Impact of minor actinide transmutation options on geological disposal - The French case

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1. Introduction

The 2006 Programme Act defined 3 complementary research areas for the long term management of HLW and ILW-LL:

- partitioning and transmutation (P-T) (CEA)
- geological disposal with respect to reversibility
  (Andra ⇨ *industrial geological repository project "Cigéo" in Meuse/Haute-Marne*)
- above-ground interim storage (Andra)

1. Introduction

The CEA has provided in 2012 an assessment of industrial perspectives of P-T of actinides.

This includes an assessment by Andra of the impact of waste induced by various P-T options, on the sizing and the safety of a geological repository.

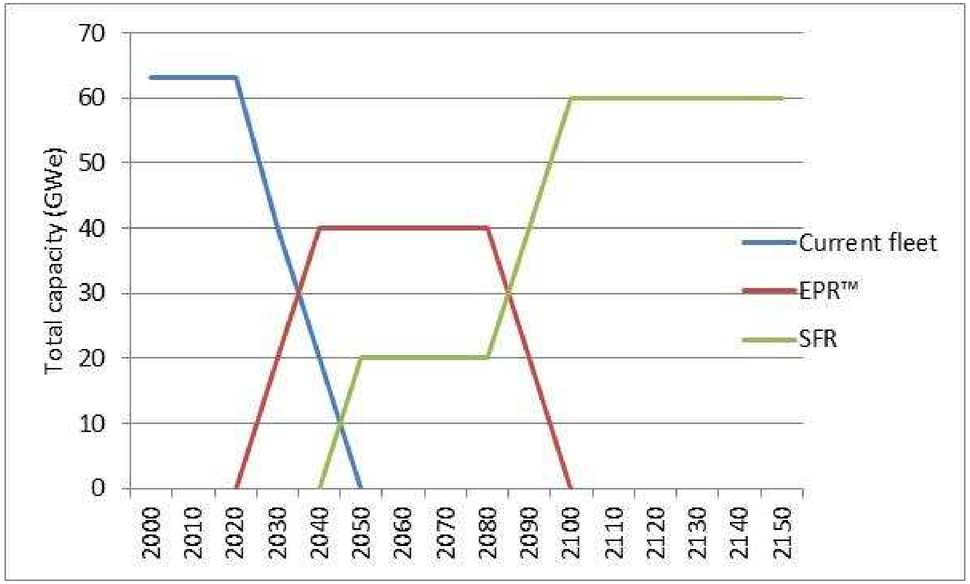
- P-T would be implemented in potential IVth generation fast breeder reactors (SFR)
- It does not apply on the waste that will be accomodated by Cigéo

2. Input data

3 scenarios selected by CEA as input data:

- Scenario **F4**: recycling of plutonium only (Pu)
  - HLW contain minor actinides (AMs) and fission products (FPs)
- Scenario **F1g**: recycling of Pu and P-T of all of the MAs (Am, Cm, Np)
  - HLW contain only FPs
- Scenario **F1j**: recycling of Pu and P-T of a part of the MAs (Am only)
  - HLW contain FPs, Cm and Np

Nuclear power generation associated to these scenarios is assumed to be constant capacity of 60GWe (430TWhe/y)



2. Main objectives and schedule

Study carried out in 2 phases between 2009 and 2012:

Phase 1 (2009-2010):

- comparison of underground footprint and excavated volume
- impact of the interim storage period of HLW : 70 years or 120 years

Phase 2 (2012):

- identification of additional gains for the underground footprint
- advantages and drawbacks of transmutation options on long-term performance and safety

Assumptions:

- one or two new hypothetical repositories specifically implemented for potential future nuclear power fleets
- geological setting similar to the one studied in Meuse/Haute-Marne, without prejudice to the future implementation

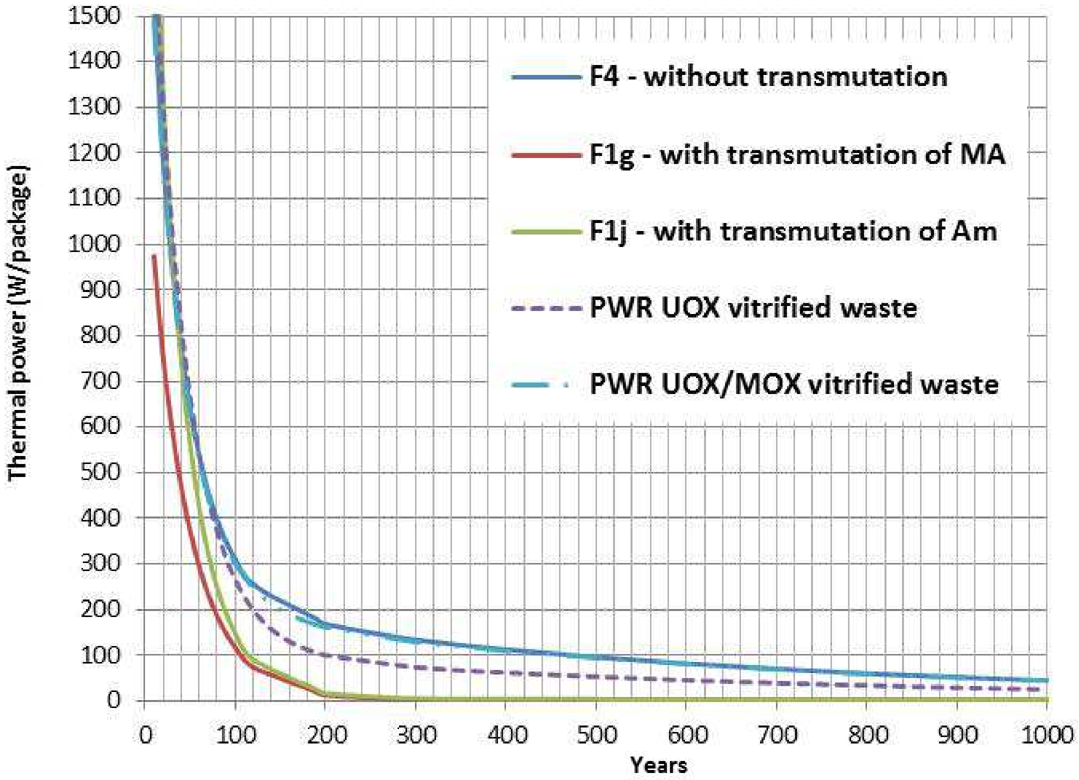
2. Input data

Inventory and characteristics of HLW and ILW-LL primary waste packages (CEA)

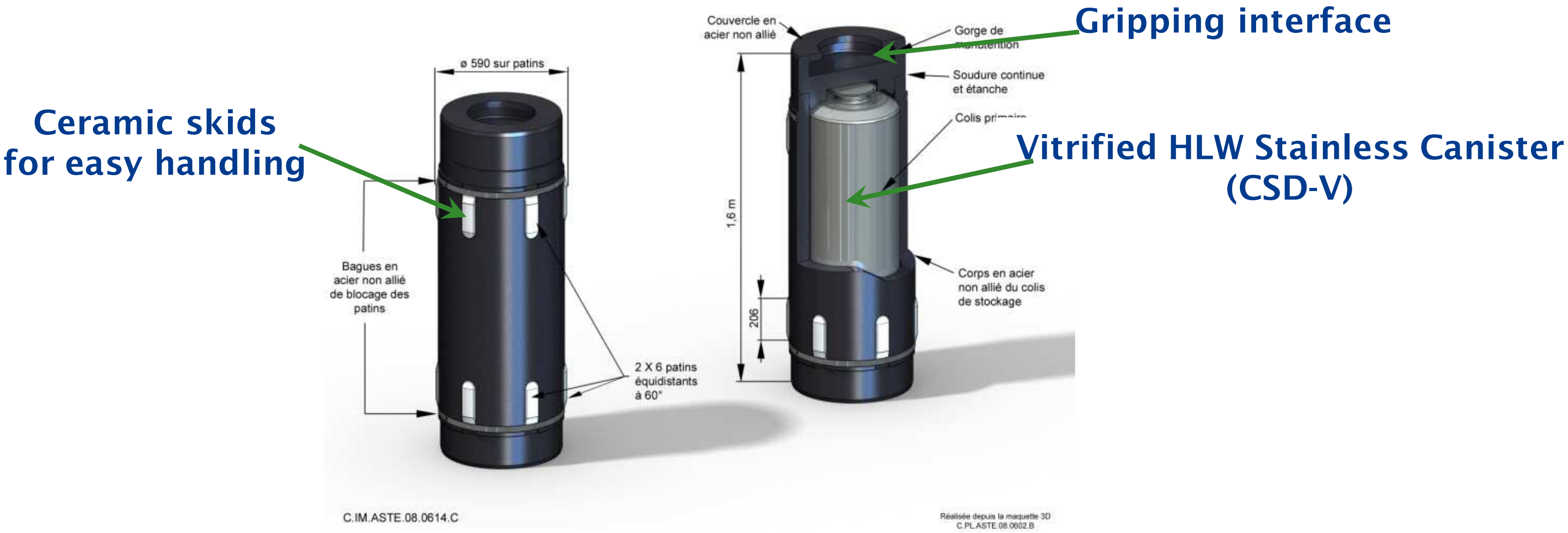
Scenarios		F4	F1j	F1g
HLW package (CSD-V)		103,000	96,000	89,000
ILW-LL package	Structural waste (CSD-C)	246,000	254,000	255,000
	Other waste (CSD-C, CBF-C'2)	56,000	57,000	57,000

Residual thermal power of HLW package (W/package)

Interim storage period	F4	F1j	F1g
70y	459	324	234
120y	256	91	74

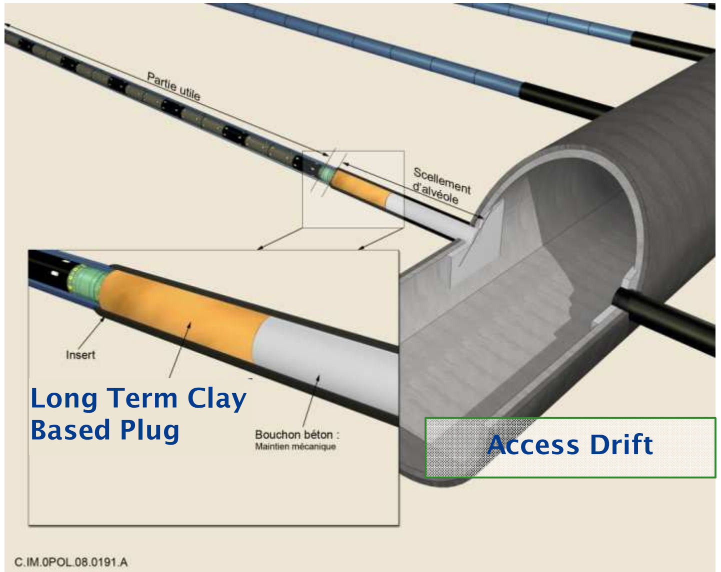


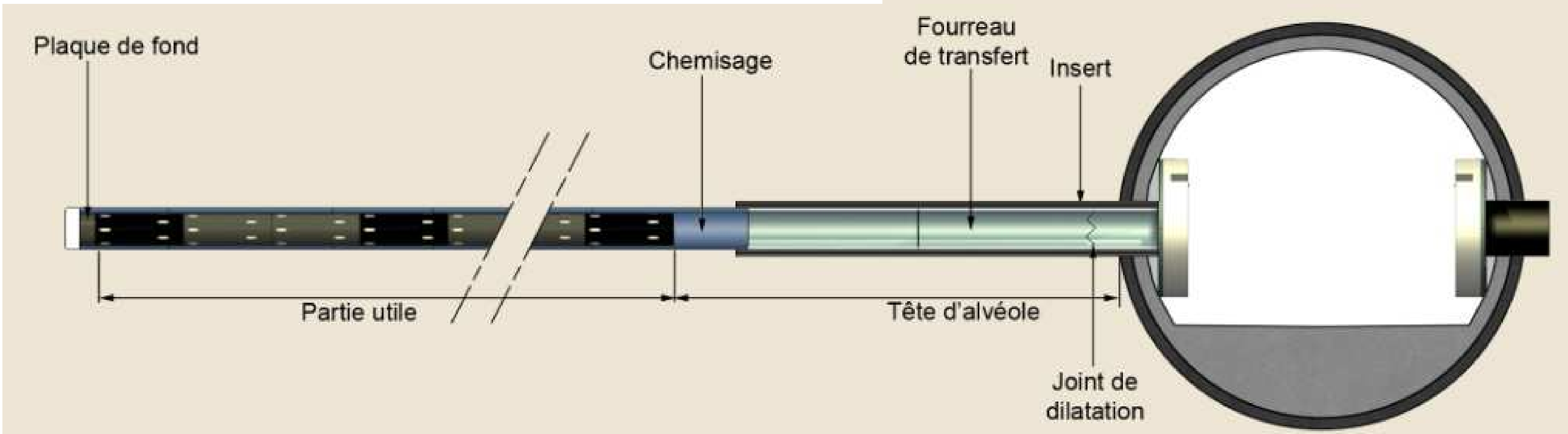
HLW will be placed in thick steel overpacks to prevent glass leaching during the thermal phase:



HLW repository cells are horizontal micro-tunnels located in the middle part of the host clay layer:

- Heat conduction in clay
  - max. temp in clay rock: 90 °C
- Steel liner
- Access by horizontal drifts
- If necessary, use of spacers between HLW packages to evenly distribute the heat flux density

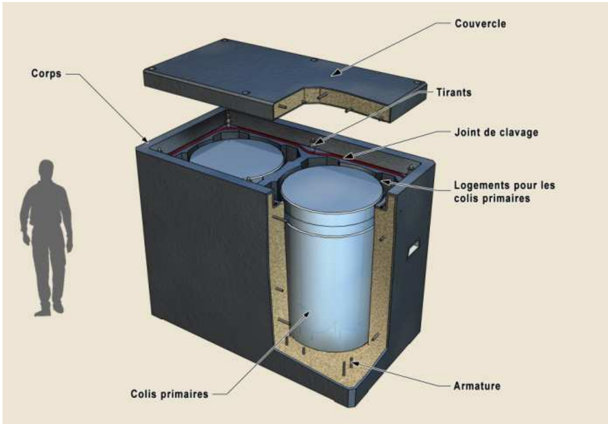




3. Repository design options for HLW and ILW-LL

Before emplacement, ILW-LL packages will be grouped into precast concrete rectangular robust containers:

CSD-C



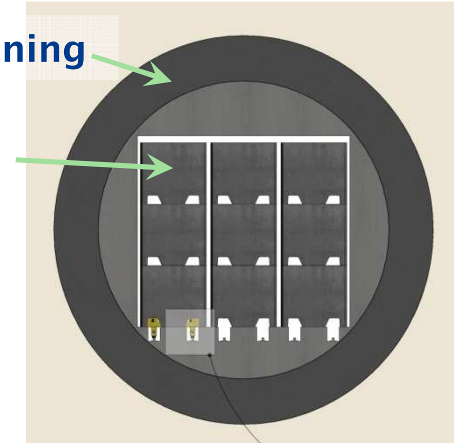
CBF-C'2

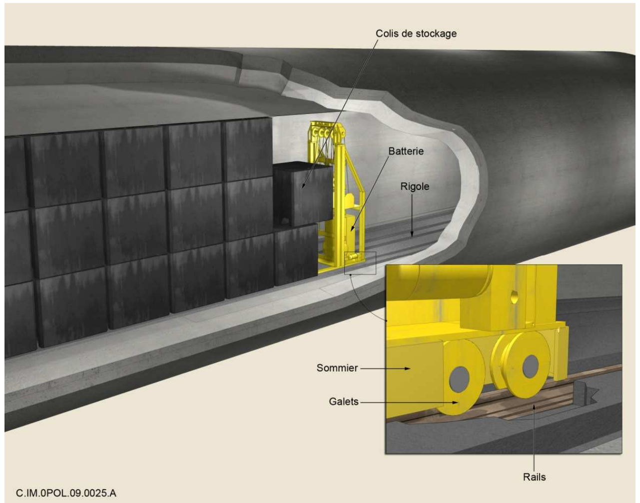
Prototype manufacturing

3. Repository design options for HLW and ILW-LL

ILW-LL repository cells are horizontal tunnels located at the median of the host clay layer:

- Concrete lining
- Ventilation of ILW-LL repository cells as long as they are not closed
- Each cell contains a large number of ILW-LL packages with a low residual thermal power.





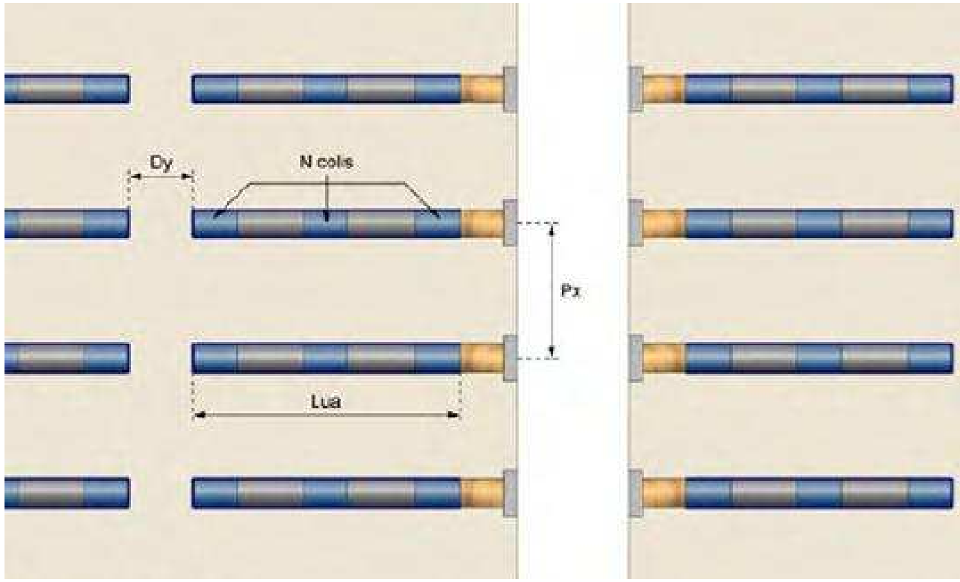
4. Thermal sizing

The temperature of the host rock induced by HLW heat should be limited.

- maximum temperature of 90°C in contact with the host formation.

Thermal design parameters:

- number (N) of waste packages per cell in relation with their spacing
- distance between two adjacent cells (Px)
- distance between bottom cells (Dy)

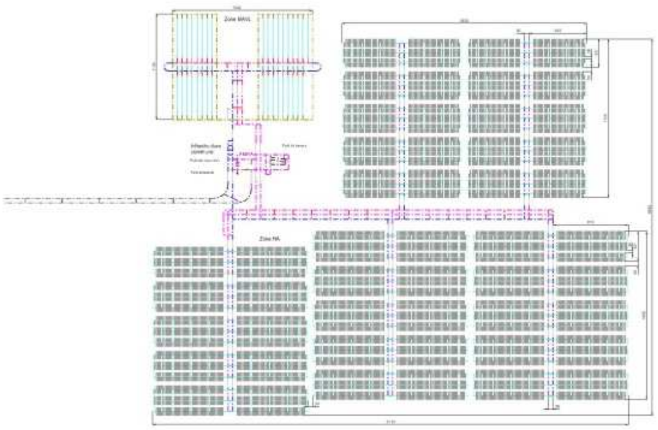


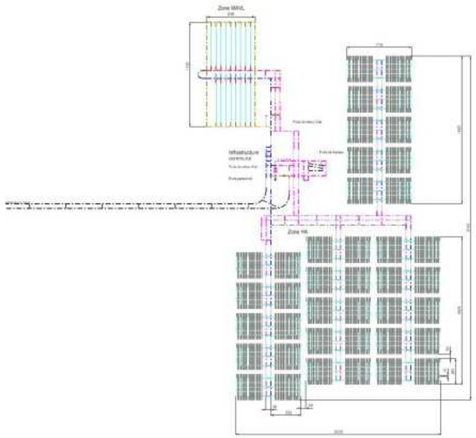
Thermal design based on finite elements calculations

(heat conduction, advection and radiation)

5. Repository underground architectures

Architectures associated to scenarios F4 (left) and F1g (right) for an interim storage period of 70 years (issued from phase 1)





Compared to the multiple recycling of Pu, P-T of actinides provide:

- A reduction by a factor 2 (Am) to 2.5 (MA) of the footprint of the HLW zone
- A reduction of 30% (Am) to 40% (MA) of the excavated rock volume

For an interim storage period from 70 to 120 years:

- F4 : gain of 25% on the footprint of the HLW zone and 7% on the total excavated volume
- F1g : gain of 60% on the footprint of the HLW zone and 12% on the total excavated volume

5. Repository underground architectures

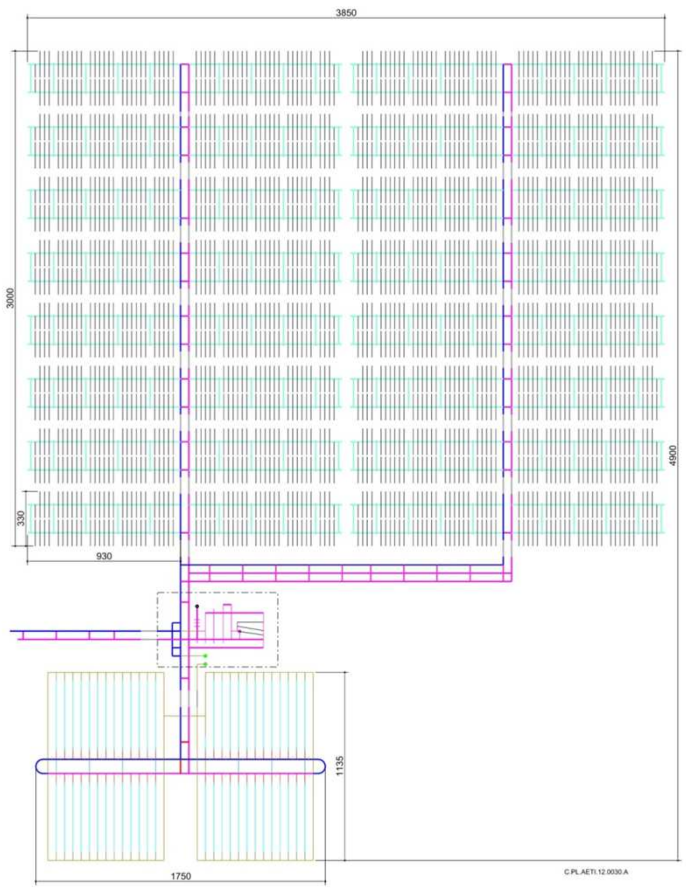
The second phase (2012) consisted for a search for ways for a more drastic decrease of the repository footprint. It takes into account an interim storage period of 120 years.

⇒ Compared to the multiple recycling of Pu, P-T would provide :

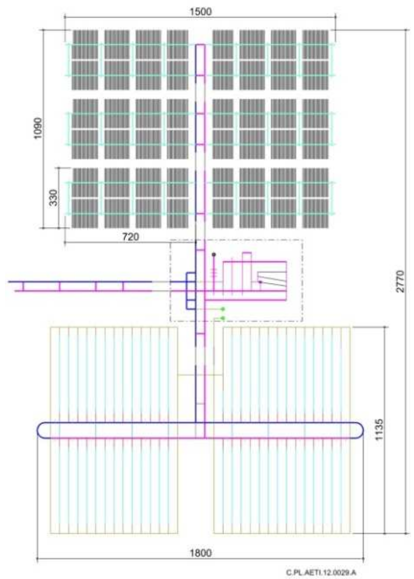
- A reduction by a factor up to 7.3 (Am) to 9.8 (MA) of the footprint of the HLW disposal zone
- A total reduction by a factor 3 of the repository footprint taking into account ILW-LL and common infrastructures
- A total reduction by a factor 2 of the excavated rock volume

5. Repository underground architectures

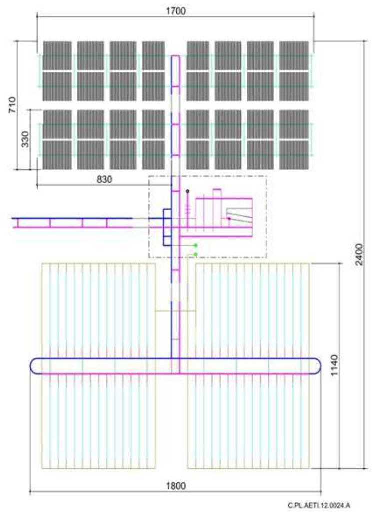
Underground repository architectures for various scenarios with an interim storage period of 120 years (phase 2, 2012)



F4



F1J



F1g

6. Safety issues

Along with a reduction of the underground footprint, P-T also decrease the duration of the thermal phase to 200 years (against thousand years without transmutation).

The consequences of P-T on the long-term safety functions of the repository were assessed in a preliminary approach taking into account the potential densification of the repository

- P-T of actinides do not reduce the long-term radiological impact;
- In an altered evolution scenario, such as intrusive drilling, the impact of FPs and APs may increase to some extent because of the densification. But the impact remains acceptable.

7. Conclusions

P-T concern the waste produced by future generation reactors

- It does not apply on the waste that will be accommodated by Cigéo.

P-T cannot eliminate the need for geological repository.

P-T makes it possible to:

- Reduce the duration of thermal phase of HLW;
- Reduce the underground footprint and the excavated rock volume with respect to temperature limits, provided a long interim storage period is considered.

No significant impact on long-term safety assessment is being considered.