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Session 2 - Paper N 07:

Operational Safety and Radioprotection Considerations When Designing the ILW-LL Disposal Drifts

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Overview

1. **Geological disposal design and safety principles**
2. **Presentation of the French ILW-LL 2005 Design**
3. **Risk analysis methodology and interaction with design development**
4. **Safety analysis related to the major risks**
   - Radiological risk in normal conditions
   - Waste disposal package drop risk in disposal drift
   - Hydrogen explosion risk
   - Fire hazard in underground installations
5. **Synthesis and the way forward**

1. Geological disposal design and safety principles

- **Deep geological disposal design is specific in comparison to other nuclear facilities. It needs to combine requirements from:**
  - Long term safety (Post Closure)
    - ("more specific - uncertainties analysis")
  - Operational safety and radioprotection
    ("more conventional – risk analysis")
  - … and Reversibility/Retrievability (French approach)

This is a real challenge because an improvement for one safety axis may be a drawback for the other safety: there is a need to build a combined view

- **Two basic principles for the safety analysis and design options:**
  - **i.** **Robustness**: meet safety requirements, take into account events and uncertainties on solicitations level and nature
  - **ii.** **Demonstrability**: avoid complex solutions, support by experiments, technological demonstrators (such as ESDRED) , use of analogues…

2. Presentation of the French ILW-LL design

- **Repository design and safety approach is unique (and applicable to all wastes to be stored):**
  - Need to coordinate different **life phases** (operation and post closure) with long term timescale considerations
  - Unprecedented mix of **mining** and **nuclear** operations

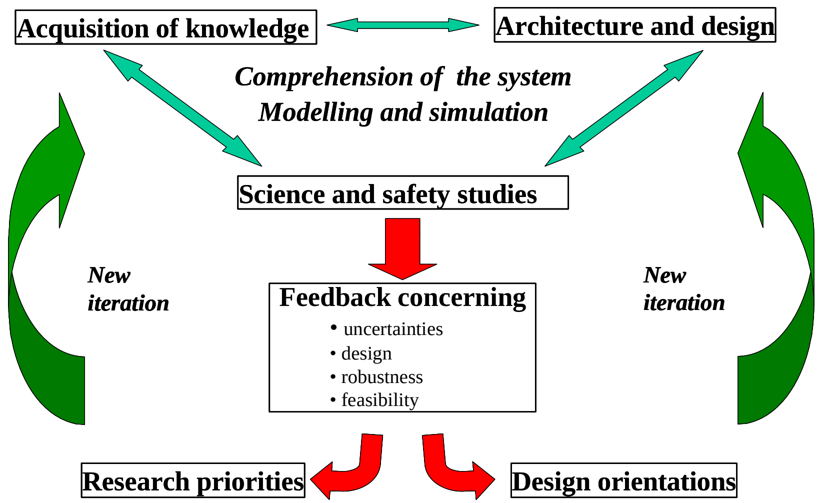
- **A step by step design process with milestones**

Science, Technology and Safety have

✓ To be balanced

✓ To be kept consistent

✓ To merge in an integrated process



→ Milestone 1: From 1991- 2006 – towards a feasibility (Dossier 2005)

→ Milestone 2: From 2006- 2016 – towards a license ("DAC")

ILW-LL Waste in France

- **French nuclear power plant fleet induced waste comes from:**
  - Nuclear power plants (i.e. fuel rods, activated & dismantled structures)
  - Spent fuel reprocessing activities
  - Research facilities

- **An inventory of 200 000 packages with a volume of 80 000 m³**
  - Large variety of type of waste: contents, conditioning, geometry, mass, etc.
  - Large range of dose flow rate: from less then 0,1mSv/h to more than 1 Sv/h

Bitumen sludge (B2)

STE3/STE2

STEL

STEL en EIP

Technological waste (B3)

1000 l shells

CBF-C'2

Stainless steel 500 l

Concrete 500 l

Compacted hulls & ends (B5)

CSD-C

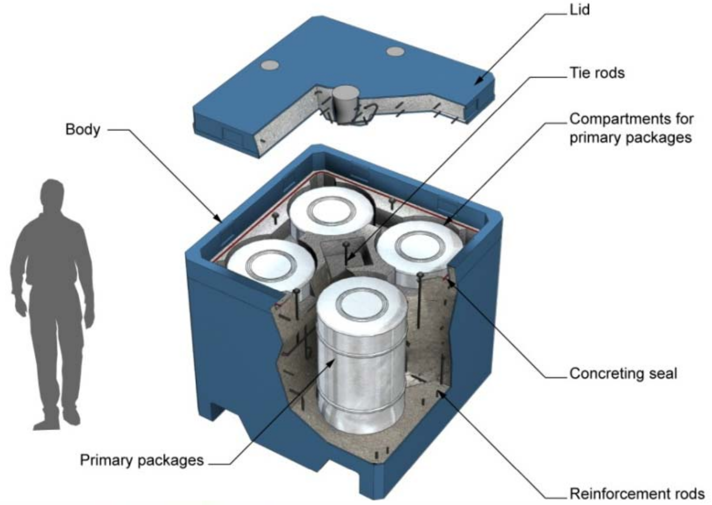
ILW-LL waste disposal package (2005 Andra Report)

- **A standard design**
  - HPC concrete with rebars
  - Prefabricated body and lid
  - Anchor bolts to secure lid to body
  - Capacity : from 1 to 4 packages

- **Mass and dimensions**
  - 6 to 25 tons
  - Width: up to 2,5 m
  - Height: up to 2,5 m
  - Length: up to 3 m

- **Stackable packages**
  - Up to 4 layers in disposal drift

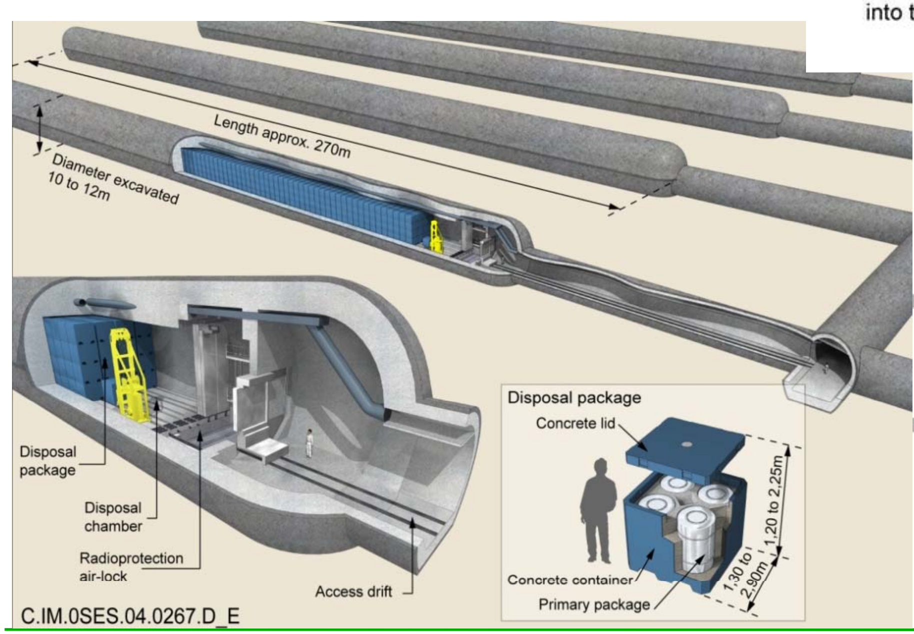
- **Handling by forklifts in a 250m long disposal drift**



ILW-LL handling operations in the facility

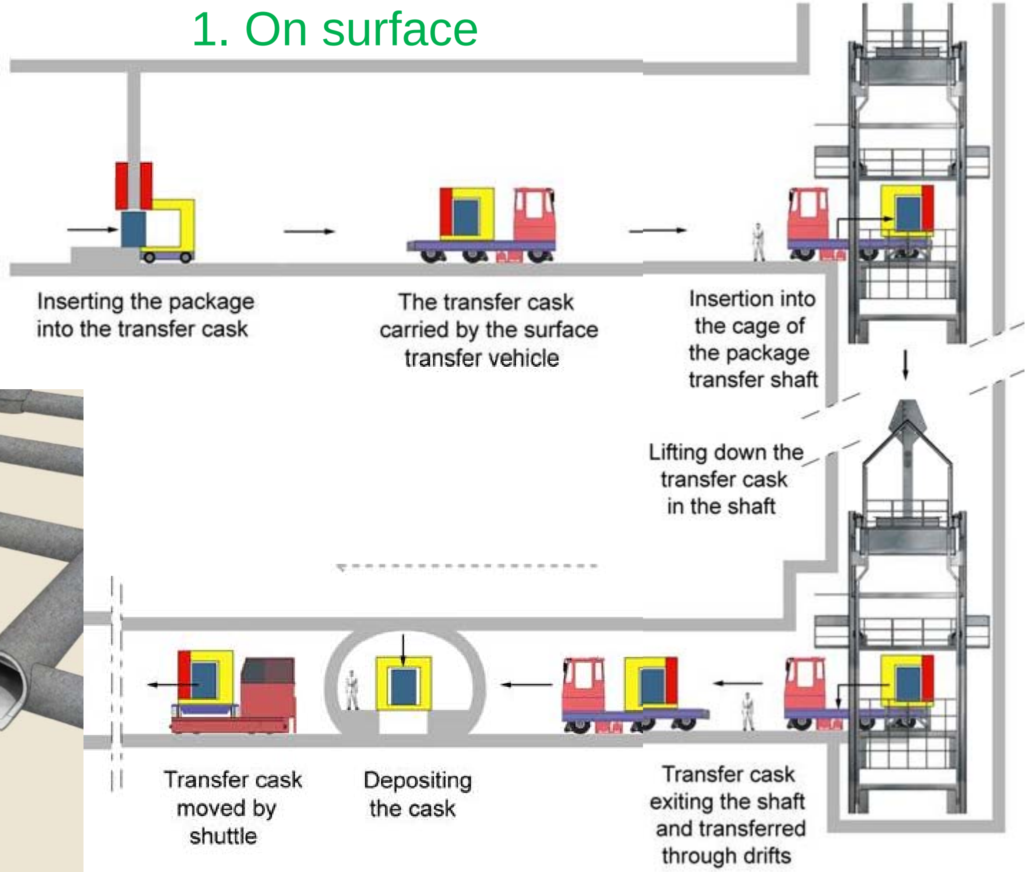
Transfer from surface to disposal horizon and cell

- ILW LL Zone of 80 ha
- 38 ILW LL disposal drifts each 250 m long
- 10 to 12m excavated diameter



2. Shaft or decline

1. On surface



3. Transfer underground

Risk analysis methodology and interaction with design development-1/2

- **The purpose of the risk analysis is to select design options in order to:**
  - Prevent risk
  - Control all risks induced by radioactive waste
  - Take into account risks involving the external environment

- **The main safety functions during the operational period are similar to other nuclear facilities:**
  - Confine radioactivity
  - Protect persons from radiation
  - Provide criticality hazard safety
  - Evacuate residual heat
  - Evacuate gases (radiolysis)

- **Andra's radiation protection objectives are**
  - A fraction of the regulatory limit of 20mSv/y for workers (5 mSv/y)
  - A fraction of the regulatory limit of 1 mSv/y for the public at site boundaries (0,25mSv/y)

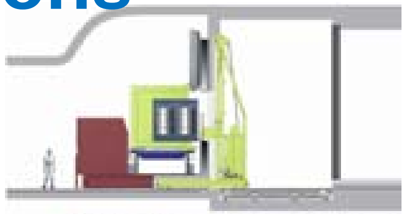
Risk analysis methodology and interaction with design development-2/2

- **There is a need to develop regulatory guidance dedicated to repository design**
  - Surface nuclear facilities regulatory guidance is well developed. It could in some cases be transposed to the repository
  - Specific regulatory basis may prove to be necessary (nuclear and mining environment mix)
- **An iterative process**
  - between **operational** risk analysis and **long term** safety design options
- **And a step by step risk analysis for operational safety:**
  - From a description of the transfer process; inventory of hazard sources involving any product, equipment and process being used
  - Qualitative characterisation of risks (description, likelihood, severity, etc.)
  - Proposal of risk-limiting measures: prevention, mitigation
  - Identification of accidental scenariis to be quantified
- **The demonstration combines**
  - the use of proven methodologies (risk analysis)
  - and the robustness based on feedback of expertises in the different technical fields, such as nuclear facilities.

Radiological risk in normal conditions

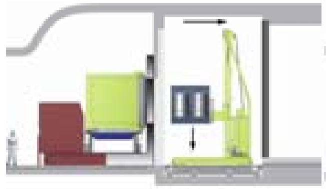
- **Main risk** : **external exposure** of personnel (in operation and in maintenance)
  - Waste disposal package dose flow rate range (at 1m):
    - 1,6 Sv/h for hulls & ends (B5)
    - 47mSv/h for bitumen sludge (B2)

    ⇨**Need for radiological protection (transfer cask, shielded doors, …)**
- **Transfer cask shielding design : less than 3µSv/h at 1 m**
- **Automated process in the disposal drift**



Opening the cell/transfer cask doors ar taking up the package with the forklift tru

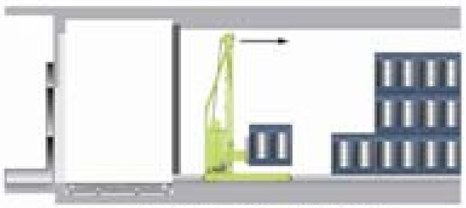
1) Opening of cask shielded door
   - Cask with an automatic shielded door (opening when docked)



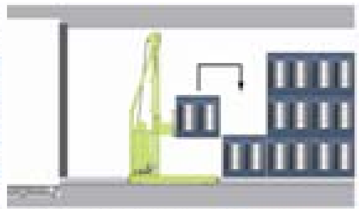
Moving the lifting machine to the moveable floor and lowering the package

Rotating the lifting machine on the moveable floor with turntable

2) Move & rotate the lifting machine
   - Easy access to equipment in the radiation protection chamber (when free of package)
   - Set a very low failure probability (redundancy of actuators)

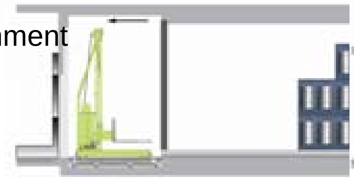


The lifting machine travels with the package in low position

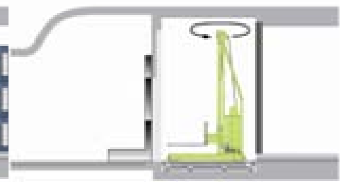


cing the package in the disposal cell

3) Travel in disposal cell
   - Cinematic chain with a 10^{-8}/h reliability factor
   - Provide means to repair the failed equipment in an irradiation free environment
   - Use of a specific towing machine for machine recovery in case of failure



Returning the lifting machine to the moveable floor



Rotation and restoring its initial position

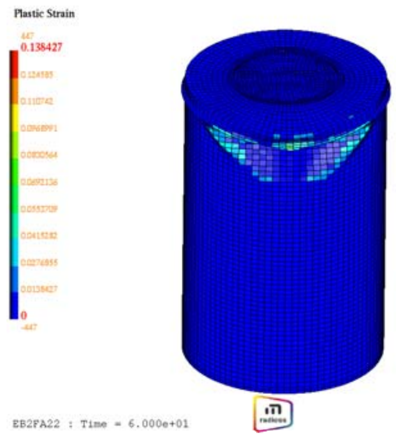
4) Way back

Waste disposal package drop risk

- **Prevention design features on the lifting machine for the handling process**
  - Ensure a good stability of the package on the lifting system
    - Design of a specific frame for a better location of the centre of gravity
  - Transfer of package in lowered position through the disposal cell
  - Redundancy of components for drop prevention
    - such as cinematic chain, brakes, safety sensors
  - Step by step monitoring of package emplacement and stacking

- **Analysis of a drop event**
  - Worst case: **a 6m high drop on the lid**
    - Three drop scenarios: falling onto a flat surface, on an edge, on a corner
    - Alignment of the centre of gravity in order to maximize the damages
  - The design objective is primary package integrity
    - For this objective the **corner drop** appears to be the severest scenario
  - Drop consequences analysis: **satisfactory**
    - Combination of drop tests and simulation analysis
    - Full scale drop tests in 2005 on hulls and ends (B5) and bitumen sludge (B2) disposal package (resp 12t and 6t)
    - The disposal package showed cracks but stayed in one piece and provided protection for the primary package

Waste disposal package drop risk



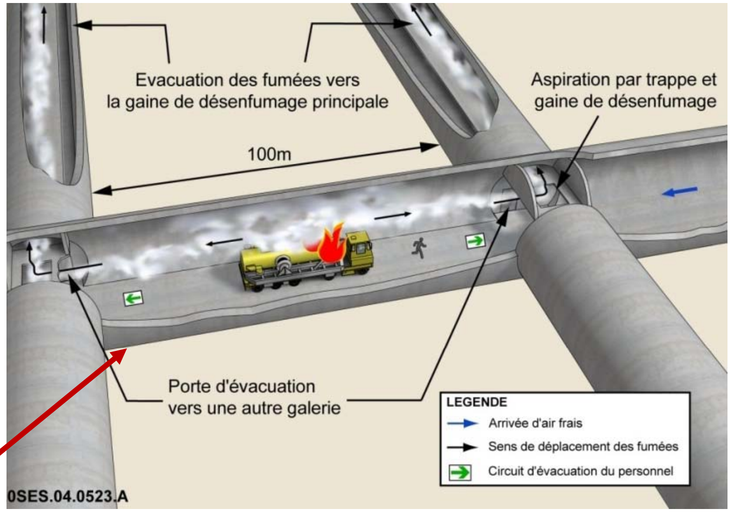
- **Dossier 2005 : Drop mitigation: requirement for ventilation system design**
  - Feasibility studies ⇔ no loss of containment of radioactive material
  - Accidental scenario ⇔ loss of containment and contamination of the air in the repository cell => The ventilation system has to provide an isolated return air circuit to the exhaust shaft with a dynamic leak proof design in the disposal cell and HEPA filters
- **Design orientations for further studies**
  - The drop accident gravity is acceptable: the forklift handling design is acceptable
  - However a new design objective is set for **handling equipment**
    - to reduce the gravity of such event
  - **Nuclear ventilation design**: a key issue for future studies

Hydrogen explosion risk

- **Hazard sources identification**
  - Gas generation mainly by radiolysis of organic materials or water of concrete matrix
    - 90% of gaseous release is hydrogen
  - Design flow rate: 10l / waste package/ year
    - In bitumen disposal cell: 10 000 drums, 100m^3/year, 274l/day
- **Measures in the disposal package: dilution**
  - Prevent hydrogen accumulation in the disposal package by dilution
  - Design objective: limit the hydrogen concentration to less than 2%
  - Two **design options** are envisaged :
    - Use a specific HPC concrete with a guaranteed minimum porosity value (under wet conditions, with a maximum thickness of 15cm and a 60MPa HPC concrete, according to CEA studies)
    - Provide the disposal package with hydrogen vents or exhausts paths at the lid junction
- **Measures in the transfer cask: dilution or recombination**
  - 2005 **design option**: Provide for door clearances or vents to dilute hydrogen
  - New **design option:** Use small hydrogen recombining devices within the cask
- **Measures in the disposal cell : dilution**
  - Prevent hydrogen accumulation in the disposal cell by dilution
  - Air flow of 3 m^3/s in the 250m long cell: air renewal rate of 5/hour
  - **Analysis of ventilation failure consequences:**
    - With average values of gas emission, the explosive limit of 4% is reached in only 30 days
    - Satisfactory result in connection with a moderate mean gas flow rate emission value
- **Measures during sealing phase of the disposal cell**
  - **Need to maintain ventilation operating** as long as possible during the first stages of the sealing process
  - Final stage of sealing will be well below the 30 days limit
  - Post closure situation should not cause explosion risk in the access drift:
    - The drift is ventilated
    - The disposal cell is isolated by a concrete retaining plug

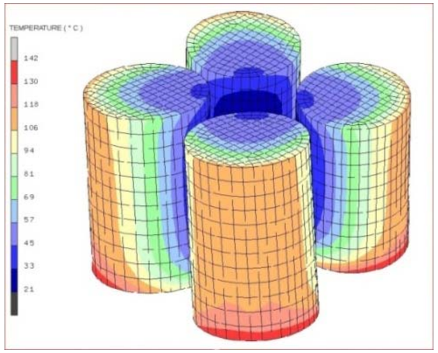
4.2 Risk in accidental conditions

Fire hazard in underground installations

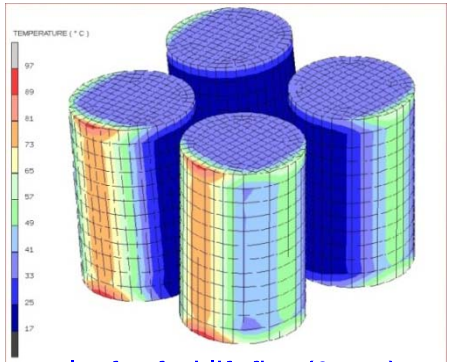


Design recommendations are driven by the analysis:

- **Prevention design features**
  - Minimize the amount of calorific load available for a fire
- **Worst waste package case: bitumen waste**
  - maximum temperature needs to be < 120°C
- **For the transfer vehicle underground (shuttle):**
  - Use of a self propelled electric transport vehicle on tires
  - Preliminary study in order to determine cask thermal protection for the disposal package
    - Fire breaks out and spreads in connecting drift
    - Road tunnel study centre fire (15Mw x 1hr) based on envelope of vehicle characteristics
- **For the forklift during waste emplacement in the disposal cell**
  - Use of a self propelled electric vehicle on rails
  - Electrically caused fire implying batteries and motors
  - Normal ventilation at $3m^3/h$
  - Fire of 3MW, ½ hr duration, based on vehicle characteristics
  - Design option:
    - isolate the disposal package from the batteries rack with a 2cm thick thermal shield
  - Satisfactory results



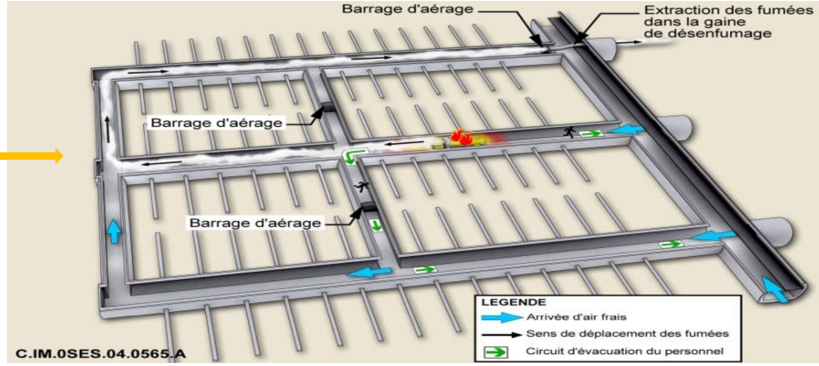
Results for transfer vehicle fire (15MW)



Results for forklift fire (3MW)

Risk Analysis – Overview of results

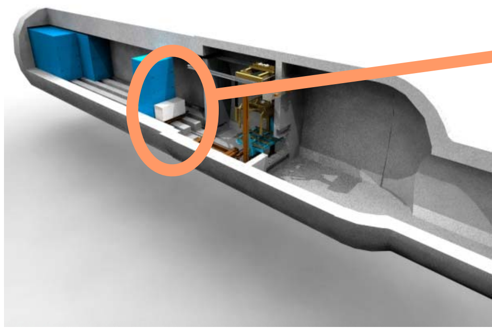
- ❑ Fire Hazard
  - Architecture to permit personnel escape
  - Personnel Training
  - Nuclear ventilation in ILW disposal cells

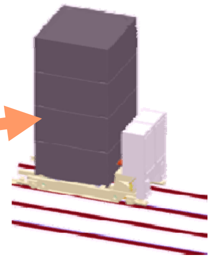


- ❑ Explosive Gases (most of ILW wastes) - Nuclear ventilation in ILW disposal cells and ventilation characteristics

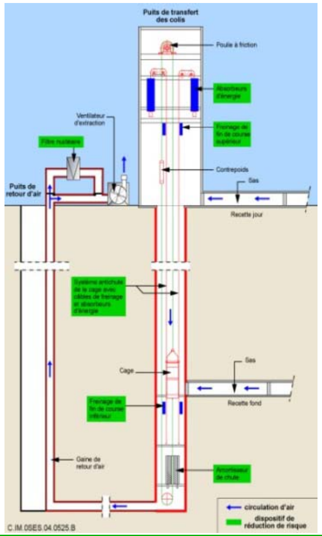
- ❑ In Cell "Fall" – ILW waste packages' drop risk in disposal cell

A new Option





- ❑ In Shaft "Fall" – Two new options => Ramp or Decline



- ❑ Criticality – Geometry constraint

Synthesis and the way forwards

- ❑ No elements that jeopardise the technical feasibility
- ❑ Robustness and demonstrability: Results to be further confirmed by tests on demonstrators (drop test for ILW package, handling test for HLW & ILW packages, etc.).
- ❑ Alternative options remain to be investigated on safety grounds :
  - Transfer of packages by shaft, or decline, or steep ramp (operational risks versus post closure hydraulic effect)
  - Emplacement of ILW packages (handling equipment and drop risk)
  - Ventilation and closure of disposal cells for ILW packages in relation to the presence of hydrogen,
- ❑ …with a challenging issue: Balancing operational and long term constraints
  - Layout of underground ILW-LL installations : Dead end or once through disposal cell? (operational ventilation versus Long term hydraulic circulations)

Towards the licensing phase

Key milestones defined by the French Act of June 2006

- ✓ **Mainly** ILW, HLW
- ✓ Reversibility
- ✓ 2012 – Public debate
- ✓ 2015 : Application for license
- ✓ Reversibility to be prescribed by a future Act
- ✓ 2025 : Disposal commissioning

The challenge goes on !