Nuclear Waste & Fuel Recycling

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Natural Uranium Resources

Millions t U naturel	Red Book 2009	Red Book 2011
Ressources identifiées <260$/kgU	6,3	7,1
Ressources à découvrir	10,4	10,4
Consommation	59000 t/an	64000 t/an
Dont production des mines	75%	85%

Identified Uranium "conventional" Resources exceed 100 times 2011 world Consumption

With Breeders, Resources are practically limitless

Spent Fuel Management

Spent fuel.

Reversible direct SF disposal

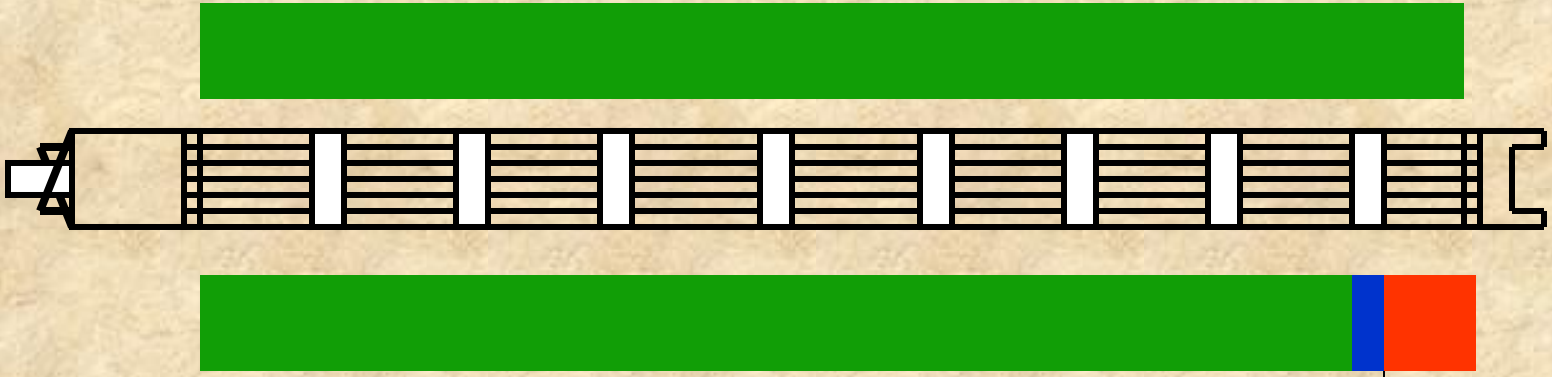
Storage, then decision *(later)*

Reprocessing & Recycle + HLW Disposal

PWR Spent Fuel Composition

Fresh Assembly

Uranium (4% ^{235}U) : 500 kg



Uranium (0,9% ^{235}U) : 475 kg Pu : 5kg FP* : 20 kg

recyclables

Spent Assembly

*(and a few Minor Actinides)

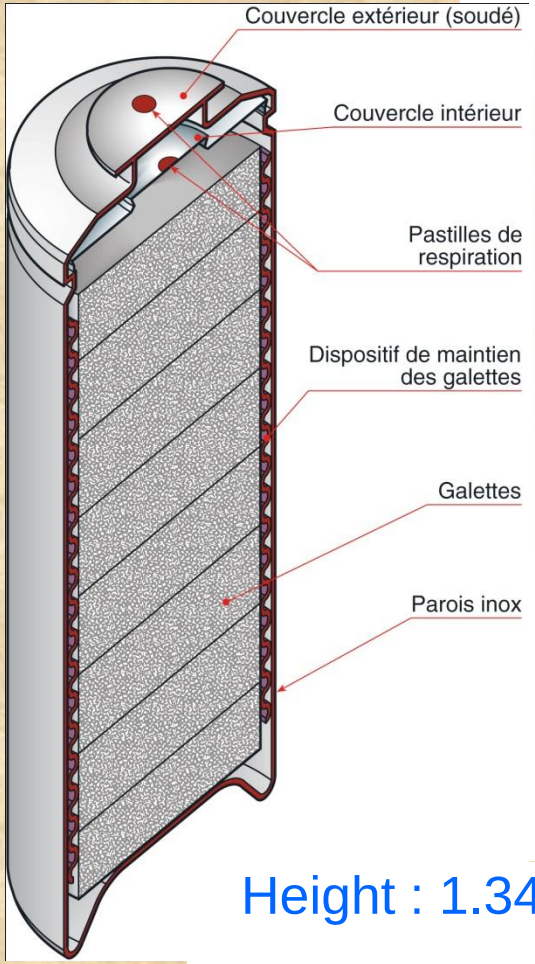
Why Reprocess ?

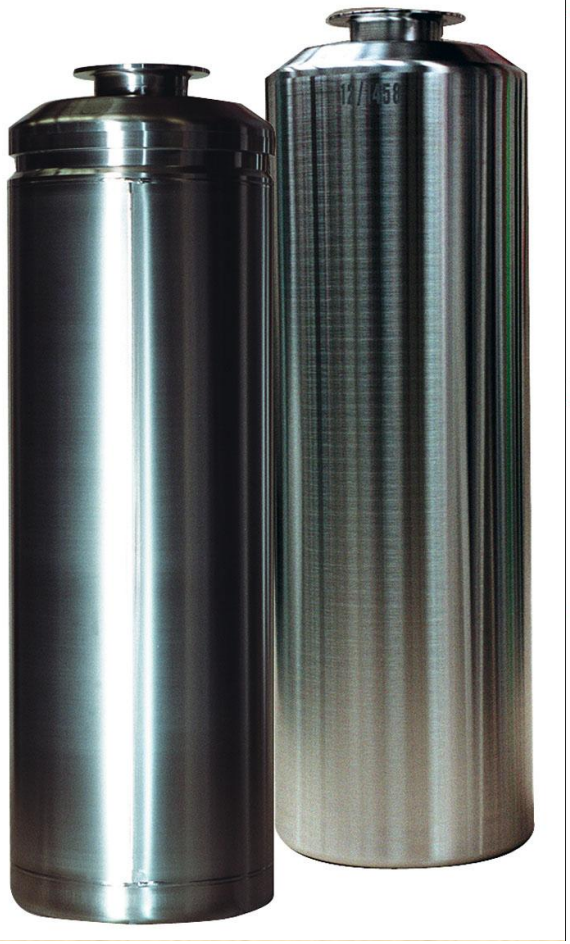
- ***Reprocessing and Recycle*** *fit the requirements of sustainable development :*
  - *Revovery and reuse of recyclable materials****, uranium and plutonium.***
  - ***Glass is a very good Waste Form for Interim Storage, then Disposal***
  - *Decreasing as low as possible the* ***potential nocivity of ultimate radioactive waste. ALARA Principle. (As Low As Reasonably Achievable).***
- ***Without recycle, no 4th Generation***

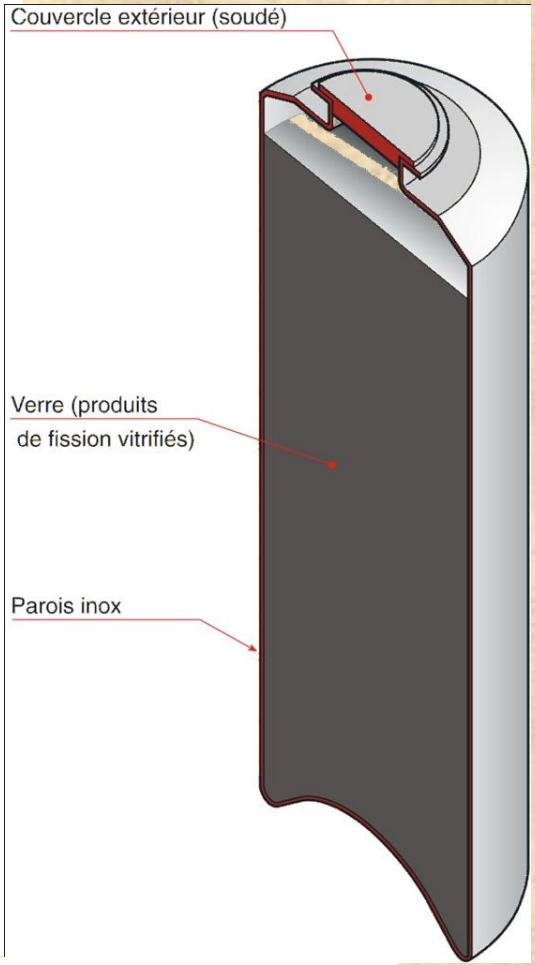
Ultimate Waste Packages

Vitrified FP

Metallic parts





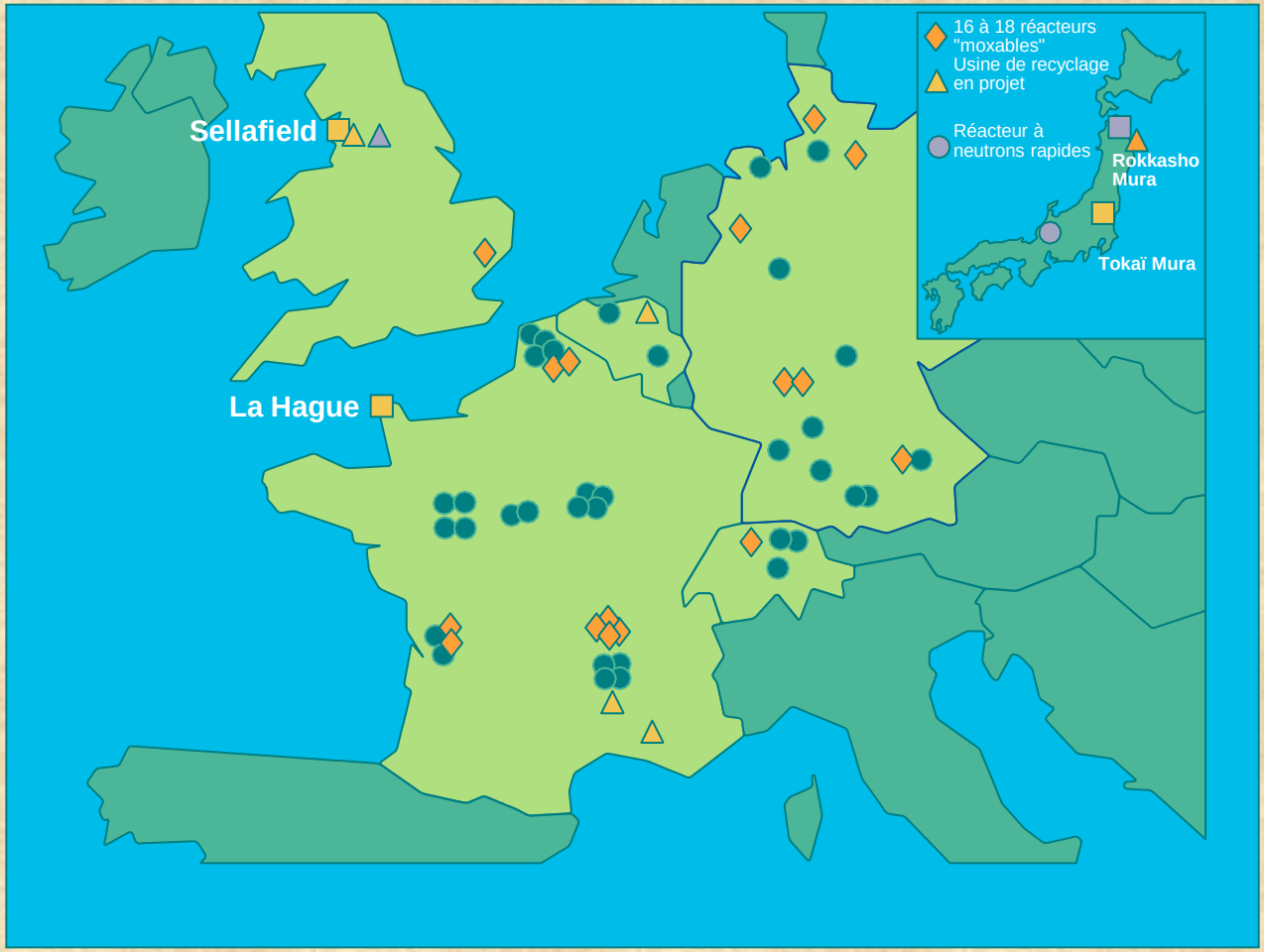


Height : 1.34 m Diameter : 43 cm Weight 400 kg
Volume Glass 150 l

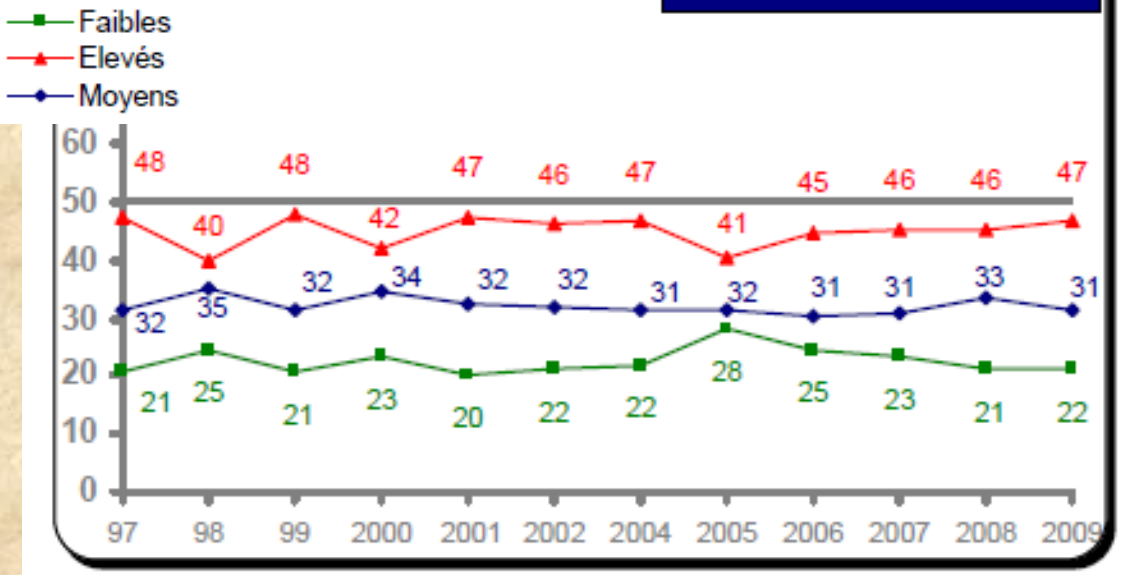
Fission Products : 14% (from 1.7 t spent fuel)

Reprocessing-Recycle in Europe

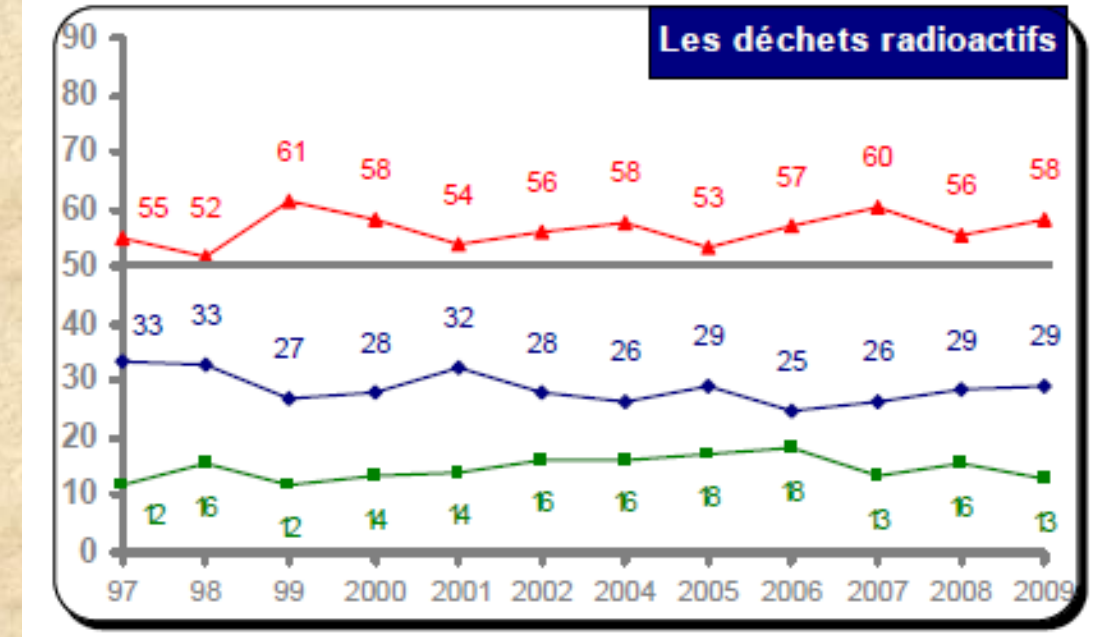
- *MOX loaded reactors*
- *MOX compatible reactors*
- *Reprocessing Plant*
- *Recycle plants*



Les centrales nucléaires



Les déchets radioactifs



French Waste Classification

Radioactive waste class	Very short-lived (< 100 days)	Short-lived (< 30 years)	Long-lived (> 30 years)
Very low-level waste: VLLW (10 - 100 Bq/g)	Waste managed by allowing the radioactivity to decay on site	1 surface disposal center (Morvilliers, Aube) started up August 14, 2003; capacity: 650,000 m³, (850,168 yd³) 16,644 m³ (21,770 yd³) in disposal as of the end of 2004	
Low-level waste: LLW (also called class A waste) (100 - 100,000 Bq/g)		2 surface disposal centers: - Centre Manche (Beaumont-Hague), operated from 1969-1994, now full and being monitored. 527,000 m³ (689,290 yd³) in disposal - Centre de l'Aube (Soulaines), in operation since 1992; capacity: 1,000,000 m³ (1,307,951 yd³). 167,823 m³ (219,504 yd³) in disposal as of the end of 2004	Sub-surface disposal in clay (projected). This class includes radon waste and graphite waste from the first NUGG power plants.
Intermediate-level waste: ILW (also called class B waste) (thousands – millions of Bq/g)		Disposal under design. This class includes waste containing tritium used for defense applications	Retrievable deep disposal under design – art. 3 of the law of June 28, 2006
High-level waste: HLW (also called class C waste) (billions of Bq/g)		Retrievable deep disposal under design - art. 3 of the law of June 28, 2006	

Waste per capita in France

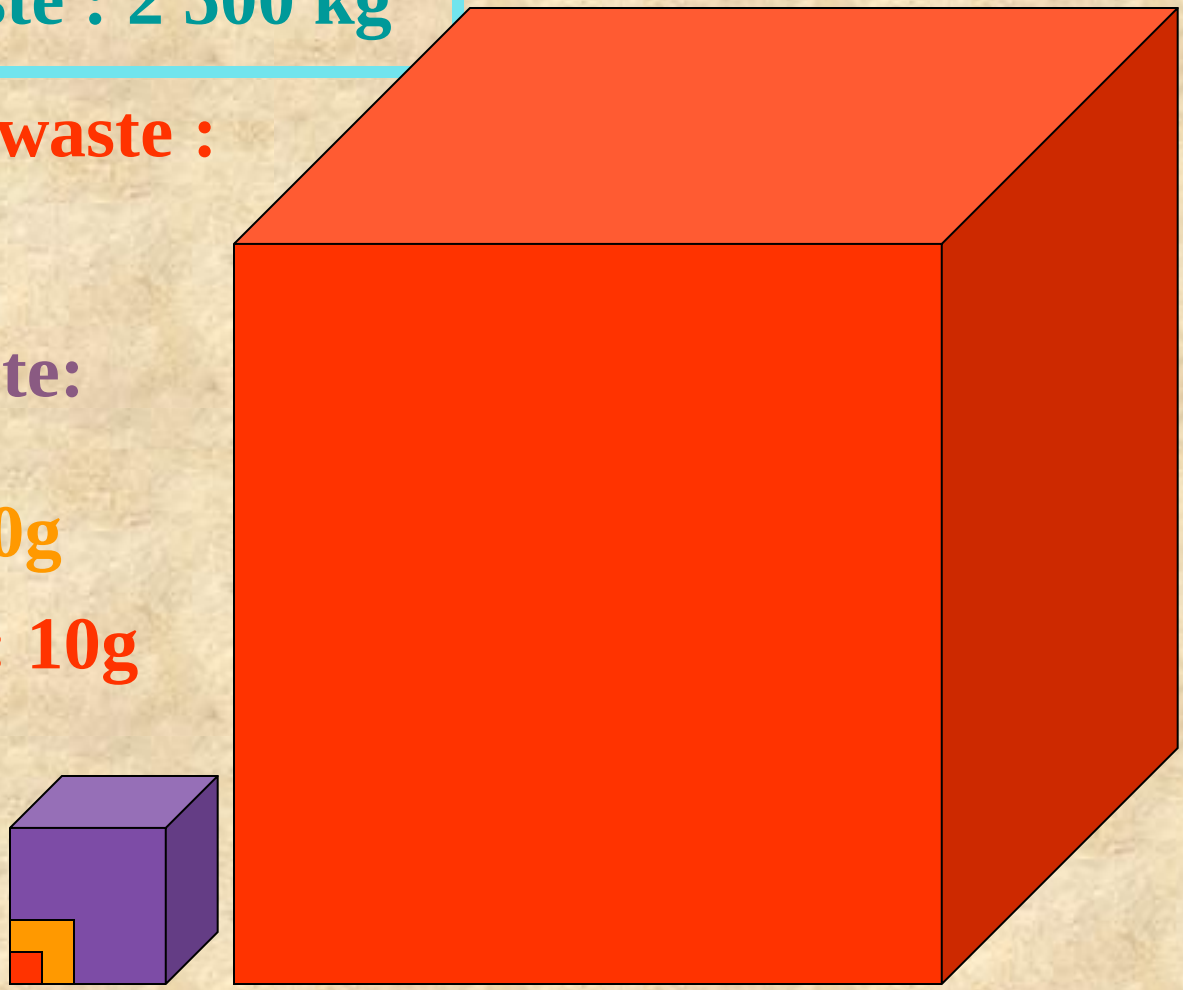
Industrial Waste : 2 500 kg

Including toxic waste : 100 kg

Radioactive waste: less than 2 kg

Of wich LL : 100g

Of which HA : 10g



The amount is small enough to allow for complete management

Nuclear Waste : We care !

They are neither orphans nor released freely

LLW are diposed of

HLW and LL-MLW are concentrated, contained, stored under surveillance:

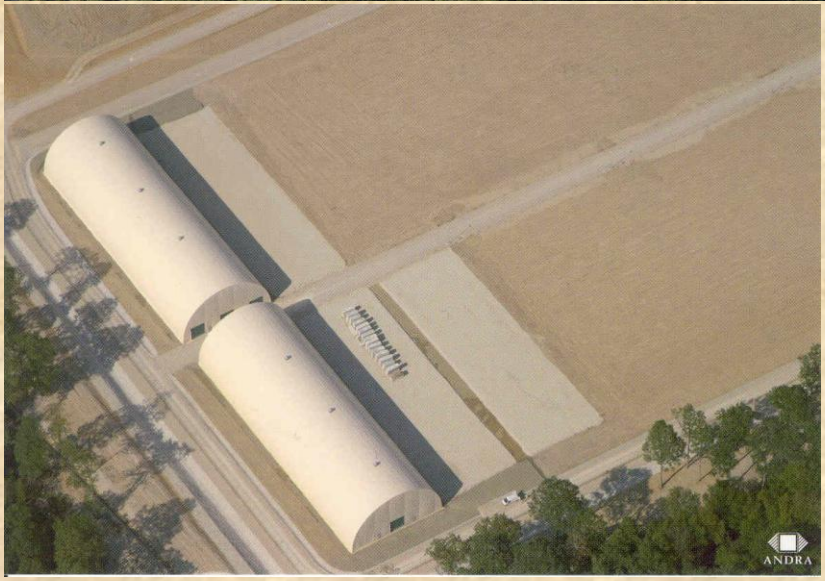
Where they are, they create no hazard to anybody,

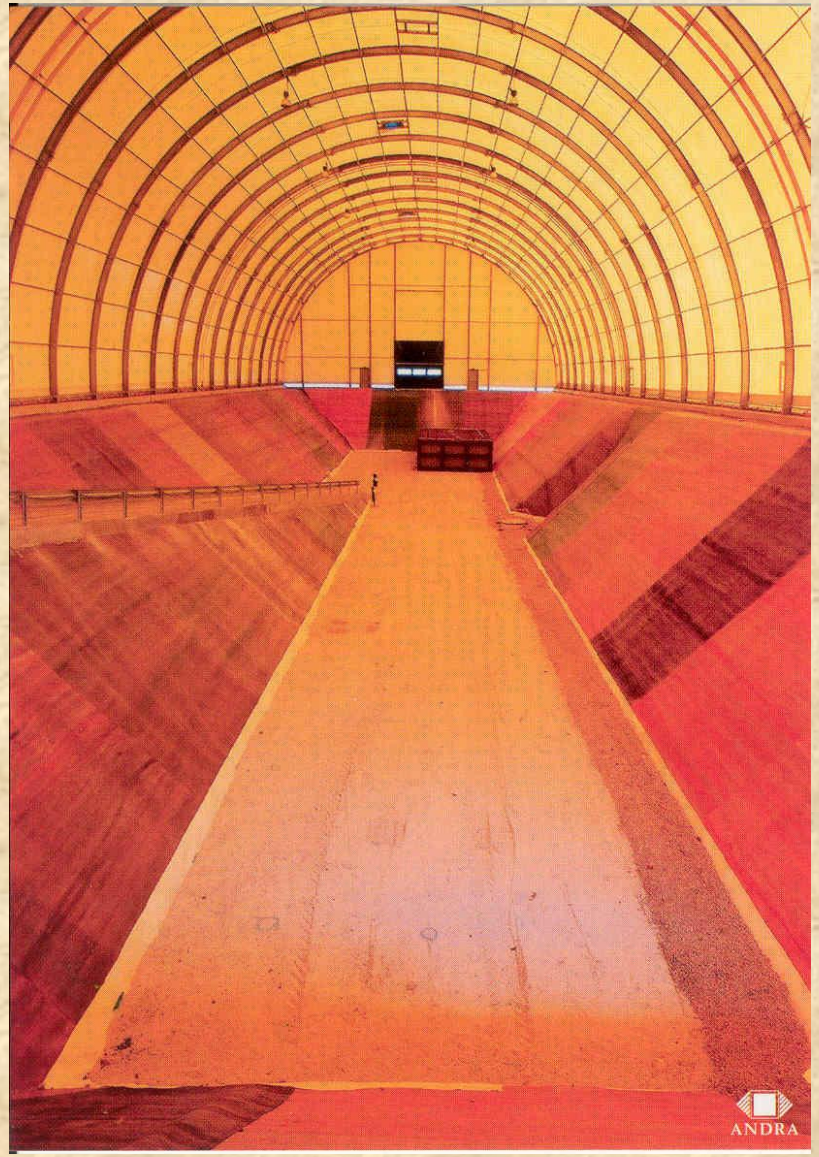
But it is a interim solution:

The 28 june 2006 French Law defines a roadmap

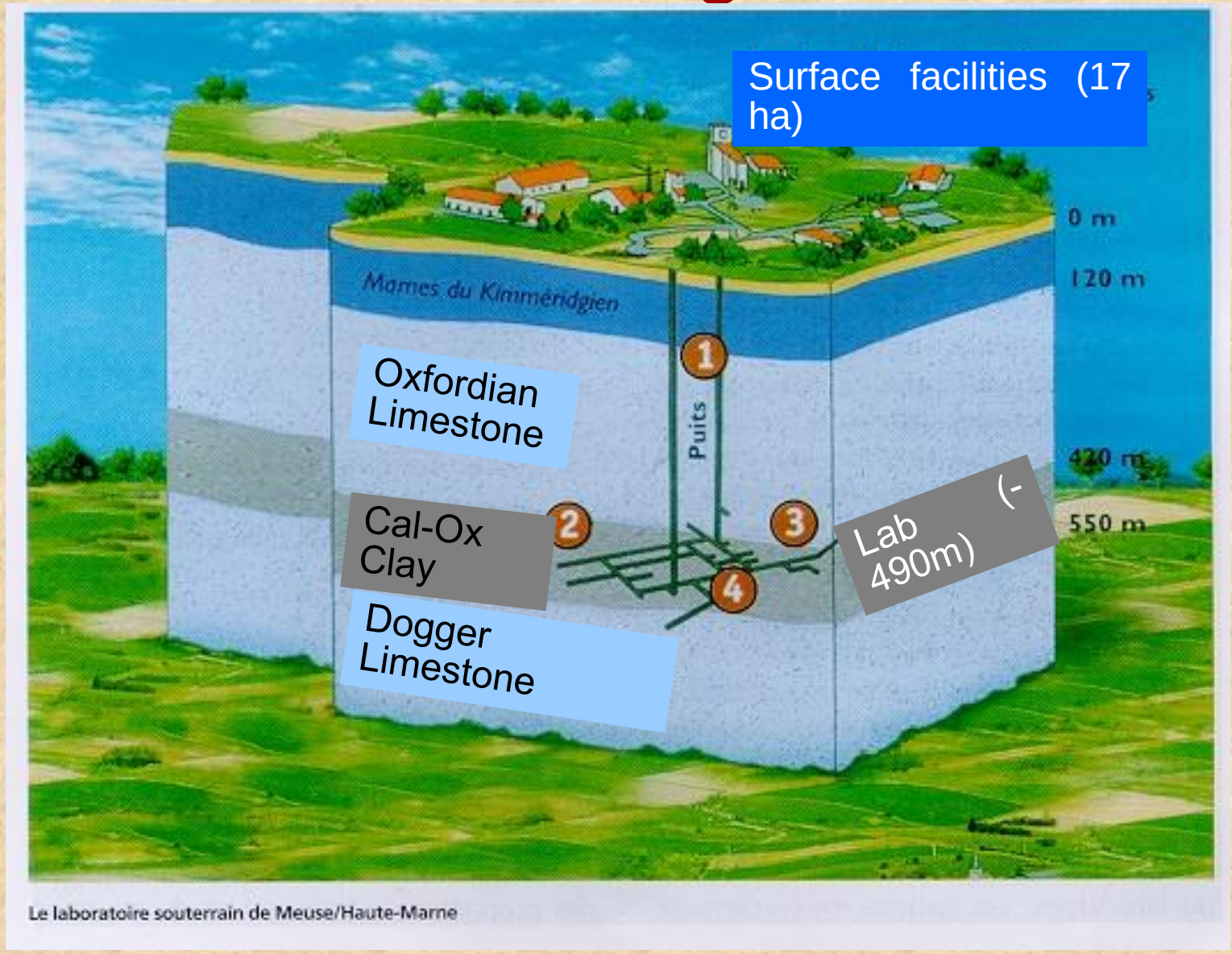
LLW Waste disposal site in Soulaines

Very Low level waste disposal in Morvilliers





Bure Underground Lab



Le laboratoire souterrain de Meuse/Haute-Marne

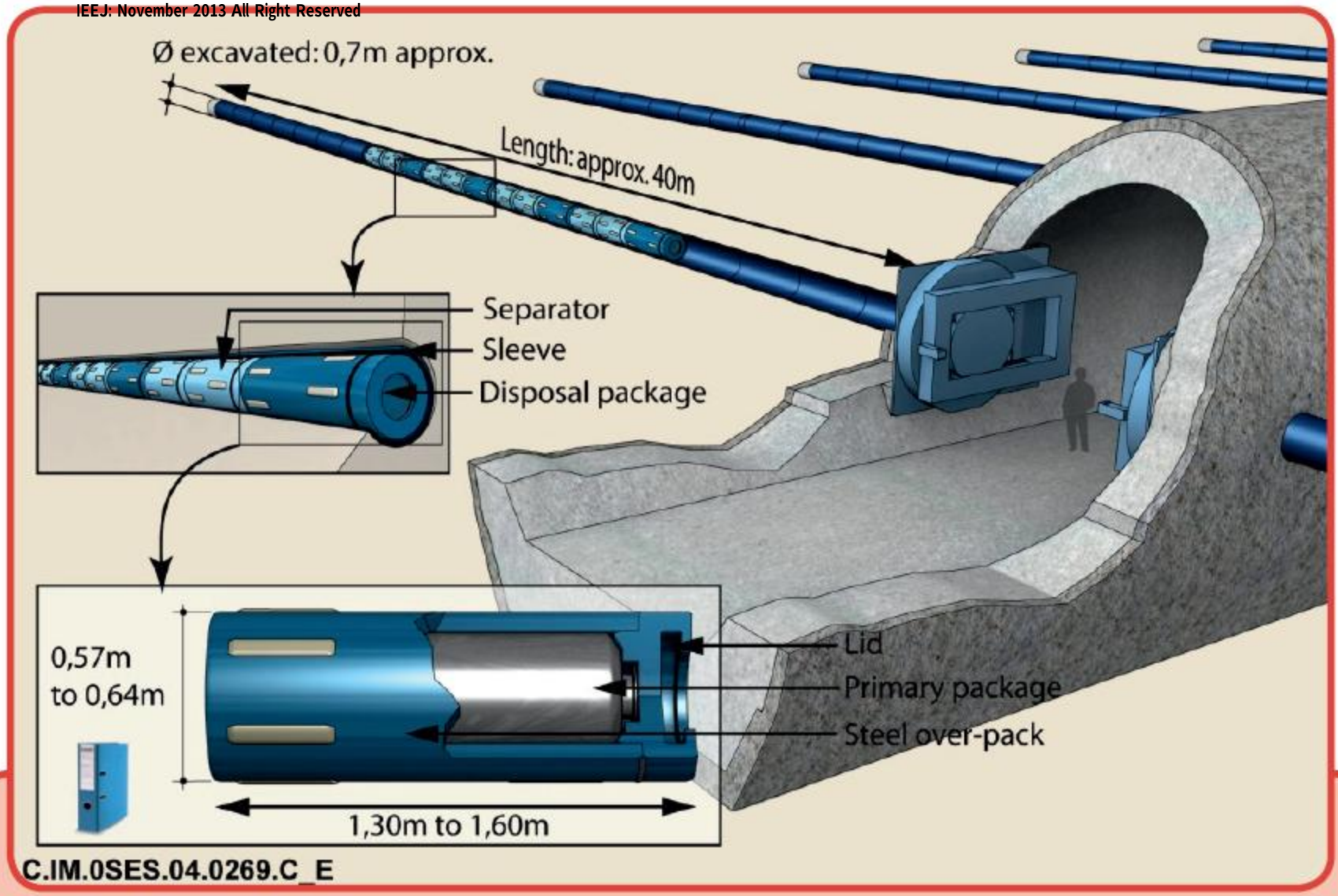
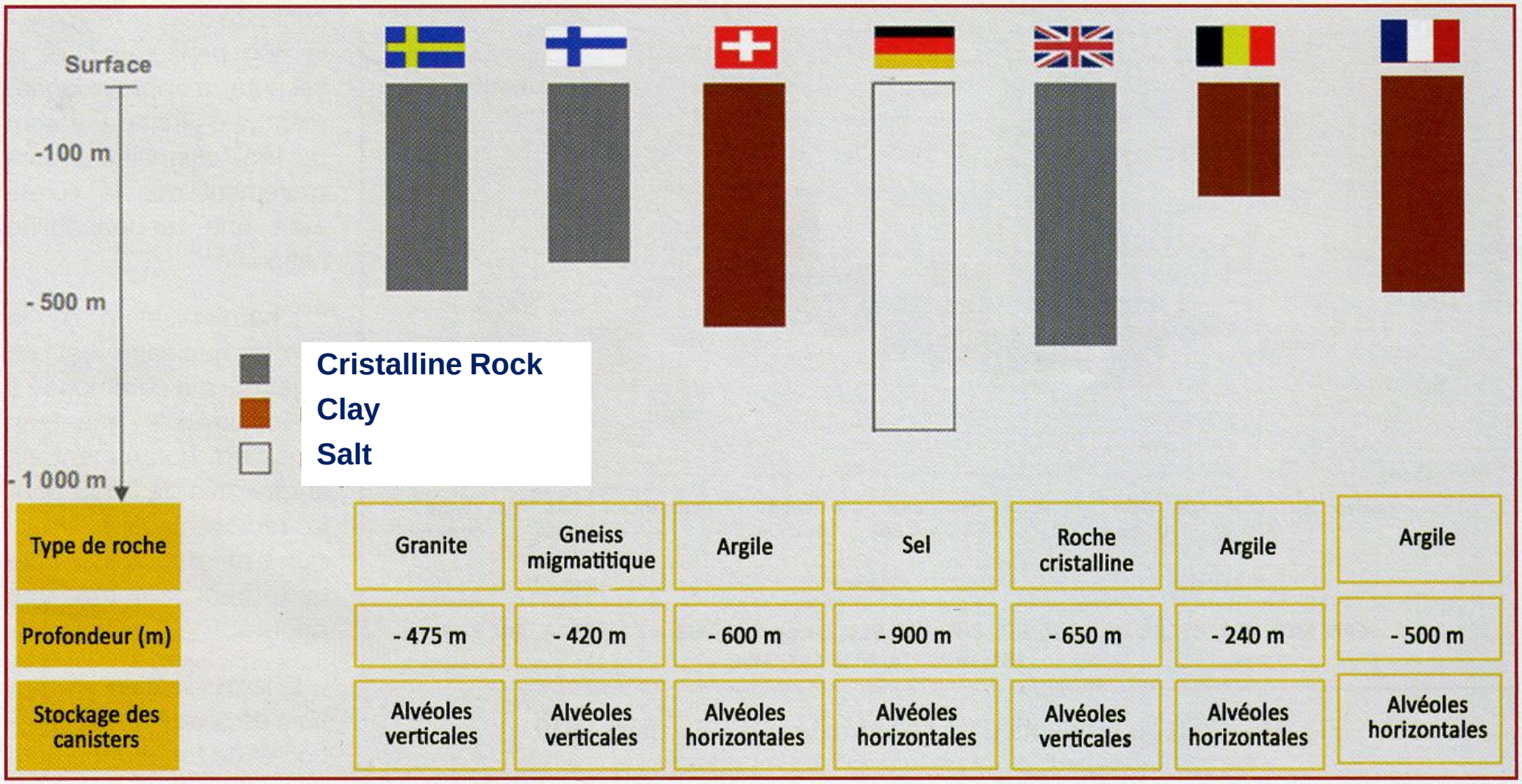


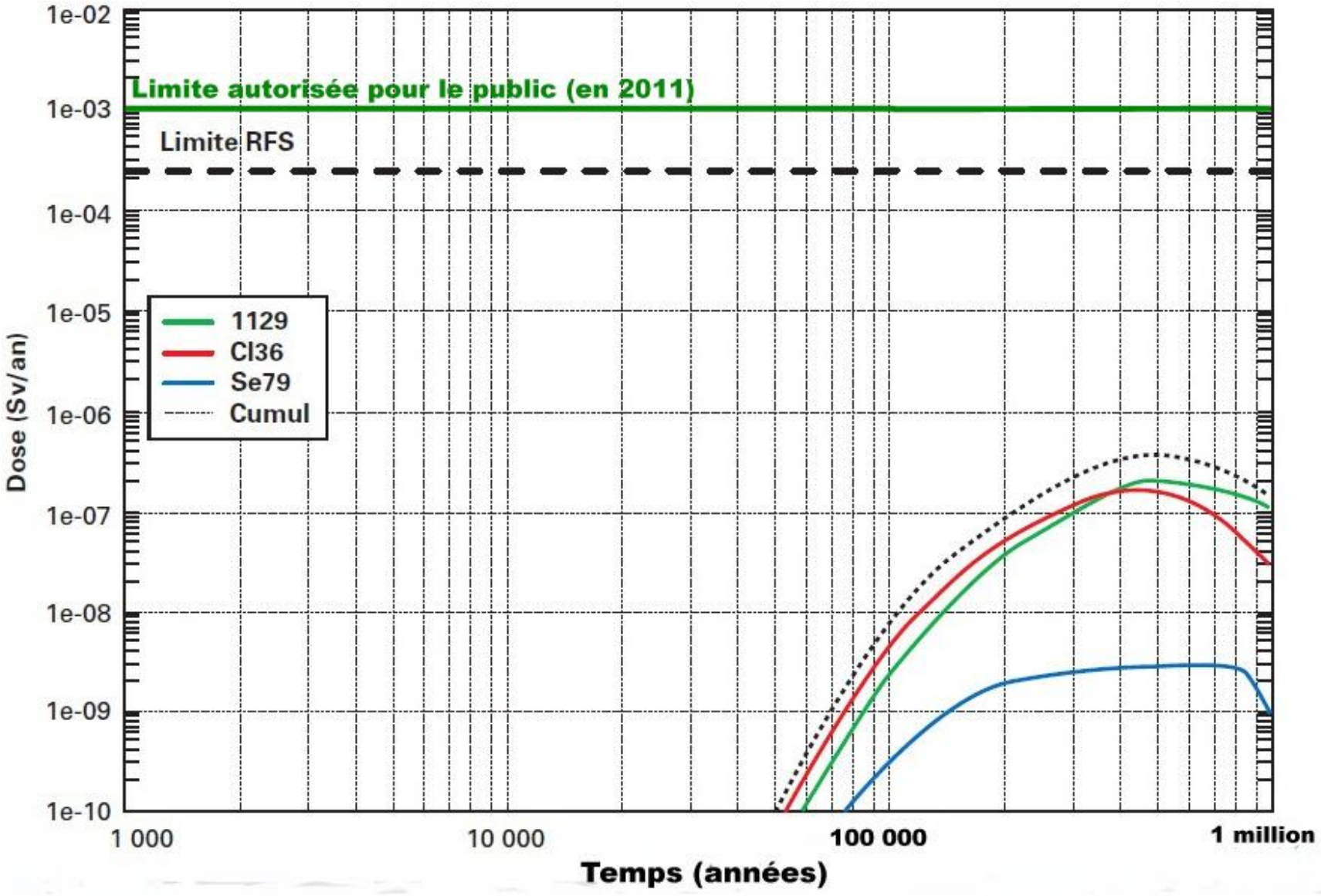
Figure 9. *Illustration of the French repository design for high-level waste in a clay formation. Courtesy: Andra.*

Deep Geological Disposal Projects in Europe



Type de roche	Granite	Gneiss migmatitique	Argile	Sel	Roche cristalline	Argile	Argile
Profondeur (m)	- 475 m	- 420 m	- 600 m	- 900 m	- 650 m	- 240 m	- 500 m
Stockage des canisters	Alvéoles verticales	Alvéoles verticales	Alvéoles horizontales	Alvéoles horizontales	Alvéoles verticales	Alvéoles horizontales	Alvéoles horizontales

Fig. 13 - Projet de stockage géologique dans les principaux pays nucléaires européens



Stockage Argile : Dose à l'exutoire en fonction du temps [4]