



FINAL DISPOSAL OF DISUSED SEALED RADIOACTIVE SOURCES IN FRANCE : OPERATION AND POST-CLOSURE PHASE PROTECTION @ CSA & CIGEO

Jérôme ROBIN

Workshop on end-of-life management in support of
radiological security and technology transition

28-30 March 2023

Aix en Provence, France

SRS manufacturer/supplier/distributor in France



Last french manufacturer
(only low activity SRS)



Former major manufacturers/suppliers

*Last SRS supplied in 2006
(only return and conditionning now)*



All other SRS distributed today in France are imported
(and, normally, re-exported)

Regulatory Framework in France

Public Health regulation

National SRS inventory kept by
import/export, distribution, return, ...



Supplier/manufacturer distributing in France have to :
provide a **return** service / **recycle** / manage **disposal**

Environment regulation

DSRS considered as a **waste** when the decision of its disposal is made

- Supplier/manufacturer becomes a waste producer responsible for **characterization**, **conditionning**, **cost of handling** + **disposal**
- No specific regulation for DSRS compared to other radioactive waste
(disposal limited to waste with french origin)

Andra's status and purposes



Status :

- governmental agency operating under the auspices of the Minister Of Energy, Research and the Environment
- independent from radioactive waste producers

Purposes :

- Studying and designing disposal facilities for waste with no long-term management solution available
- Operating existing facilities
- Managing radioactive waste in France and ensuring the safety of current and future generations

Disposal safety principles and objectives

Protection during all life phases of the facility : operation and post-closure

Protection objectives broken down into 2 protection functions

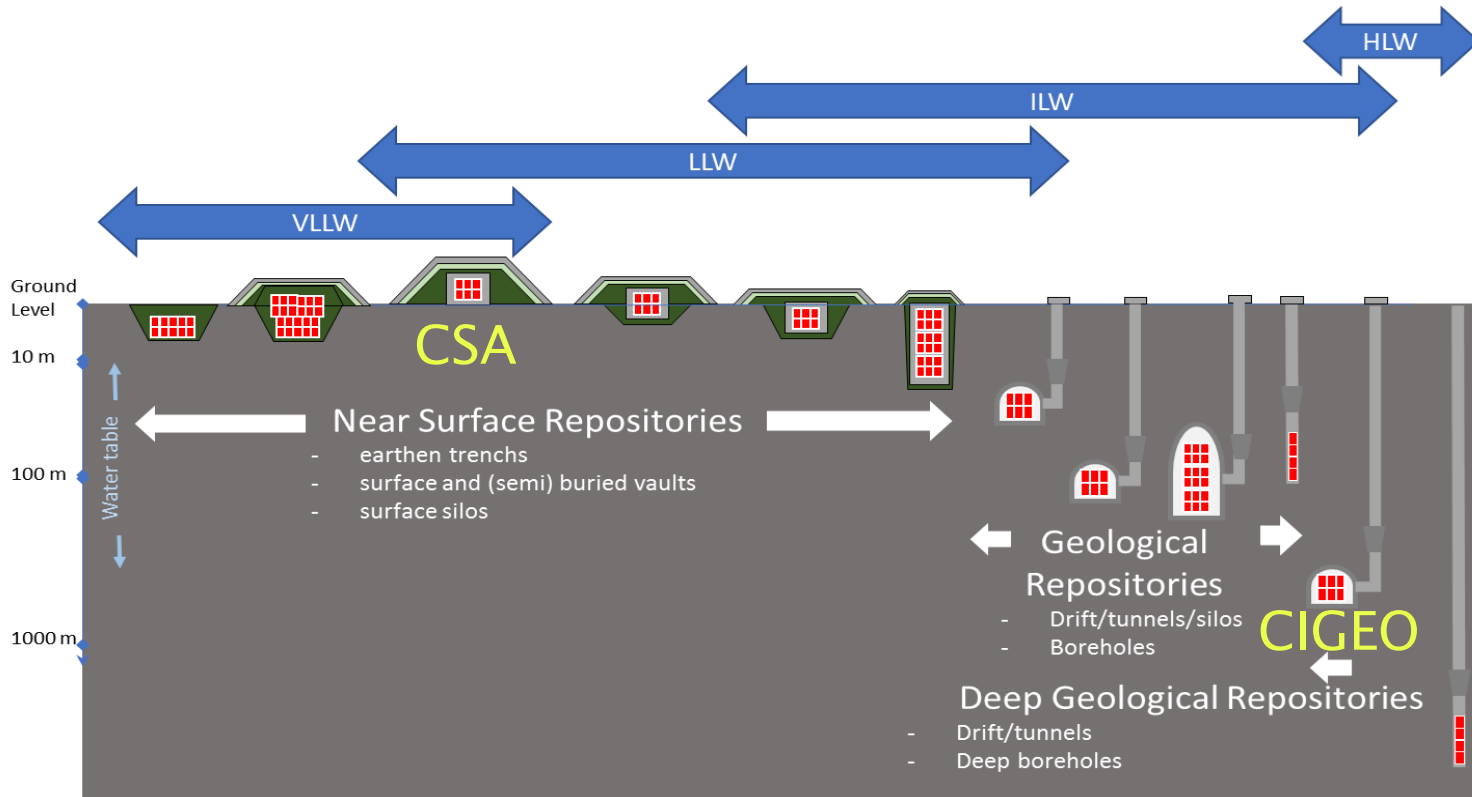
- Isolate wastes from human beings and environment for the time necessary for their decay
 - SL ~300 years, LL > 10,000 years
- Limit the transfer of radionuclides and toxic chemicals to the biosphere

Principle of defense in depth

- Ensure that the failure of the safety functions of one of the barriers is compensated by the safety functions of other barriers



Disposal safety concepts vs waste category

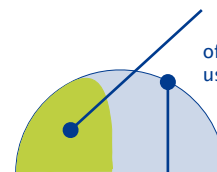


CSA : safety disposal of SL-LL&IL Wastes

(mainly exploitation wastes from Nuclear Power Plants)

37 %⁷

of the capacity
used at end 2022



1 million ^{CAPACITY AUTHORIZED} m³

BNI
n° 149

SV69 : example of DSRS package for ^{60}Co sources

1. Dismantling of devices in hot cells by CEA/CisBio
2. Sources collected in stainless capsules
3. Conditioning in a disused transport package for radiological shielding ($< 20 \mu\text{Sv/h}$ at contact to enable human handling / conditioning /disposal operation on CSA)
4. Over-conditioning in a type B transport package (Manon) for ADR regulation



SV69 : conditioning operations (08/2019)



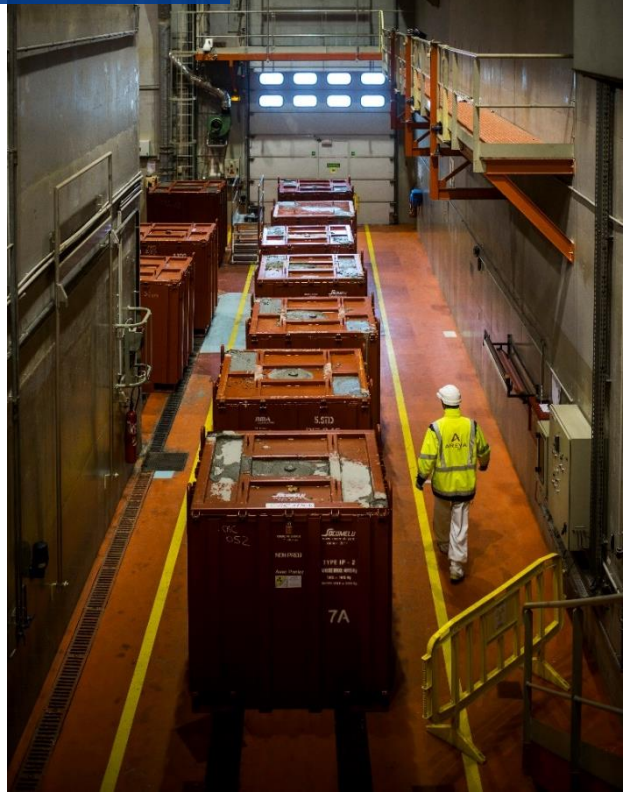
SV69 : conditioning operations (08/2019)



SV69 : conditioning operations (08/2019)



Injection of 5 m³ metallic boxes



Disposal vaults for metallic waste packages



Disposal vaults for metallic waste packages



CSA : operation and post-closure phase protection

Compared to other radioactive waste, DSRS present two specificities for disposal safety

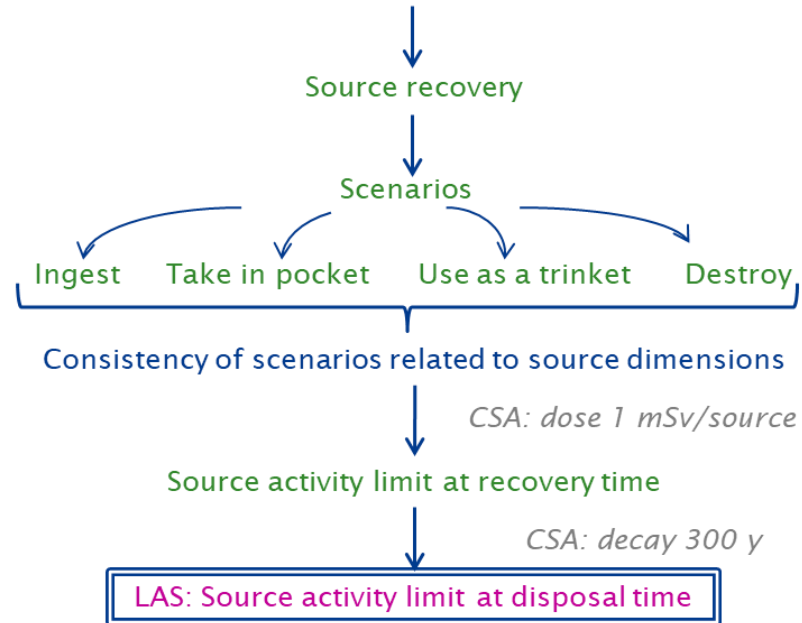
1. During operation phase:

- Risk of “hot points” relatively to exposure in case of accidental situations (fall)

2. During post-closure phase:

- Risk of recovery in case of inadvertent human intrusion
- Sources are considered attractive and durable

Inadvertent human intrusion in the repository after loss of memory



CSA : DSRS main acceptance criteria

- Half-life ≤ 30 years
 - Operation safety: package activity ≤ 270 TBq
 - Post-closure safety: source activity \leq RN-dependant limits (LAS)
- Half-life $\leq 5,27$ years (^{60}Co): no LAS (cat 1&2 sources after decay)

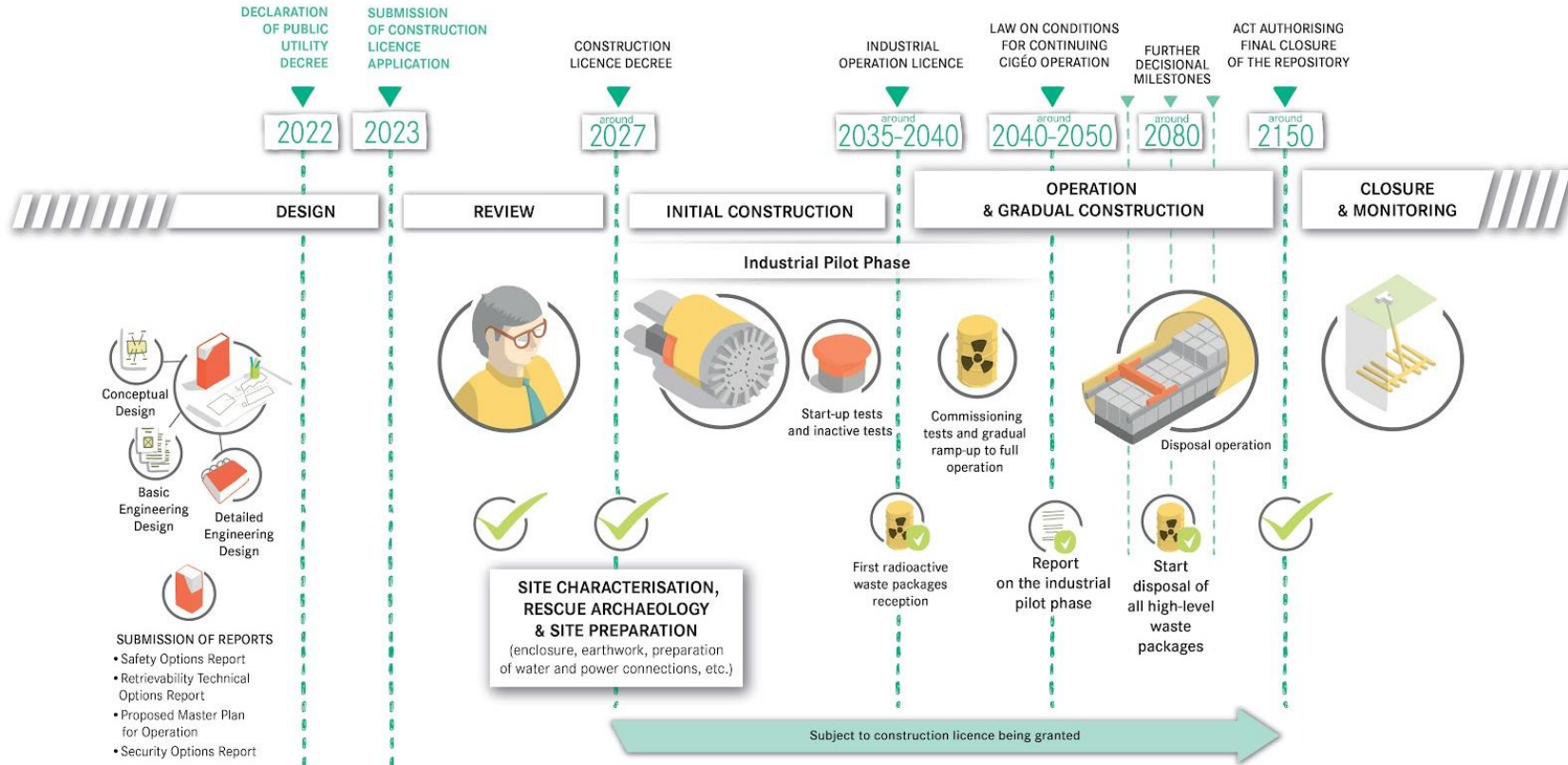
Rn	Half life (y)	Small size		Medium size		Large size	
		LAS (Bq)	Main scenario	LAS (Bq)	Main scenario	LAS (Bq)	Main scenario
^{133}Ba	11	$2,55.10^{13}$	Ingestion	$6,79.10^{13}$	Pocket	$6,78.10^{14}$	Destruction
^{152}Eu	13	$1,36.10^{11}$	Ingestion	$1,49.10^{11}$	Pocket	$1,49.10^{11}$	Destruction
^{90}Sr	29	$8.18 \cdot 10^6$	Pocket	$8.18 \cdot 10^6$	Pocket	$8.16 \cdot 10^7$	Destruction
^{137}Cs	30	$2.19 \cdot 10^7$	Pocket	$2.19 \cdot 10^7$	Pocket	$2.19 \cdot 10^8$	Destruction

CSA : CisBio waste packages impact on radiological capacity @ 01/01/2023

- Number of waste packages @ CSA : 423 565
 - Total activity in Co60 : 7 956 TBq
 - Radiological capacity in Co60 : 400 000 TBq
- For 32 CisBio DSRS waste packages (19 SV69, 7 SV34, 1 OTER and 5 TWB)
 - Total activity of 4 700 TBq in Co60
 - **59%** of Co60 total activity @ CSA
 - **~1%** of CSA Co60 radiological capacity

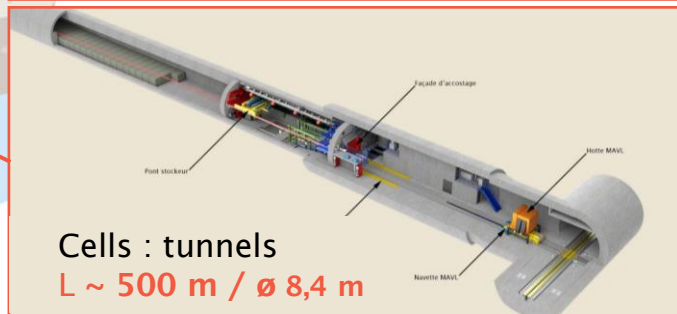
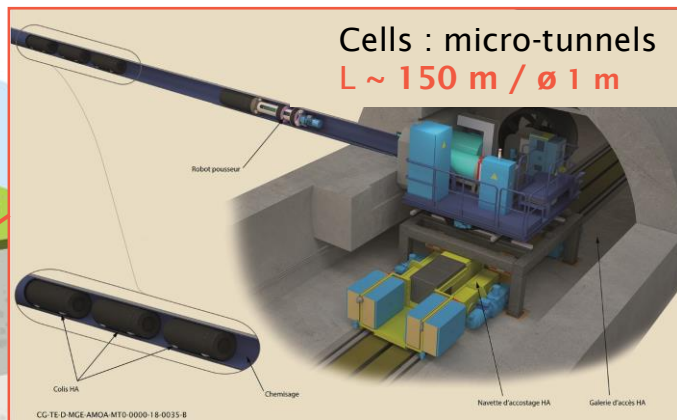
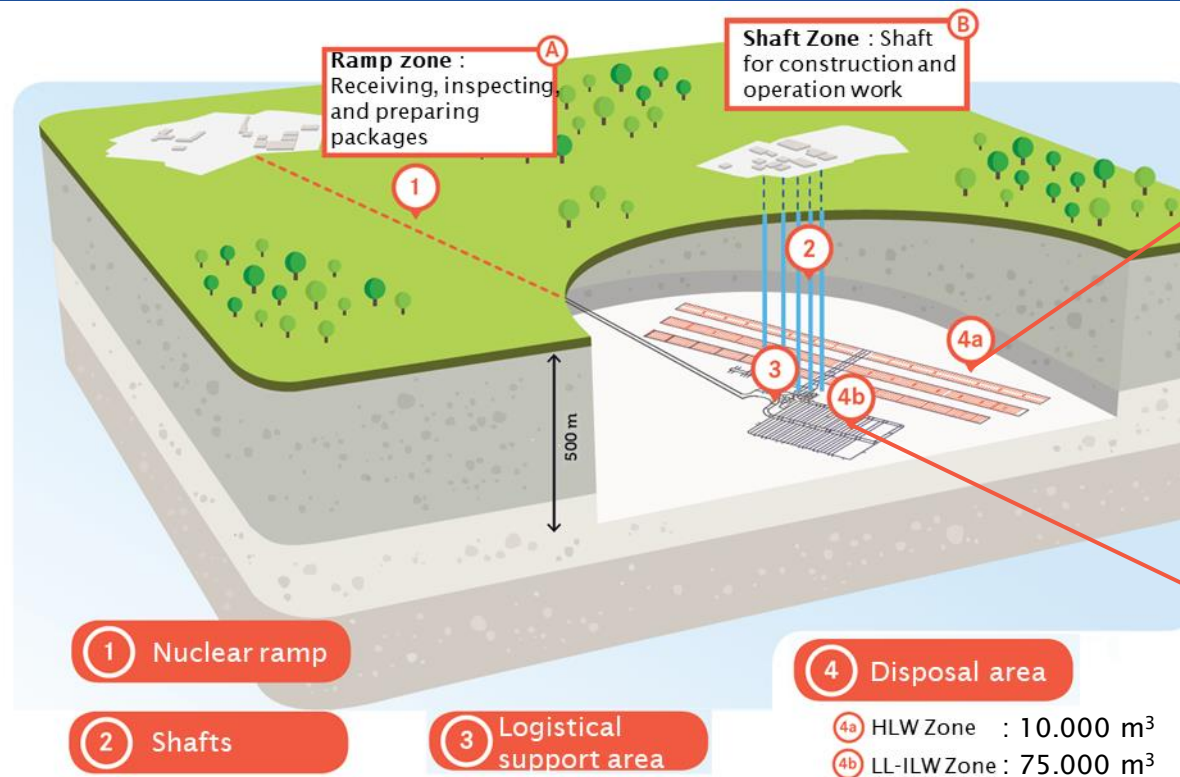


CIGEO : major milestones



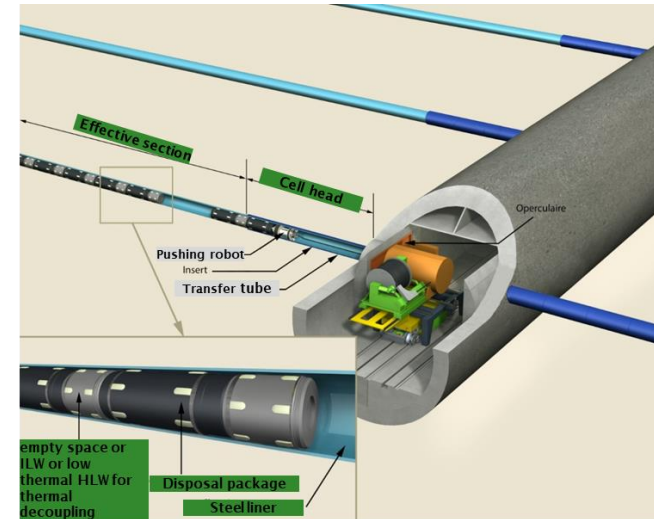
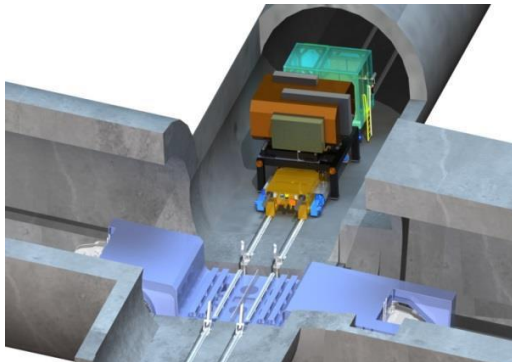
This document is the sole property of Andra.
It cannot be reproduced or communicated without its prior permission.

CIGEO : safety disposal of LL-IL&HL Wastes



CIGEO : operation phase protection

- DSRS packages managed like other irradiating waste packages
 - CSDC dose rate ~ 15 Sv/h (after 10 years of decay/cooling)
 - CSDV dose rate ~ 240 Sv/h (after 60 years of decay/cooling)
- Automated process, few human interventions
 - Remote control, pushing robot
- Safety of handling operations
 - Shuttle on rails, transfer shielded cask, funicular, ...



CIGEO : post-closure phase protection

Disposal depth ~ 500 m

- Recovery of DSRS is unlikely
- No limit criteria for DSRS activity

DSRS packages characteristics are included in the set of other waste packages


- No specific design or criteria for the disposal of DSRS packages in CIGEO

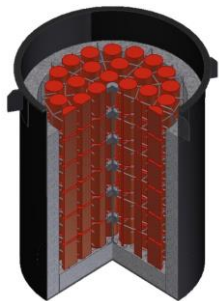


CIGEO : examples of DSRS packages

CIGEO ILW (eventually LL-LLW repository)

For low thermal DSRS not allowed at CSA

- Ex : ^{239}Pu , ^{241}Am , ^{226}Ra , smoke detectors sources, neutron sources, RTG, ...
- Sources collected in stainless boxes 
- « Multi-purpose » 870 L cemented package designed for both CIGEO ILW quarter or LL-LLW repository
- Adapted for devices which cannot be dismantled (Alcyon, RTG, ...)



CIGEO HLW

For high thermal DSRS

- Ex: ^{137}Cs HL sources
- Sources collected in stainless boxes
- 200 L welded package designed for CIGEO HLW quarter



National Plan on Management of Radioactive Materials and Waste (PNGMDR)

PNGMDR's requirements on DSRS management:

- Complete inventory → by Andra before 31/12/2024
 - specify for each family of sealed sources the associated management routes, the entities involved and the difficulties encountered, in conjunction with their holders
 - all DSRS that do not comply with the acceptance specifications in force at Cires (VLLW) or CSA (SL-LL&ILW) disposal facilities are included in CIGEO inventory (ILW/HLW)
 - long lived RN in DSRS are flagged for deep geological disposal
- Specify the meaning of principle and implementation methods of taking back used sealed sources “as a last resort” → PNGMDR working group (2023-2026)
 - enable the operational implementation of the obligation to take back DSRS defined in the law
- Case of DSRS is considered in the preparation of acceptance specifications for packages in planned disposal facilities for LL-LL&IL or HL wastes

Inventory forecast of DSRS for a decade (2019)

Wastes	Type of packages	Number of packages			Volume (m ³)	Disposal routes	Disposal capacity (m ³)
		Stock	Traffic (10 years)	Total			
SL-LL&IL	Package 5 m ³	31	21	52	265	CSA	1 000 000
LL-LL or IL	Package 870 L	78	61	169	121	CIGEO	75 000
	CSM packages	41	0	41	123		
LL-HL	CDT 175 L	6	1	7	1,2		10 000

In France, repositories for radioactive waste, in operation or planned, are sufficient for the disposal of DSRS

- Very small volumes compared to other radioactive wastes
- No need of specific repository for DSRS in France
 - Strategy adapted to an electro-nuclear country.
 - Other strategies exist in different countries.

International management – AIEA recommendations

In non-electro-nuclear countries :

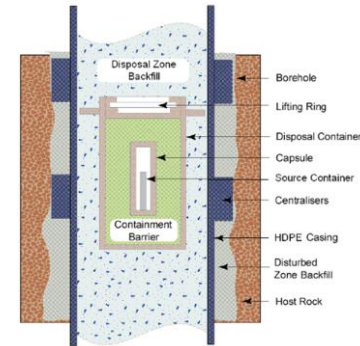
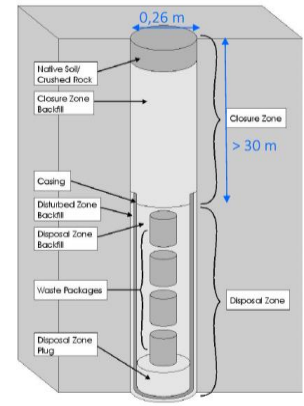
- Regulatory Framework is applied : return of DSRS to native country
- Safety disposal option privileged : boreholes

Today, only Ghana and Malaysia have declared to be willing to use boreholes disposal (~ 100 m depth)

- Borehole Disposal of Spent Sources (BOSS) concept developed in South Africa
- Safety disposal concept privileged by AIEA

Case of Saudi Arabia

- Inventory of DSRS comprising cat. 1 sources (RTG type)
- Andra's proposition :
 - Subsurface disposal (~30 m depth) for cat. 3, 4 and 5 sources
 - temporary storage for cat. 1 and 2 sources while waiting for the development of a deep geological facility necessary for nuclear spent fuel management



A yellow industrial crane is lifting a large, grey, cylindrical container. The container has a label with the number '31708' and a warning symbol. In the background, there are many similar containers stacked in rows on a concrete floor. The scene is set in a large industrial facility with a high ceiling and red structural beams.

**THANK YOU
FOR YOUR ATTENTION**

Speaker questions

What is the funding for disposal facilities in France ?

- CIGEO project is funded by the three main entities of the nuclear power sector (EDF, CEA and Orano) from a tax allocated to research and a special contribution for design studies of facilities and preliminary works.
- CSA is funded mainly by radioactive producers on a commercial basis for waste packages delivered and disposed of.

What is the cost of the disposal of a waste package ?

- CSA : 4 000 € / m³
- CIGEO (estimation) : ~250 000 € / m³