Waste management

Radwaste types : classification and management paths

	Short lived Half-life < 30 years for most key elements	Long lived Half-life > 30 years
Very Low Level (VLL)	Dedicated repository (in operation since 2003) Capacity : 650 000 m^3 108 219 m^3 (as of end of 2002) 11,1 % of total volume	
Low Level (LL)	Final disposal Centre de l'Aube (in operation since 1992) Capacity : 1 M m^3 778 322 m^3 (as of end of 2002) 0,07 % radioactivity 79,5 % of total volume	Dedicated repository being studied for radium bearing waste (35 717m^3) and graphite waste (8 842 m^3) 0,01 % radioactivity, 4,5 % of total volume
Medium Level (ML)		45 359 m^3 end of 2002 3,87 % radioactivity 4,6 % of total volume Under study
High Level (HL)	December 30, 1991 Law 1 639 m^3 end of 2002 96,05 % radioactivity 0,2 % of total volume	

⇨figures are quoted from the Inventaire national document (October 2004);

⇨more info at : www.andra.fr.

Goal 2 research

Goal : demonstration of the deep geological repository feasibility

- ⇨the URL at Bure (250 km east from Paris);
- ⇨repository design & engineering studies;
- ⇨safety assessment of the deep geological repository;
- ⇨a significant investment : 1007 M€ (to the end of 2004).

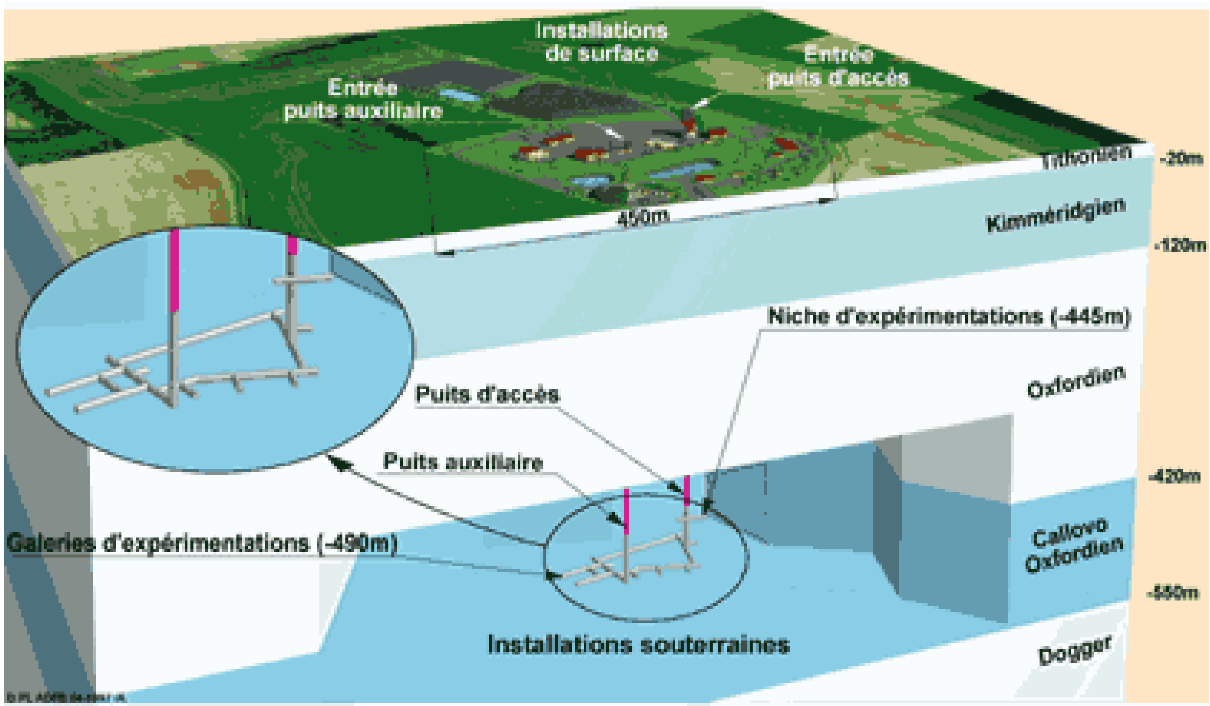
Andra, as research leader

- clay rock as host formation : URL of Bure in Meuse/Haute-Marne;
- granite rock as host formation : generic study since no actual site is available.

⇨ **CEA has contributed research work in each of the following areas:**

- **geochemistry,**
- **materials used in repository,**
- **computer modelling of geological media and interfaces (ALLIANCES simulation tool),**
- **involvement in actual experiments conducted in situ at the URL site (diffusion of tracers).**

⇨The Callovo-Oxfordian clay sedimentary layer displays highly valuable confinement properties for radwaste disposal :



Among others :

- long-lasting stability since 150 M years ago;

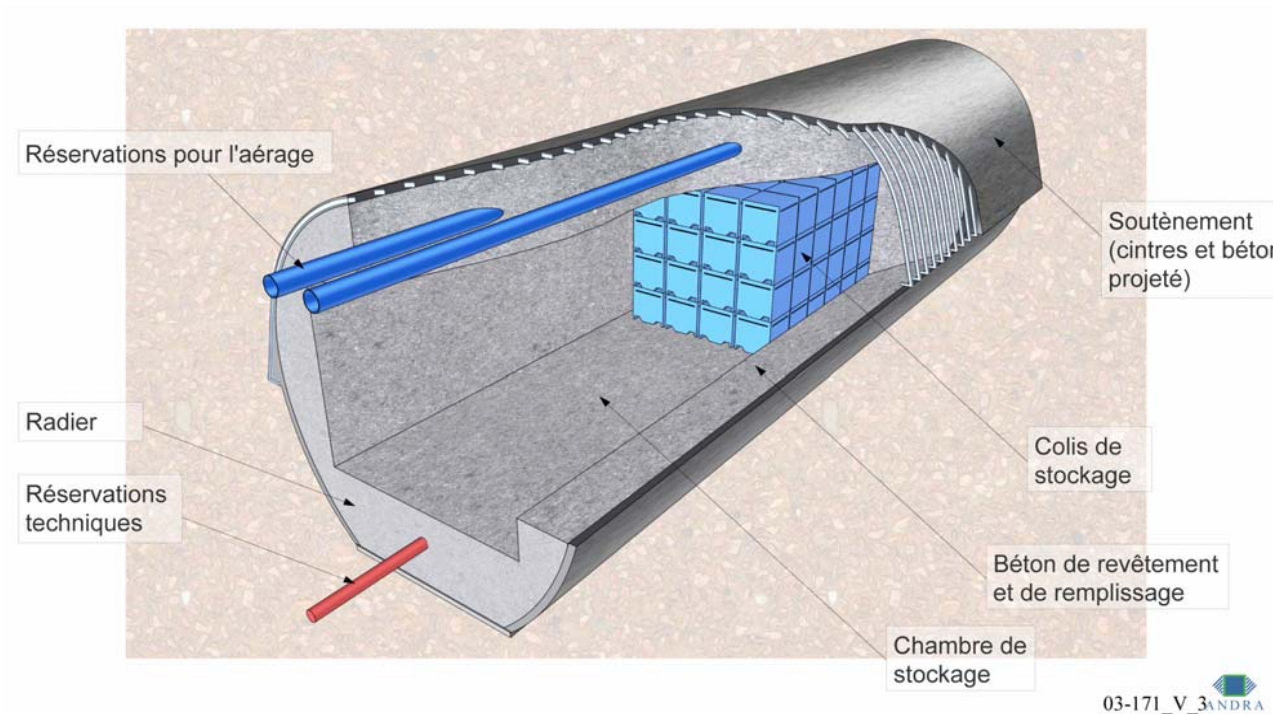
- very low permeability;

- extremely slow diffusion-controlled migration rate of dissolved elements;

- satisfactory mechanical behaviour.

Repository layout in clay rock

⇨A design yet to be improved while already meeting safety criteria :



- modular,
- a fish-bone type layout with dead-end crosscuts,
- waste type dependent module design.

Example of a dead-end crosscut for ML LL B waste type

Repository safety assessment

The « 2005 Argile » report :

- ⇨ phenomenological assessments of repository conditions changing with time;
- ⇨ simulations under normal and off-normal conditions;
- ⇨ considering current knowledge acquired, assumptions made and current design, the repository system seems to be feasible and is expected to confine radionuclides over very long periods of time;
- ⇨ an international expert peer-review report will be made available in 2005;
- ⇨ learn more at : www.andra.fr.

Conditioning processes and long term storage

Objectives :

⇨physical and chemical waste stability through **conditioning** :

- new conditioning matrices for separated elements (CEA/CNRS);

⇨knowledge of waste package content;

⇨risk-free handling capability;

⇨**long term behaviour** of waste package;

⇨waste package preservation while waiting for implementing next management step : **storage**.

Conditioning and interim storage

➢ conditioning

- making of of and knowledge base about the waste package
  - development of radioactive material conditioning processes
  - canisters
  - package characterization
  - long-term behavior studies

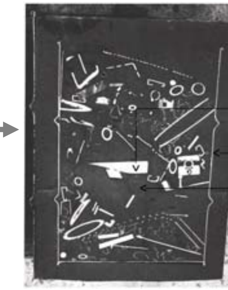
➢ interim storage

- definition and qualification of long-term interim storage concept designs
  - surface
  - subsurface

How is a waste package made ?

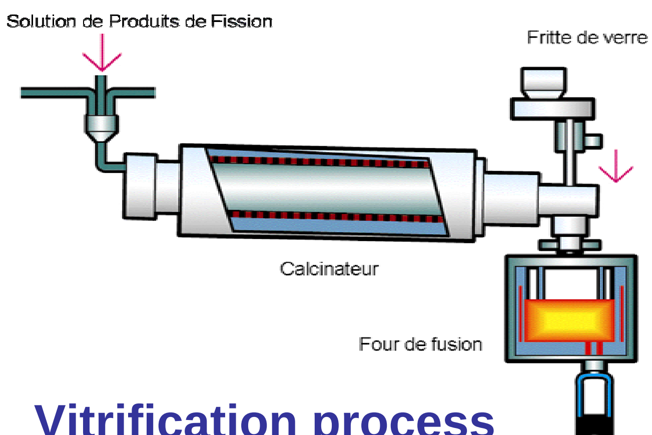
⇨ Treatment for waste volume reduction and stabilisation :

- solid waste :
  - is introduced into a canister and immobilised in cement;

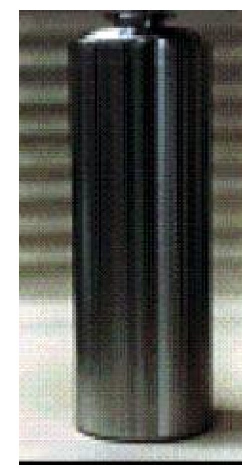


  - or compacted (volume reduction) and put into a standardised canister;

- liquid waste :
  - is mixed within a material, cement, bitumen, or glass to make it solid;
  - then introduced into a standardised canister.

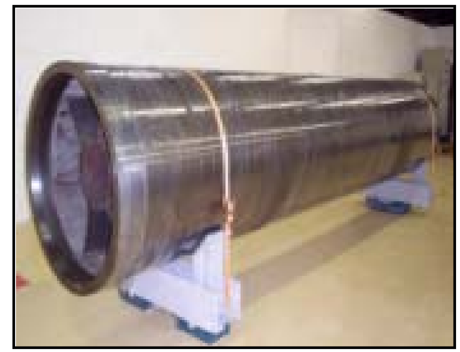


Vitrification process



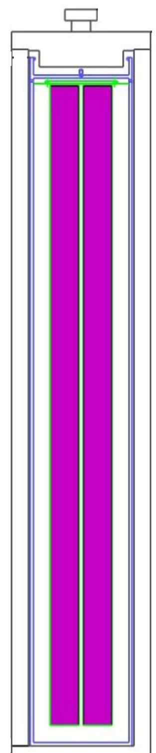
Conditioning

- canisters
- long-term behavior studies

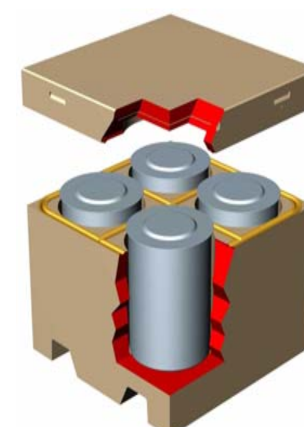


Container for spent fuel

Vitrified waste (CSD-V)

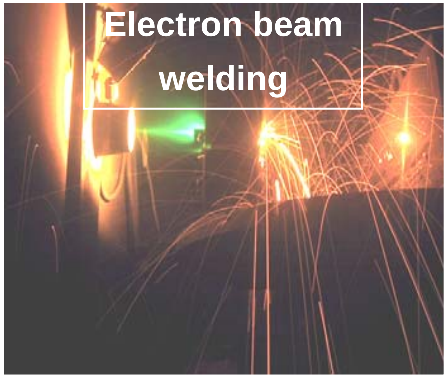


Individual case for SF

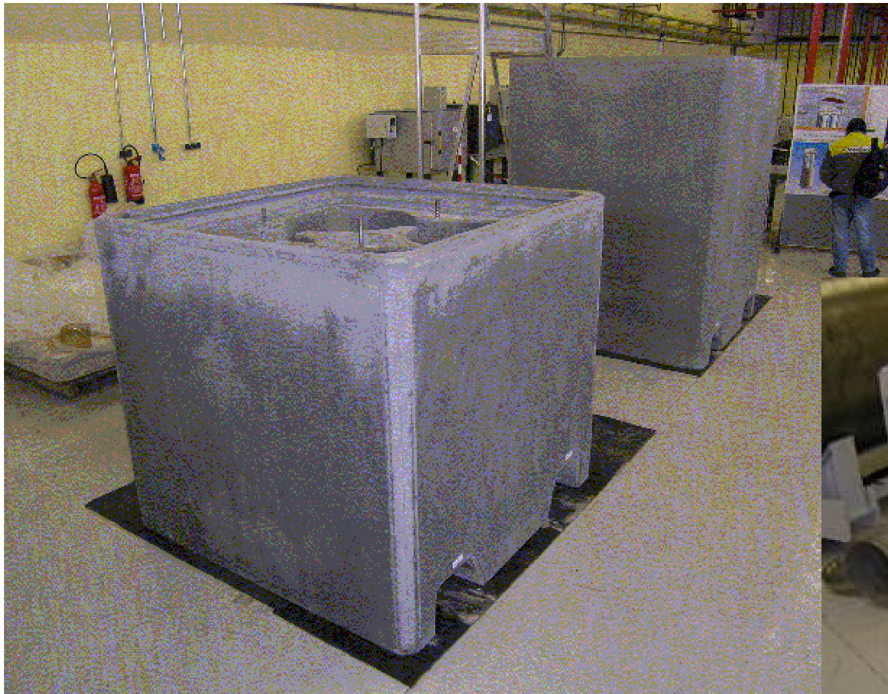


Container for ILLW

LTS canister for thermal HL waste : demonstrator fabrication



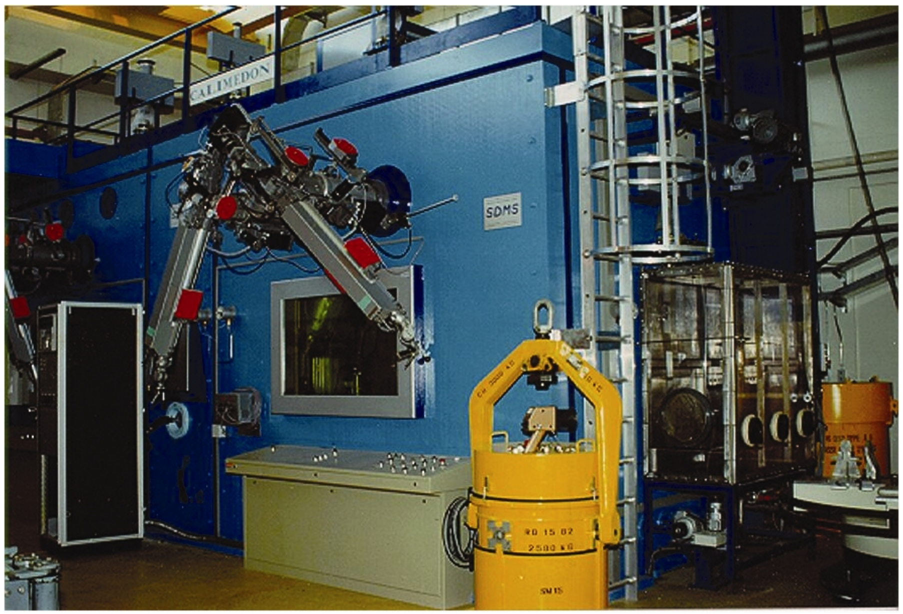
Canisters for ML LL waste



LTS and geological repository (dual purpose) canisters studied jointly with Andra

Demonstrators made of steel fibres reinforced concrete

Characterisation : knowledge of the package content



Characterisation cell in CHICADE (Cadarache)

Tomography
(CHICADE Cadarache)

Characterisation : progress achieved

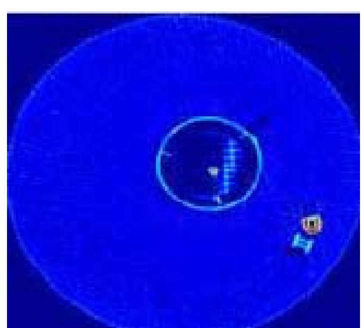
⇨**Capability to identify very small quantities of elements;**

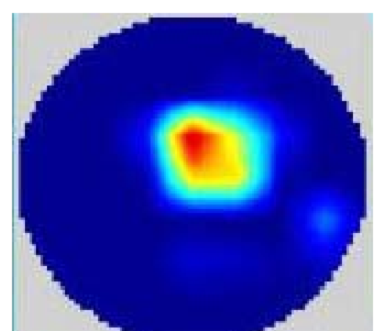
⇨**use of imaging techniques;**

⇨**coupled neutronic and gamma measurements :**

⇨**Enhancing measurements and reducing uncertainties :**

- to better quantify and to locate radionuclides;
- within the physical content of packages.





Package examination with coupled methods.

Long term behaviour of waste package (1/2)

⇨Long term behaviour science (concrete, glass, bitumen…);

⇨modelling tools describing long term behaviour phenomenology. Andra makes use of such modelling capability to run repository safety assessments.

- Methodology, evolution under dry then wet conditions :

- Experiments
- Identification and description of phenomena

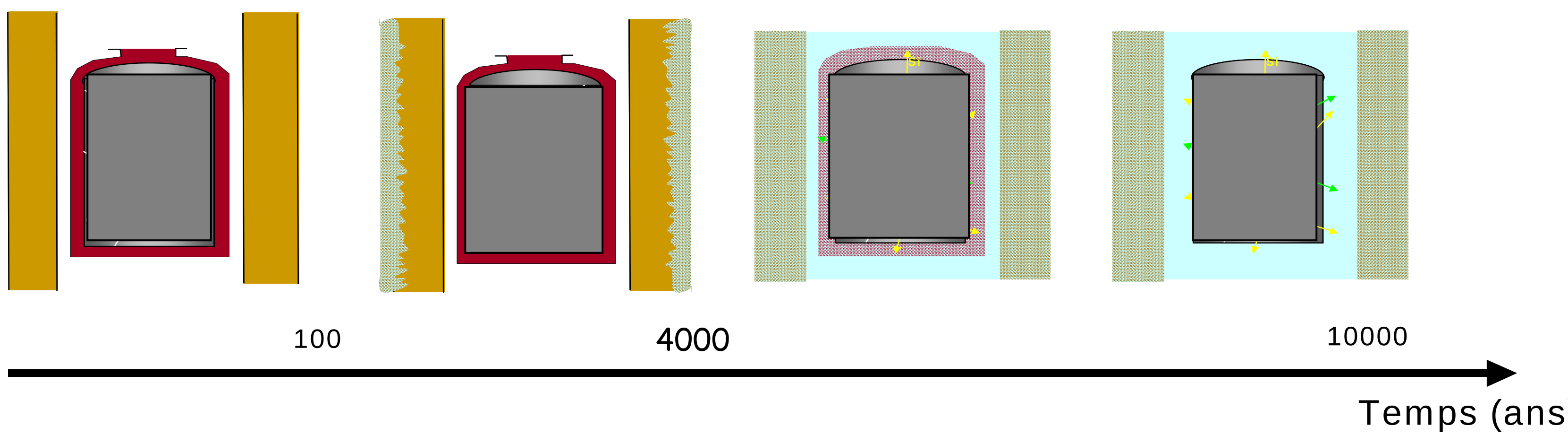
→

- operational modelling

→

- assessment of radionuclides confinement

- applied to the glass case :



Long term behaviour of waste package (2/2)

Such modelling shows a life time for glass matrices lasting a few hundreds of thousands years.

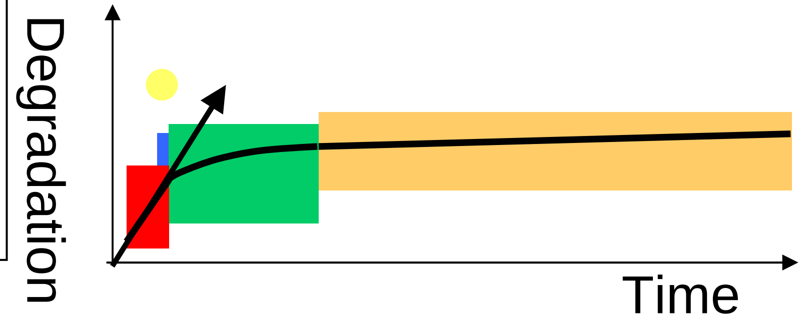
Reaction mechanisms: the R7T7 glass

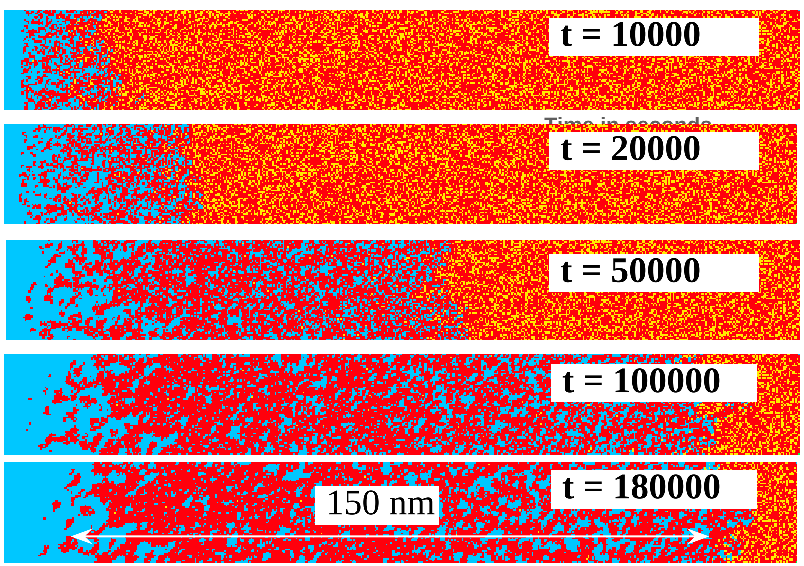
1 - Hydration / Inter-diffusion,

2 - Hydrolysis (Si, Al, Fe…),

3 - Gel layer formation,

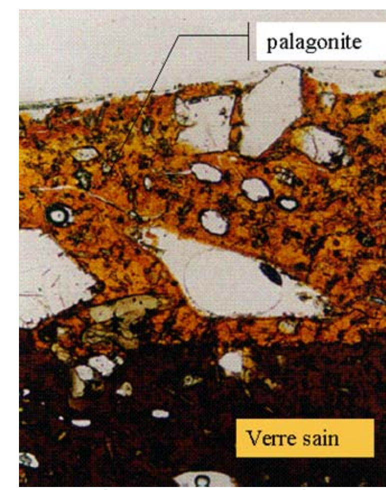
4 - Gel densification/closing of porosity - a protective layer against mechanical and chemical aggressions.





Simplified glass degradation simulation
(collab Cea-Ecole Polytechnique)

Archeological analogue



Film of palagonite at the contact of basaltic glass surface

Conclusion… for conditioning and waste characterisation

- ⇨ Waste volume reduction, standardised waste package and improved conditioning;
- ⇨ conditioning processes exist for all waste types;
- ⇨ characterisation methods to better investigate package content in order to direct them to the most appropriate endpoint and improve inventory knowledge;
- ⇨ a long term behaviour science to model the evolution of waste package with time.

Long term storage (LTS)

⇨ **Two options for LTS** :

- Prolong and/or rebuild industrial storage facility :
  - lifetime extended up to 100 years;
  - assessment made with COGEMA on the ECC installation (compacted hulls) and on the E-EV-SE installation (for glass package);

E/EV/SE

storage facility

at La Hague

ECC

storage facility

at Marcoule

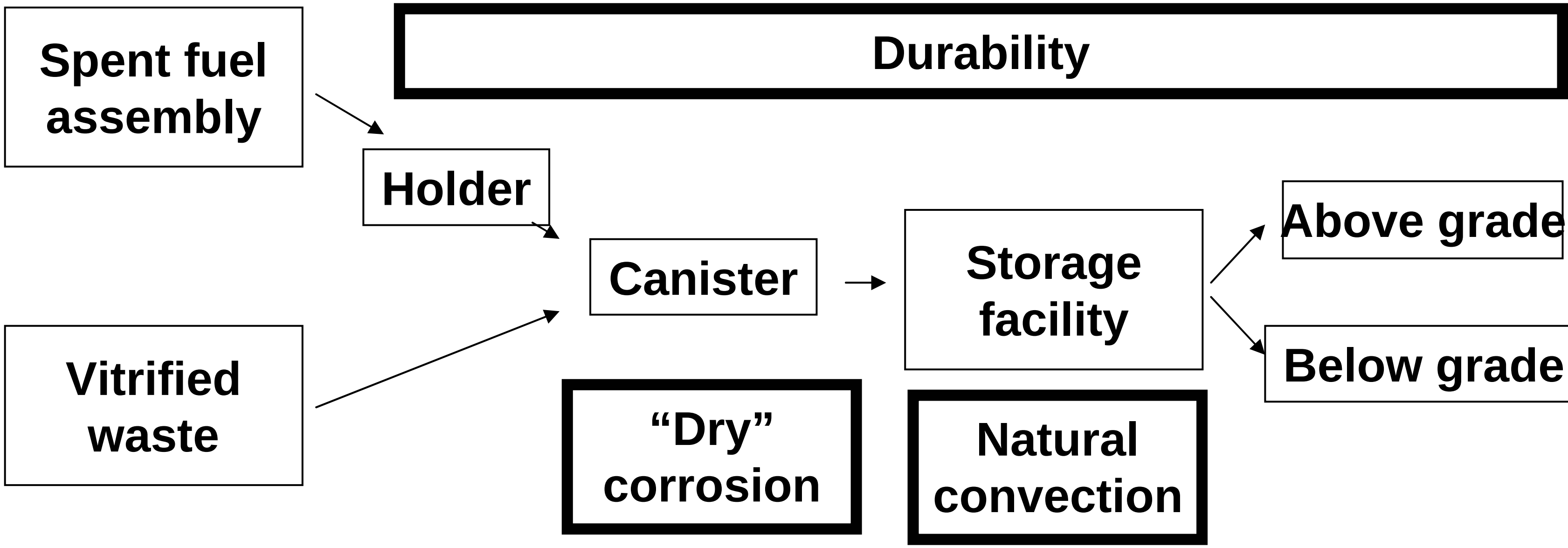
- LTS installations designed from start for a much longer lifetime (up to 300 years) :
  - specific LTS studies conducted include :

    LTS canisters compatible with deep geological disposal;

    above-grade and below-grade LTS;

    associated demonstrators - illustration.

LTS design criteria
for spent fuel and vitrified waste



- natural convection for heat removal system (**passiveness, robustness**);

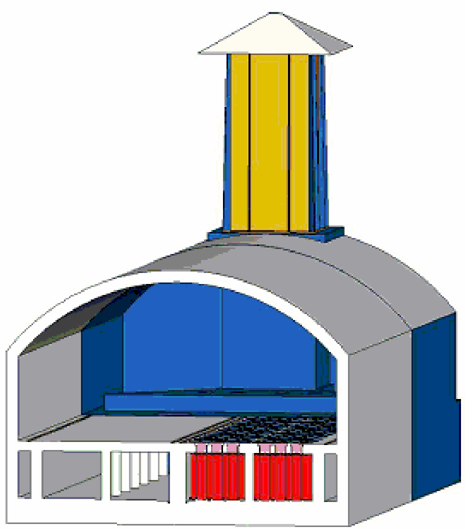
- **ageing** of LTS and canister materials taken into consideration;

- **safe confinement** of radioactive inventory within a dual wall metallic canister system, the outer wall being exposed to **dry corrosion** conditions, a **very slow process**;

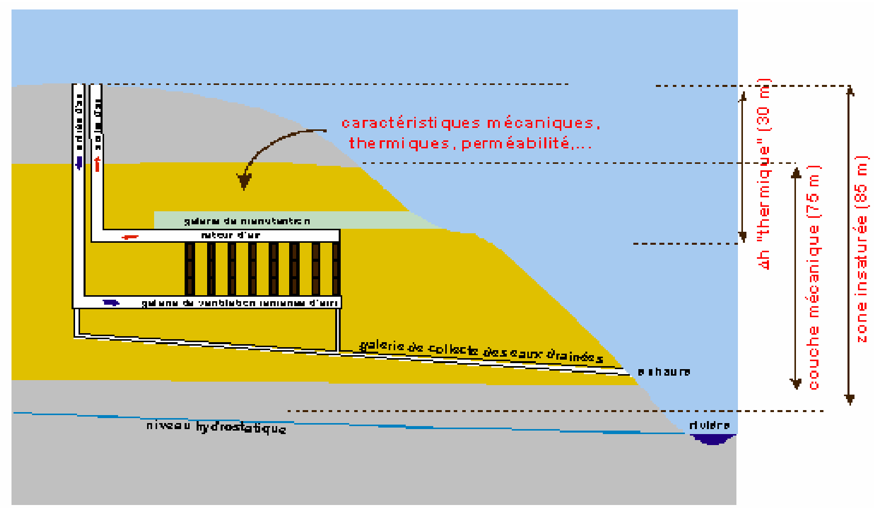
- a well preserved package allows for its future **re-handling**, including the retrieval of the **spent fuel holder**.

Long term interim storage

- protection of waste package its recovery at a later date
- State of the art existing industrial interim storage : no major difficulty (technical and industrial feasibilities)
- Research conducted by CEA :
  - **long-term interim storage of spent fuel and of high or medium-activity long-life waste packages**
  - **surface or subsurface.**



Storage in surface



Storage in subsurface

LTS surface design : general description

Dry storage

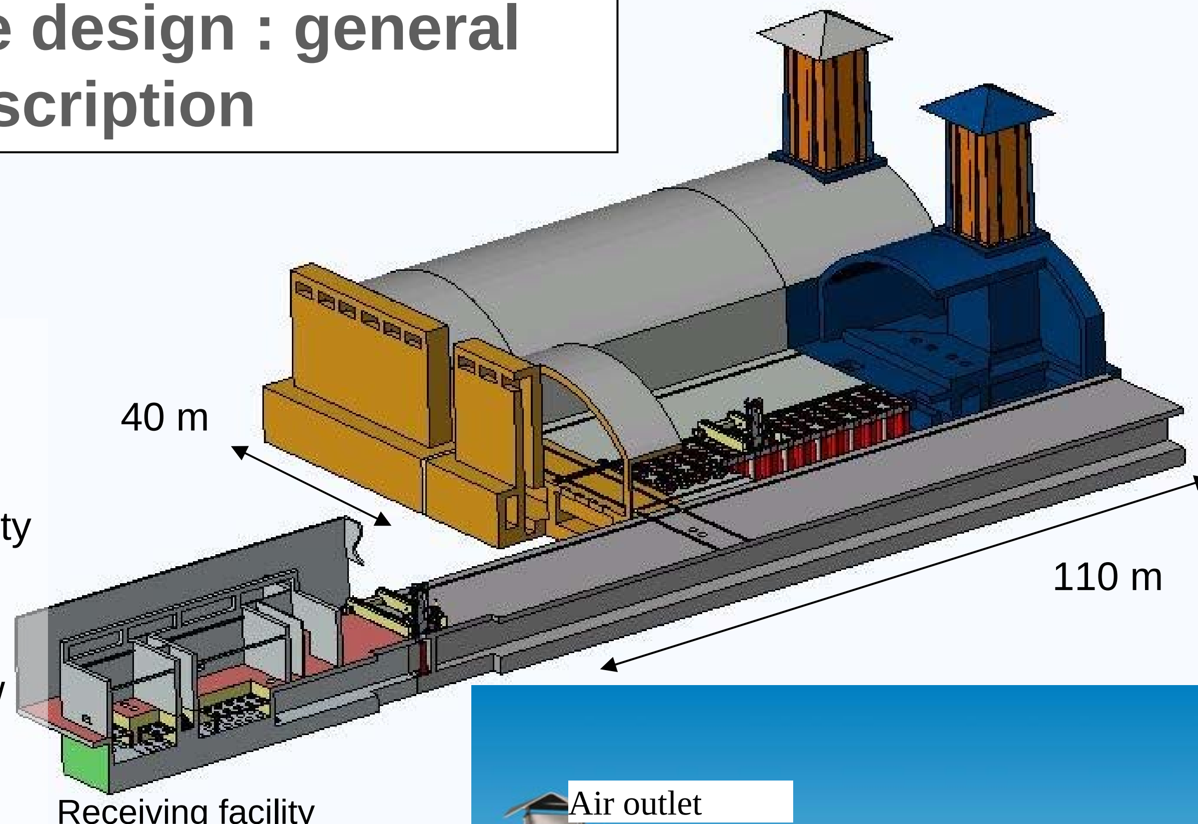
Vault type facility

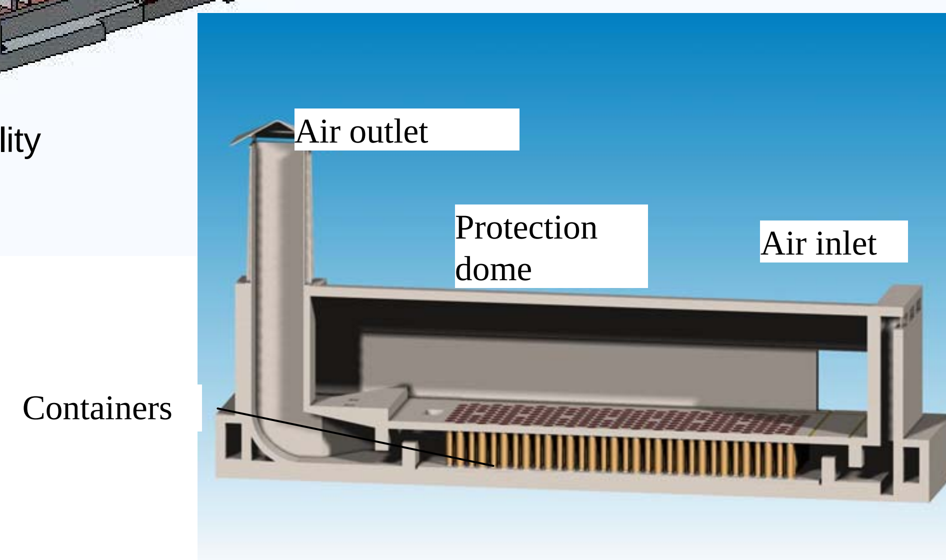
Modular design : storage capacity can be extended in stages

Passive buoyancy-driven airflow

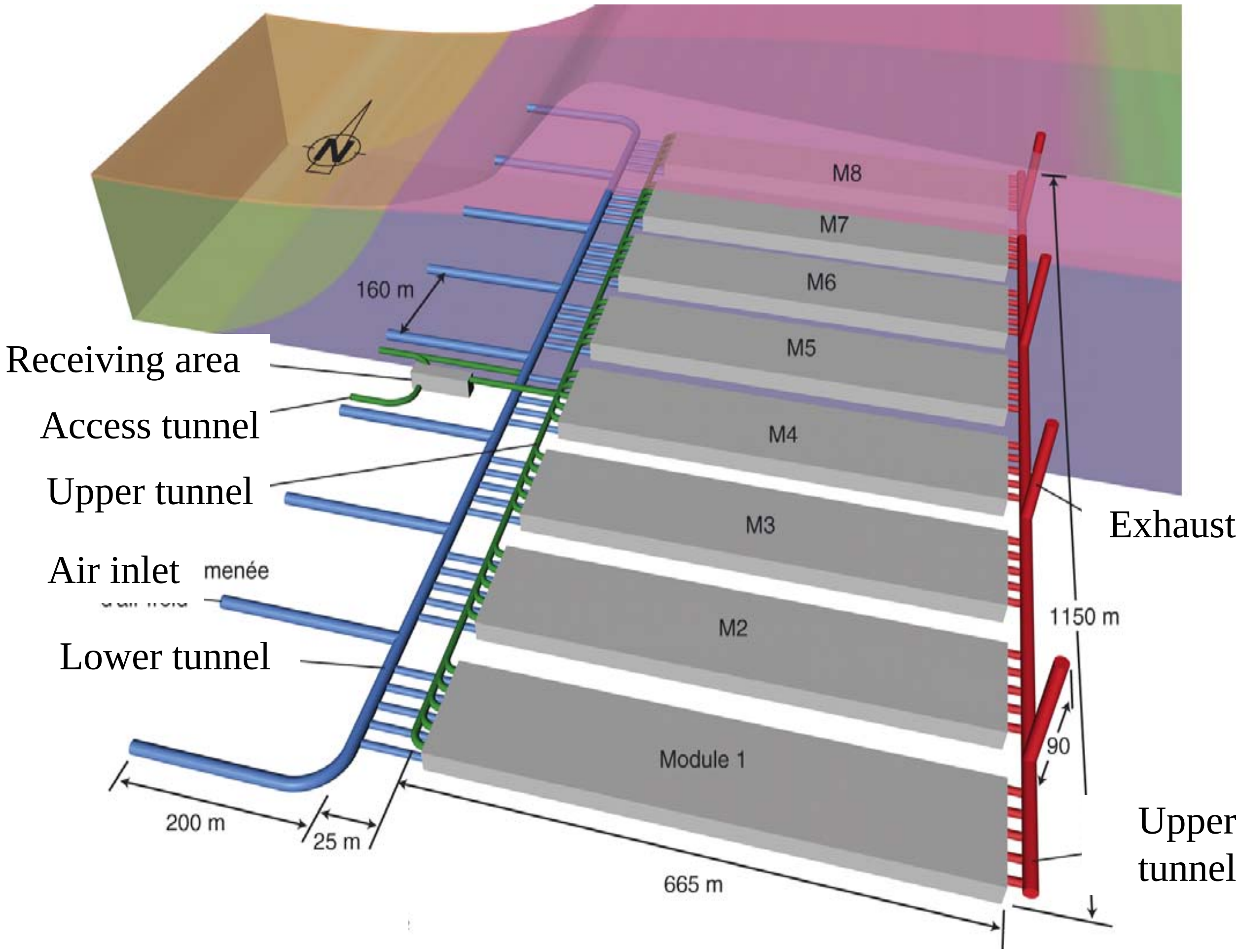
No nuclear ventilation

(container : two leaktight barriers)





LTS subsurface design **: facility layout**



Network of wells/tunnels excavated in limestone rock

Facility is located in a hill/mountain (above water table)

Main idea :

- enhanced physical protection

- use the natural properties of rock for durable and « inexpensive » construction

Modular design

No site selected for the moment

Long term storage design: techological bench tests

Heat removal

Design calculations are supported by a reduced-scale experiment

SIGAL

localized pressure losses at junctions/bends in the network of tunnels

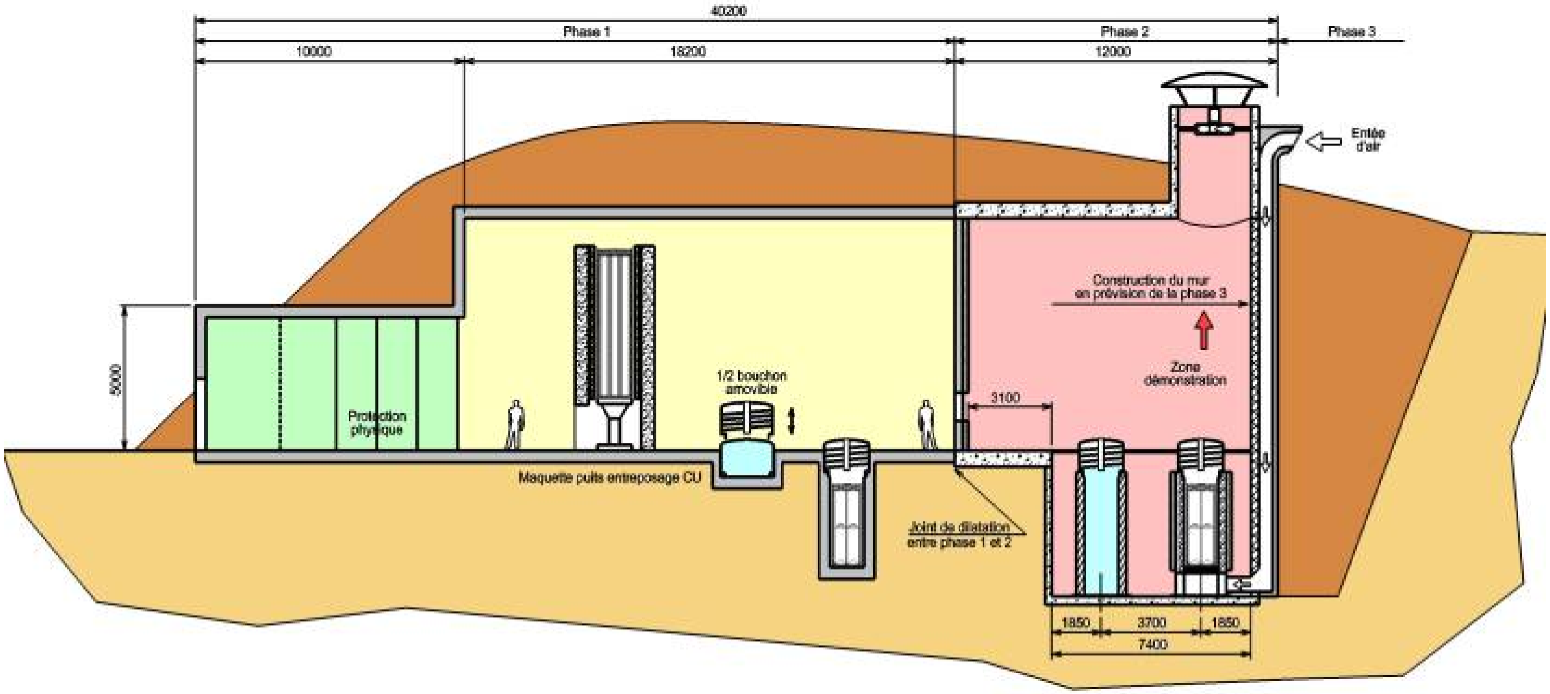
container durability and dry corrosion

Design calculations are supported by a large scale experiment

PROMETHEE

convective heat transfer around the container

Demonstration gallery of subsurface interim storage at CECER



Physical Protection | Thermics | Terrain naturel Natural soil

Handling | Monitoring | Fouille et remblai Excavation and fill in

Conclusion … for LTS

- Lifetime of current industrial storage facility can likely be extended up to 100 years subject to regulatory review and approval;
- technological demonstrators have been made as a result of LTS facility studies;
- preliminary engineering studies were conducted for both above and below grade facilities;
- LTS feasibility is recognised for all types of HL or ML LL radwaste.

Goal 3 research global output

- **Volume reduction;**
- **improved conditioning processes; one for each waste type;**
- **scientific breakthrough and results on long term behaviour of waste packages;**
- **LTS feasibility provides more flexibility to industry and decision makers;**
- **CEA alone, as research leader, has invested significant means : 613 M€ out of 672 M€** (to the end of 2004).

At present time :

1) **Significant results have been produced by R&D since 1991**

   - **partitioning of minor actinides and their transmutation**
   - **Conditioning processes**
   - **Scientific bases for long term containment of waste package proerties**
   - **Design of concepts for long term interim storage installations**

2) **Technical solutions do exist, that could be implemented in a progressive manner.**

- **Important results have already been acquired :**
  - the possibility of significantly reducing the quantity and radiotoxicity of long-lived waste,
  - methods for conditioning
  - long term storage of radioactive materials.

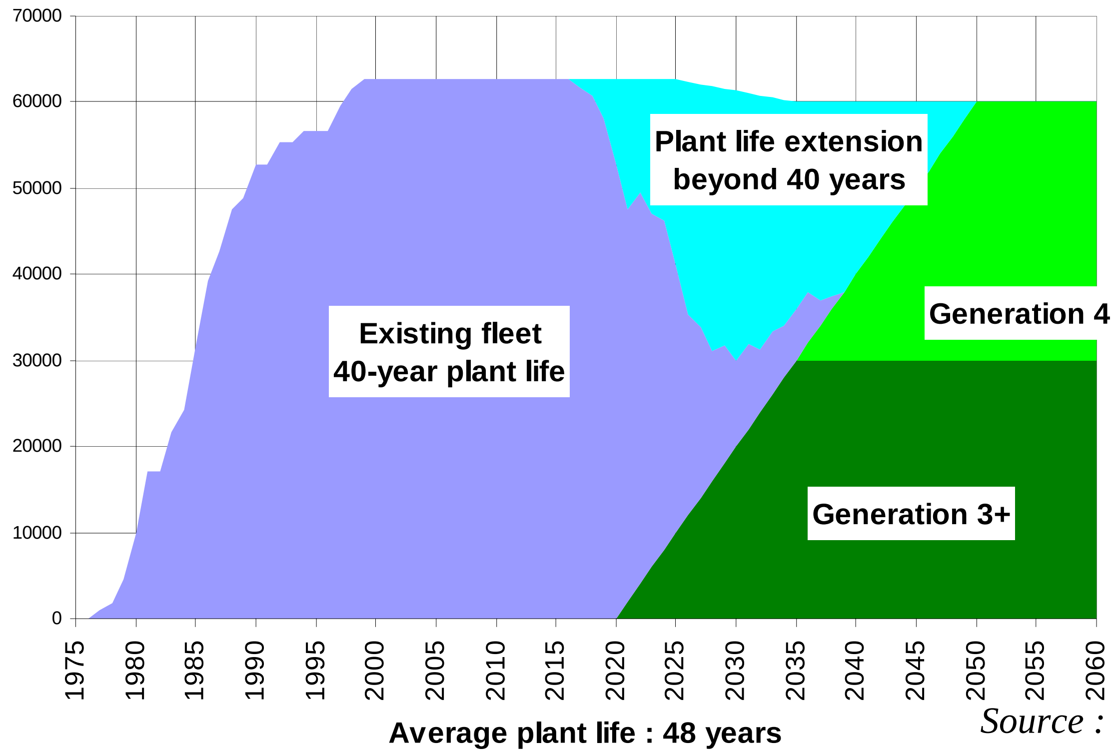
- **Additional R&D work to be conducted in coming years will supplement and consolidate these results.**

- **Sufficient technical and economic data will be available on each research area to make decisions on management methods for long-lived waste in 2006.**

Fuel Cycle Transition

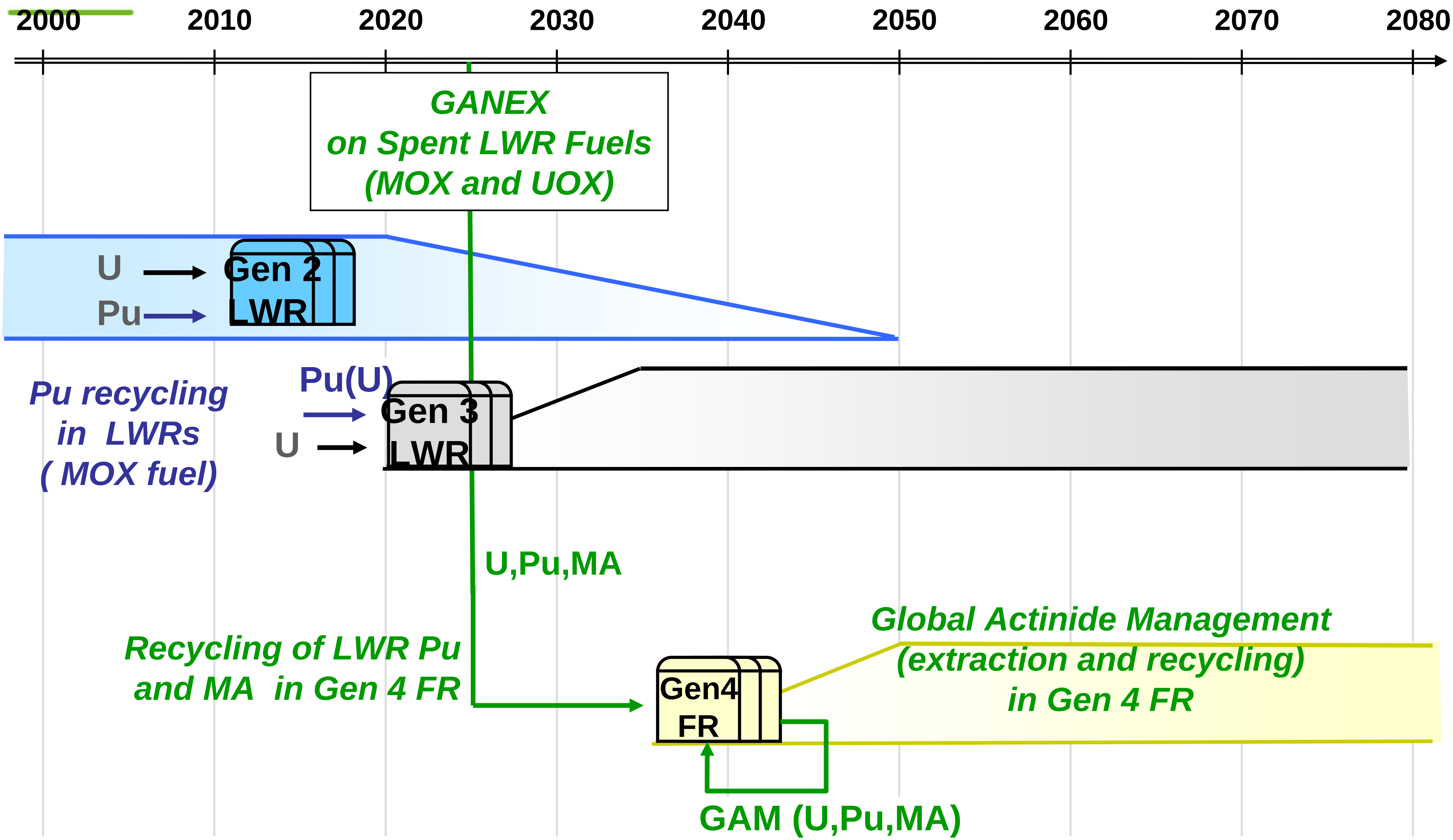
Transition scenarios between generations

- **A transition step awaiting future nuclear energy systems**
- **Major role of LWRs in the 21st century**
  - Current Gen II LWRs : life time extension
  - Gen III/III+ : Replacement existing LWRs →2015
    Will be in operation until the end of the 21st century

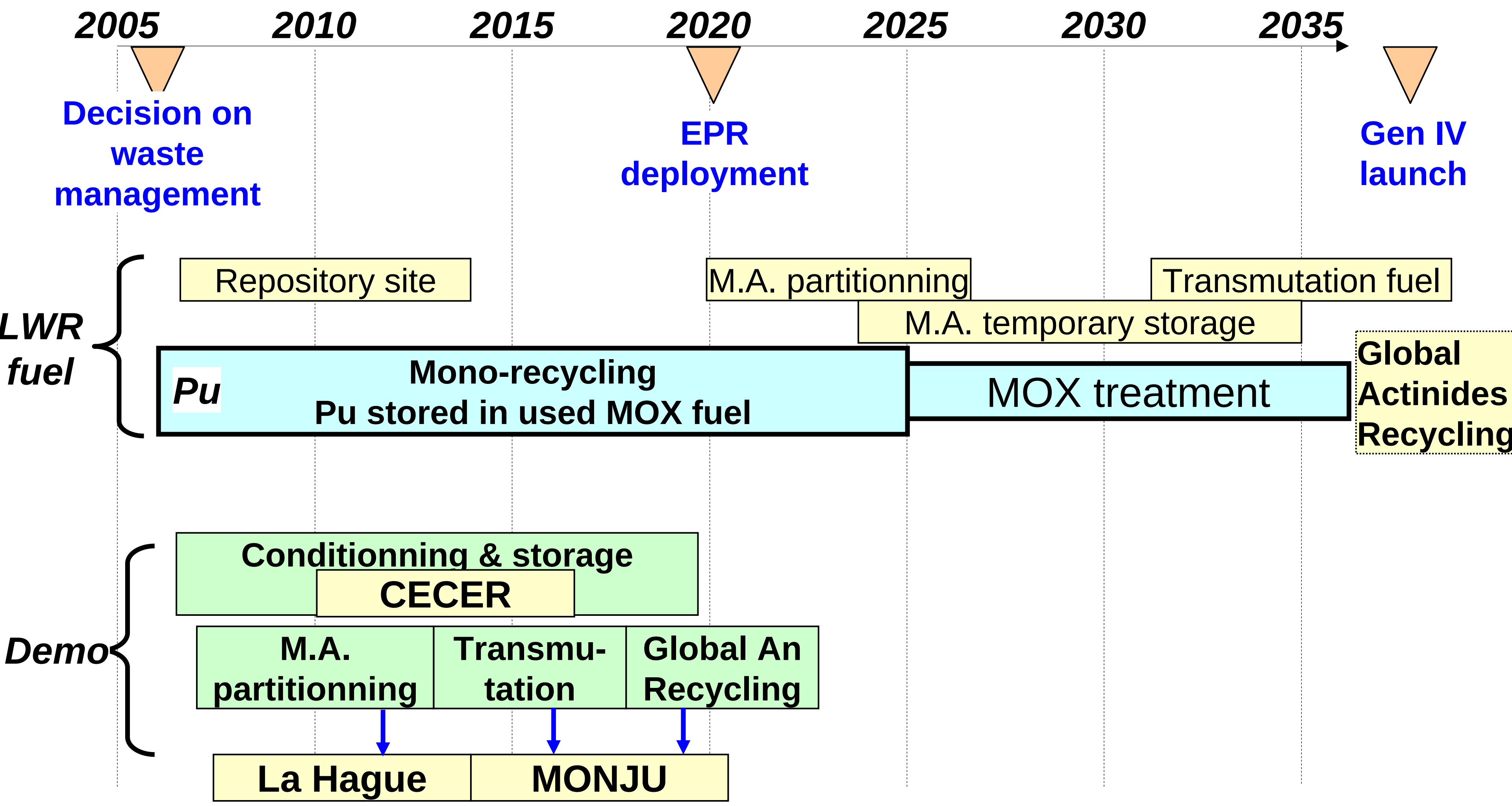


Source : EDF, ENC 2002

Perspective for actinides management



Gen II/Gen III towards Gen IV (2)



Summary

- **Fast neutrons and closed fuel cycles are essential for a sustainable energy development**

- **Securing the approach to fast neutrons through 2 technologies :**
  - **Sodium cooled Fast neutron Reactors as a mature technology with well identified critical issues to be resolved**
  - **Gas Fast Reactor with an innovative fuel technology**

- **Closed fuel cycle with an integral recycling of all actinides and group management of actinides for a better resistance to proliferation (TRU burners)**

- **A Global Actinide Management from LWRs to Fast neutron systems**

- **International collaboration as main path forward to enhance future nuclear systems feasibility and performance assessments**

Complementary slides