DE LA RECHERCHE À L'INDUSTRIE

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RESULTS OF R&D ON FUTURE FUEL CYCLE AND ASSOCIATED HL WASTE DISPOSAL: THE FRENCH CASE

Dominique Warin

CEA / Nuclear Energy Direction

www.cea.fr

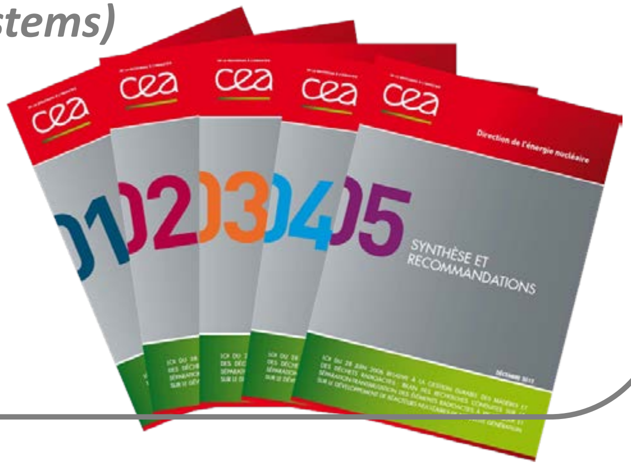
2006 FRENCH ACT: THE CEA 2012 REPORT

2006 ACT:

December 2012 : CEA issued a report to the French government about "industrial perspectives" of advanced recycling options

The report issued by CEA:

- T1 : *The guidelines for a sustainable management of nuclear material and waste (and Gen IV systems)*
- T2 : *Separation and transmutation of long-lived waste*
- T3 : *The sodium-cooled fast reactor (and ASTRID demonstrator program)*
- T4 : *Other fast neutron Gen IV systems*
- T5 : *Executive summary*



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OBJECTIVES OF STUDIES IN THE FRAME OF THE FRENCH ACT FOR WASTE MANAGEMENT

- **To analyse various fuel cycle options :**
  - with or without transmutation of minor actinides
  - extended to Pu management and U resources
  - assessment of the respective advantages and disadvantages (selection of criteria)

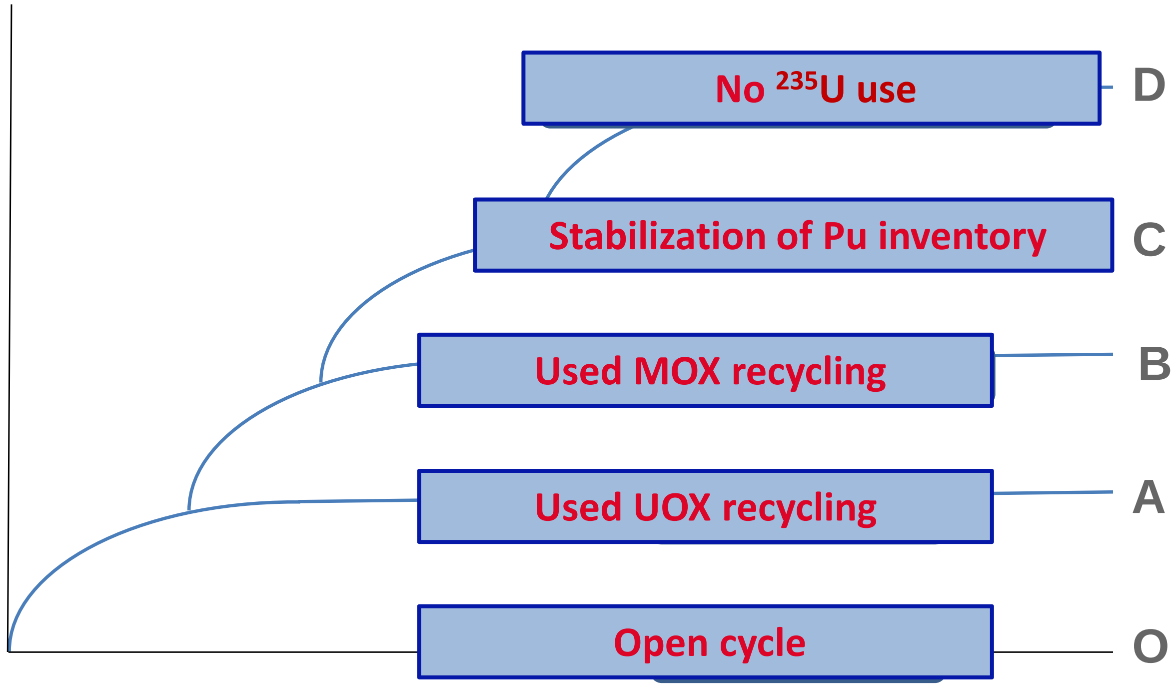
- **To study the deployment conditions :**
  - capability for FR deployment
  - taking into account specific constraints relating to transient phase

- **To conclude analysis in terms of capacities of facilities (disposal), global Pu inventory, MA inventory, radiotoxicity …**

- 2012 REPORT in the frame of the French Act for waste management
- with AREVA and EDF
- collaboration with ANDRA for studies on waste storage and disposal

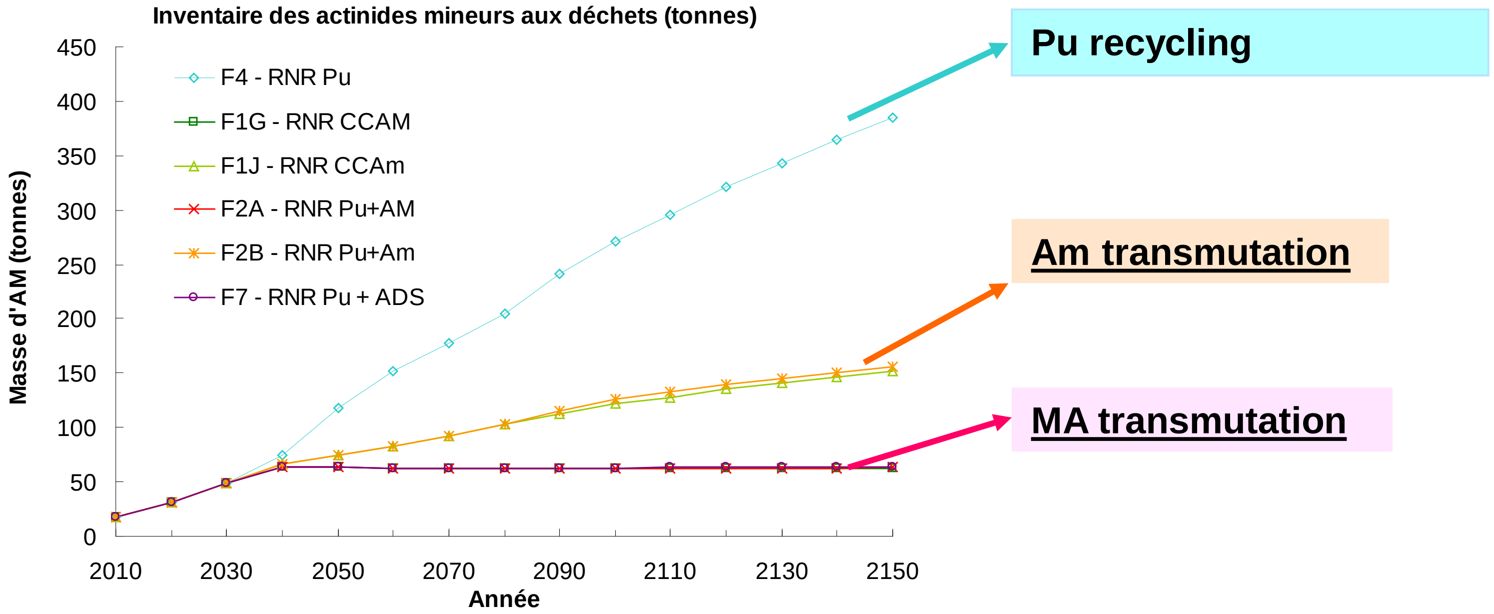
PROGRESSIVE FR DEPLOYEMENT SCENARIOS

4 « levels » have been identified for FR deployment ; CEA - EDF - Areva



- Levels based on a <u>(LWR – FR) fleet : global optimization</u>
- Specific objective of a new progress at each level
- No “a priori” date of transition between each level
- Study of phase-out (feasibility, duration,…) for each level
- COSI code for calculations

MA MANAGEMENT IN THE WASTE



Scenarios with transmutation:

- ***Reduction of MA in the waste, stabilization at around 60 tonnes***
- ***Reduction of the radiotoxicity and thermal power of the wastes***

But what impact on interim storage and geological disposal ?

APPROACH FOR THE STUDY

Two phases are considered in this study:

First part:

- ❑ **Compare the repository footprint and the excavated volume for each option**
- ❑ **Assess the impact of interim storage duration (70 years compared to 120 years)**

Second part:

- ❑ **Solutions proposed to optimize the footprint of the repository**
- ❑ **Impact on repository behavior and long term performance**

EVALUATION OF WASTE PACKAGES

The number of waste packages expected has been calculated for each of the three scenarios :

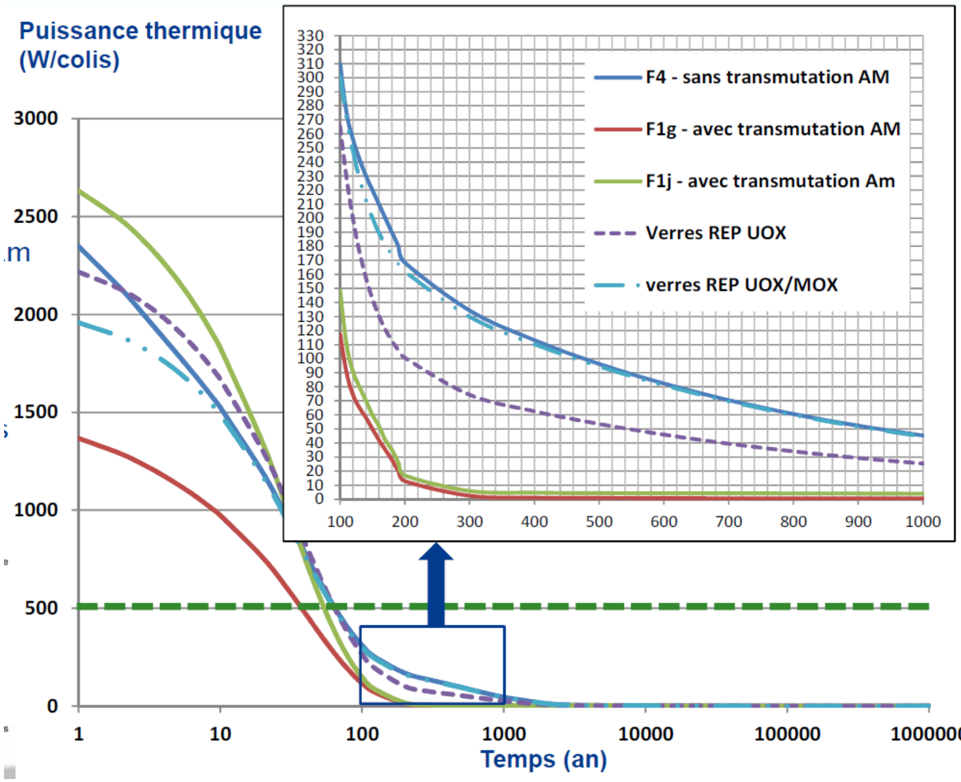
- **The quantities are similar from one scenario to the next**
- **The annual waste flows appear to be of the same order of magnitude as those expected for Andra's industrial geological repository project "Cigéo"**
- **This makes it possible to pursue the current Cigéo project options in terms of infrastructures and operating tools**

Scenarios		No transmutation	Transmutation only Am	Transmutation all minor actinides
High-level waste package (CSD-V)		103,000 packages ($18,000\ m^3$)	96,000 packages ($17,000\ m^3$)	89,000 packages ($16\ 000\ m^3$)
Intermediate-level waste	Structural waste (CSD-C)	246,000 packages ($45,000\ m^3$)	254,000 packages ($46,000\ m^3$)	255,000 packages ($46,000\ m^3$)
	Technological waste	55,000 packages ($15,000\ m^3$)		

Cigéo project has been developped for current waste from existing NPPs.
It will not accomodate the waste which might be produced by future NPP fleets.

VARIATION OF THE THERMAL POWER OF HLW PACKAGES OVER THE INTERIM STORAGE TIME

If the number of packages produced is similar for all of the scenarios, significant disparities are observed regarding the thermal power generated by the HLW packages.
They are mostly due to the thermal power of americium, which is either present in the packages or not.



⇒ Interim storage before geological disposal

REPOSITORY DESIGN
: interim storage period 70 years

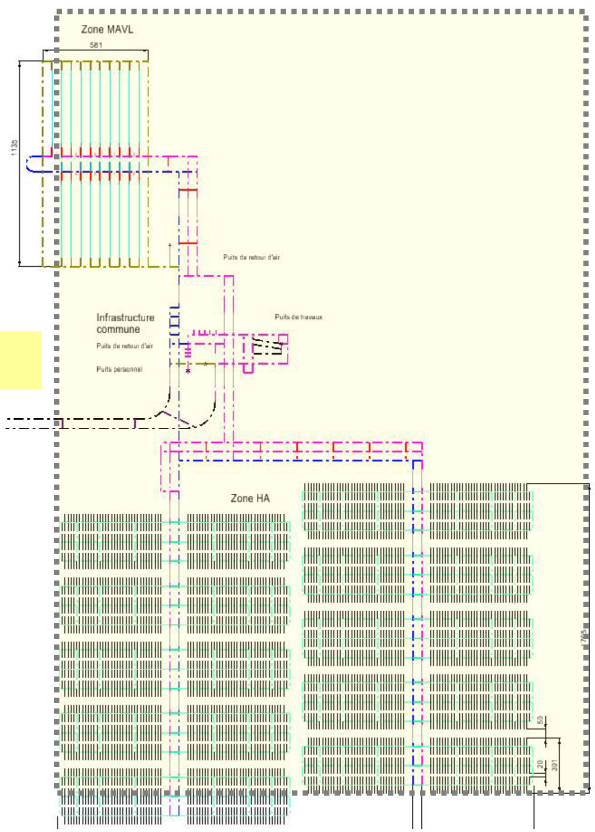
Compared to the multi-recycling of Pu in SFR, the transmutation of minor actinides provides for the scenarios at the equilibrium period (2100-2150):

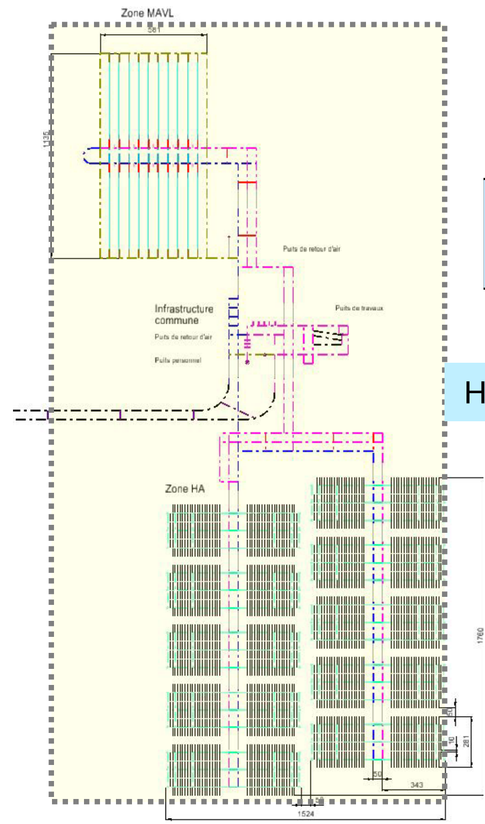
- A reduction of factor 1.8 (Only Am) to 2.5 (all minor actinides) of the area covered by the repository of high-level glass stored over 70 years.

- A reduction of 20 % (Only Am) to 30 % (all minor actinides) of the overall volume excavated.

No transmutation (70 years)

HLW area : 510 ha (1)





Transmutation Am (70 years)

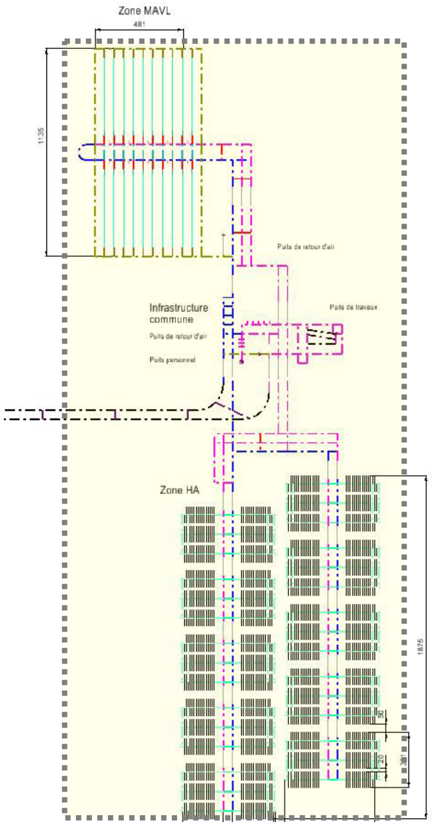
HLW area : 280 ha(/ 1.8)

Am transmutation provides a decrease of repository footprint

REPOSITORY DESIGN :
extension of the interim storage period

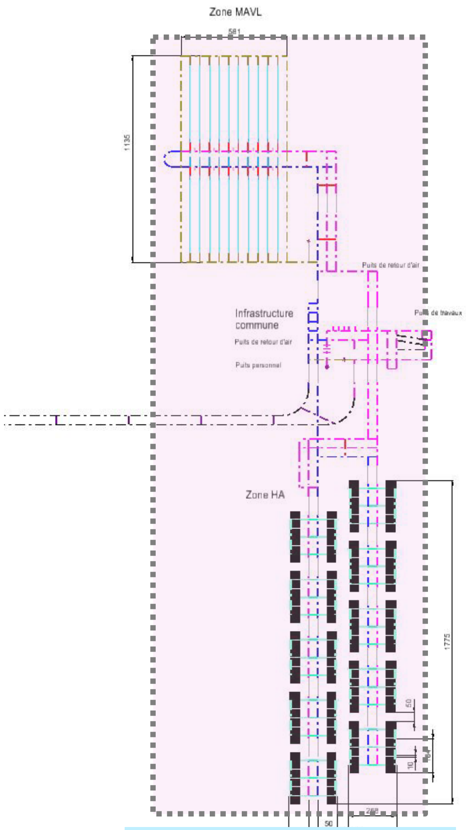
A reduction of factor 4.6 of the area covered by the high-level waste if the transmutation of minor actinides also involves a 120-year extension of the interim storage period (reduction of 50 % of the overall volume excavated).

Transmutation AM (70 years)



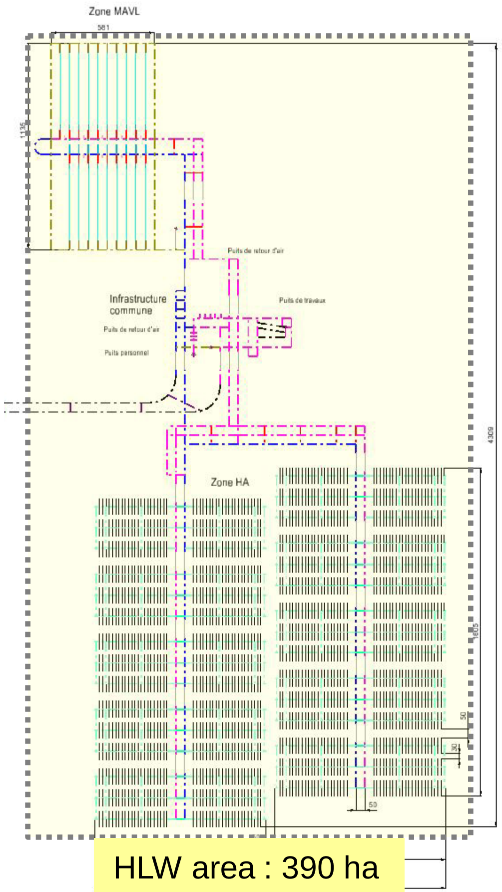
HLW area : 210 ha

Transmutation AM (120 years)



HLW area : 110 ha

No transmutation (120 years)



HLW area : 390 ha

A longer waste storage duration reduces the required volum of the repository

SECOND PART OF THE STUDY
OPTIMIZATION OF THE GEOLOGICAL DISPOSAL

- In view of the above results, the reduction of repository footprint permitted by the transmutation of minor actinides appeared limited, still improvements seemed accessible. In the second phase of the study, new design options were evaluated with the objective of a more drastic decrease of the repository footprint.

Hypotheses were limited to the following:

- An interim storage period of 120 years
- A single repository site for all the wastes generated during the total duration of scenarios

To promote the density of the high-level glass storage area, the length of the cell was increased from 40 to 80 meters which reduces the relative importance of the non-useful part (head of cell, gallery).
An other evolution concerns a simplification of the “modules” concepts

- Different solutions to reduce the repository footprint of the intermediate-level waste storage have also been investigated. They have not achieved significant gains.
- The general architecture of the repository has been optimized to make best use of available space

OPTIMIZATION OF THE GEOLOGICAL DISPOSAL

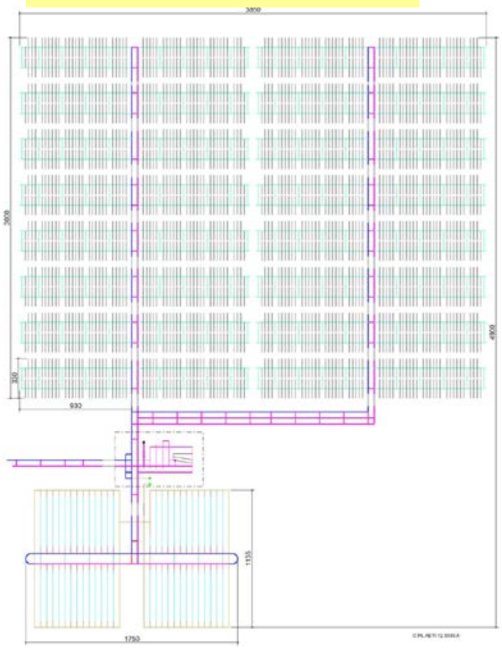
Compared to the multi-recycling of Pu in SFR, the transmutation of MA associated with the design optimization of the repository, provides for the entire duration of the scenarios (2040-2150) :

- **A reduction of factor 7.5 (only Am) to 10 (all MA) of the area of the repository of high-level glass stored over 120 years**

Thus, transmutation would reduce the repository footprint of high-level glass of 1200 hectares to 160 hectares (only Am) to 120 hectares (all MA).

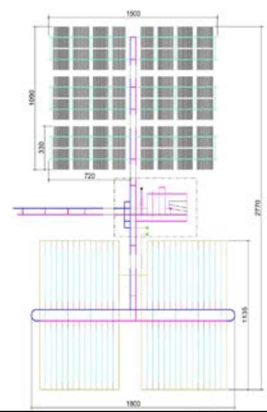
- **A reduction of factor 3 of the total repository footprint**
- **A reduction of factor 2 of the overall volume excavated.**

HLW area : 1200 ha (1)



No transmutation (120 years)

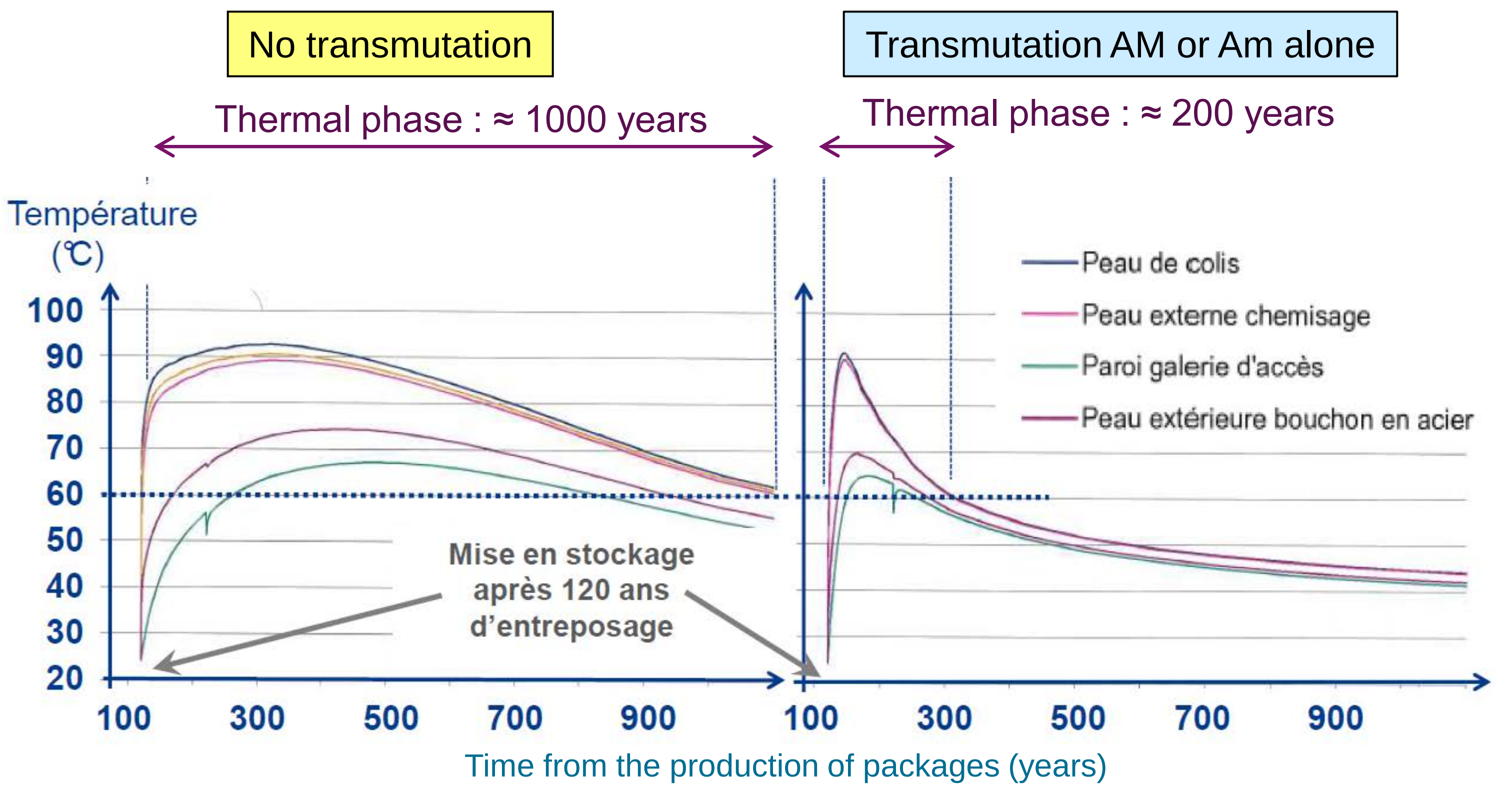
HLW area : 120 ha(/ 10)



Transmutation AM (120 years)

IMPACT ON REPOSITORY BEHAVIOR AND SAFETY PERFORMANCE

The transmutation of minor actinides is also used to reduce the duration of the thermal phase from 1000 years to less than 200 years
The thermal phase represents the period during which the glass package is at a temperature exceeding 60°C and during which any water intake in contact with the glass must be avoided



IMPACT ON REPOSITORY BEHAVIOR AND LONG TERM PERFORMANCE

- On the thermal point of view, the densification of storage would increase by a factor of about 2 the energy density of the geological environment which would lead to increase the heating of the HLW storage area; the thermo-mechanical consequences are to be examined.

- For the hydrogen production by anoxic corrosion of steel, densification will lead to a decrease in the volume expansion offered by the galleries.

- In the altered evolution scenario of "exploratory drilling", the densification could lead to multiply by 10 the radiation fraction captured by the drilling, but even under these conditions, doses remain well below the limit of 0.25 mSv / year

CONCLUSION

➢Partitioning an Transmutation R&D programs are implemented in France, and within European SNE-TP projects collaboration in order to ease future HL waste management. "Industrial" transmutation can only be started with FRs, not before 2040 at the very best.

For concepts studied today:

➢ The transmutation would allow a decreasing by a factor 10 of the high level waste repository footprint generated by the future FR fleet.

➢ Concerning the entire IL and HL geological disposal for FR fleet wastes, the footprint reduction could reach a maximum factor of 3.
In other words, in this case, for a given storage resource, transmutation would allow to handle the waste generated by a fleet power 3 times higher.

➢ However, considering these various elements, a cautious approach remains necessary about the possible densification of the repository.

THANK YOU FOR YOUR ATTENTION

Commissariat à l’énergie atomique et aux énergies alternatives
Centre de Saclay 91191 Gif-sur-Yvette, France

Etablissement public à caractère industriel et commercial | RCS Paris B 775 685 019

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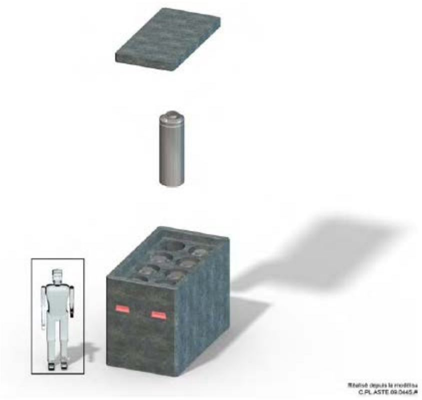
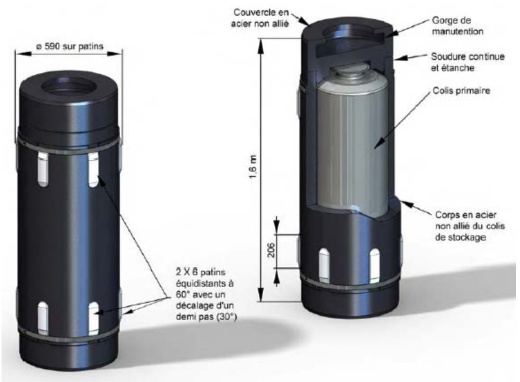
ORGANIZATION OF THE REPOSITORY

Most of the inventory is composed of compacted waste packages with a 180 liter unit volume. For the purpose of storage, they are grouped by eight in a sealed concrete container

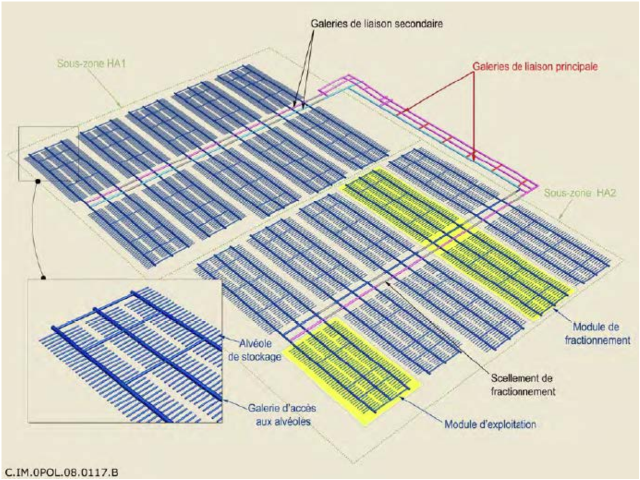
Each HLW package is inserted individually into a disposal overpack consisting of a shell of non-alloy steel in order to withstand corrosion and in situ stresses





High level waste packages are placed in the repository cells consisting of micro-tunnels with a diameter close to that of the waste packages. The cells are accessed via horizontal drifts located in the same plan as the cells. The cells are metal cladded in order to ensure their dimensional stability.

<u>In this first part of the study, the repository cells are organised as “modules”</u>, which are implemented as the waste packages are put into storage. A new module is dug while the previous cell is being used. The modules are accessed via secondary connecting galleries. The size of modules is determined by the inventory of fission products (in practice, Iodine-129). The number of modules remains constant and that is their sizes decreases when the compactness of storage increases.



Assumption for the first study: HLW cell with a length of 40 m