approaches. Each of the approaches presents opportunities for further consideration and analysis. The MNR concept is of considerable international interest. International specialized organizations and working groups would be enthusiastically ready to initiate a project that has every chance of becoming the first in its field, which will entail a whole series of similar projects around the world.