Operational Safety in the underground facilities of a deep geological disposal of nuclear waste

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General presentation

Cigéo Project

2012 Preliminary design

Radioactive waste to be disposed of in underground disposal facility

59 French nuclear reactors

Processing of spent fuel

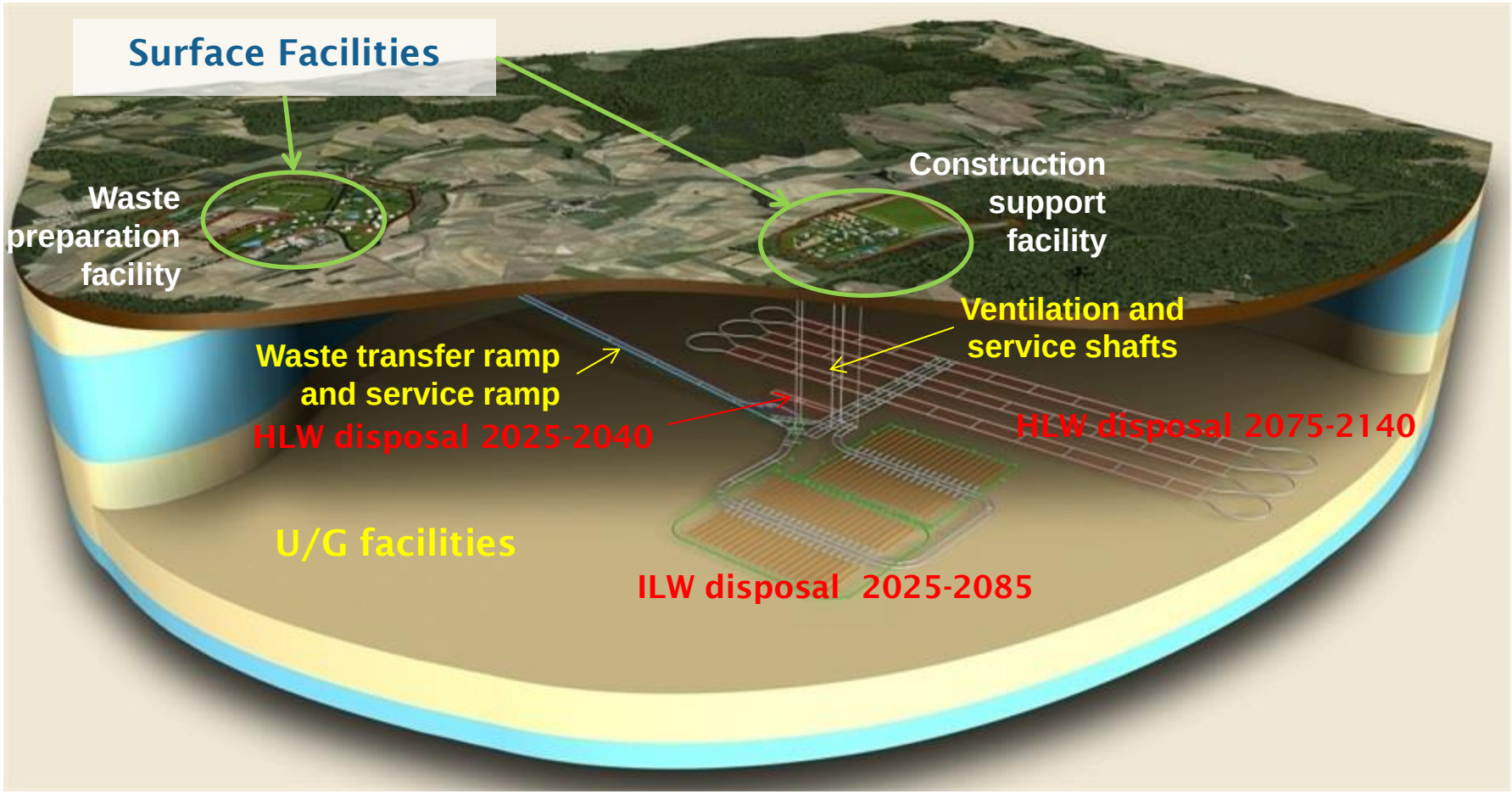
HLW: 10,000 m³

IL-LLW: 70,000 m³

Technology waste, research activities and legacy waste

A variety of waste types

The underground facility is hosted 500 m deep in thick argillite (hard clay) formation



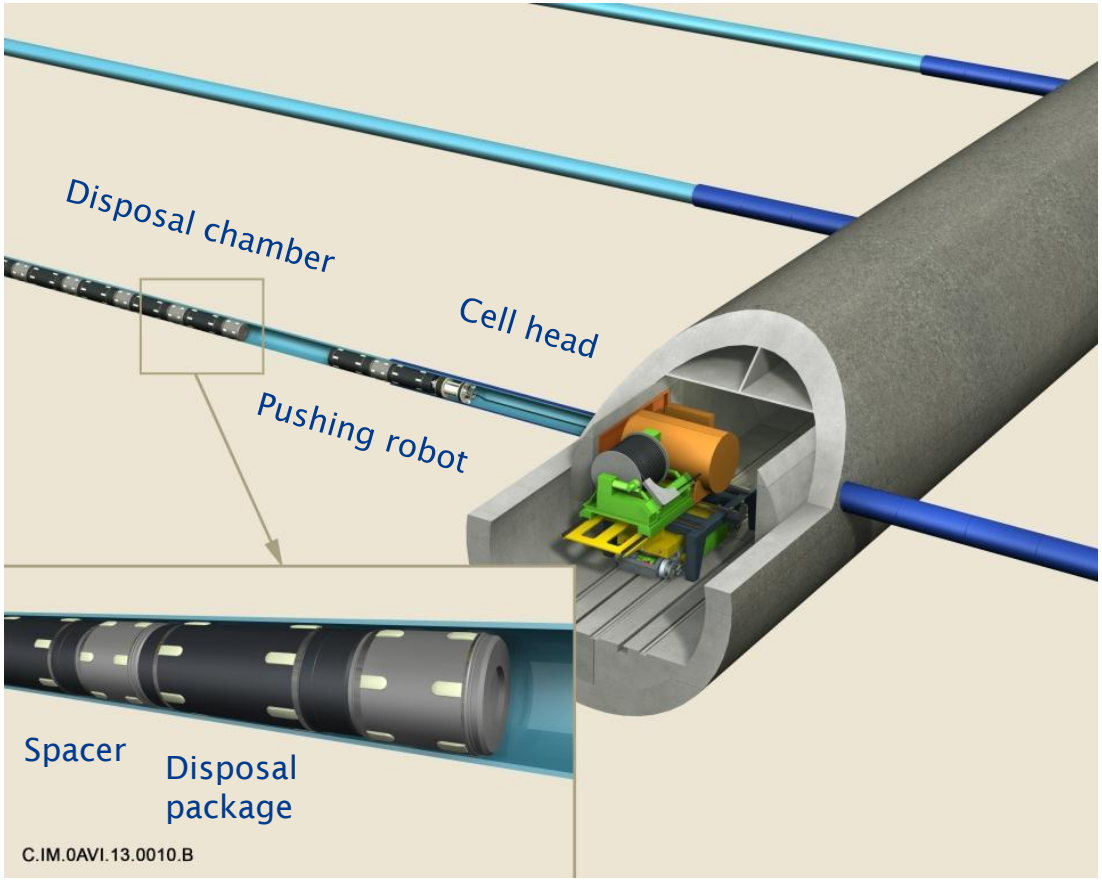
2012 Preliminary design

HLW disposal packages

High Level Waste (HLW) will be placed in thick steel overpacks

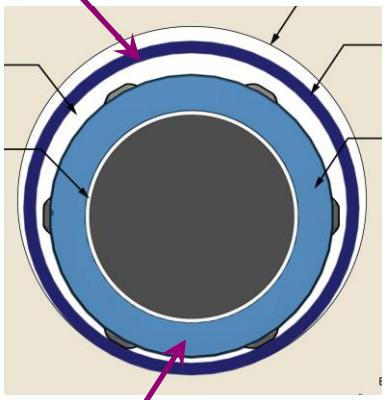
HLW Disposal Cells

High Level waste (HLW)will be disposed of in steel lined micro-tunnels



Excavation
Ø 0,70 m

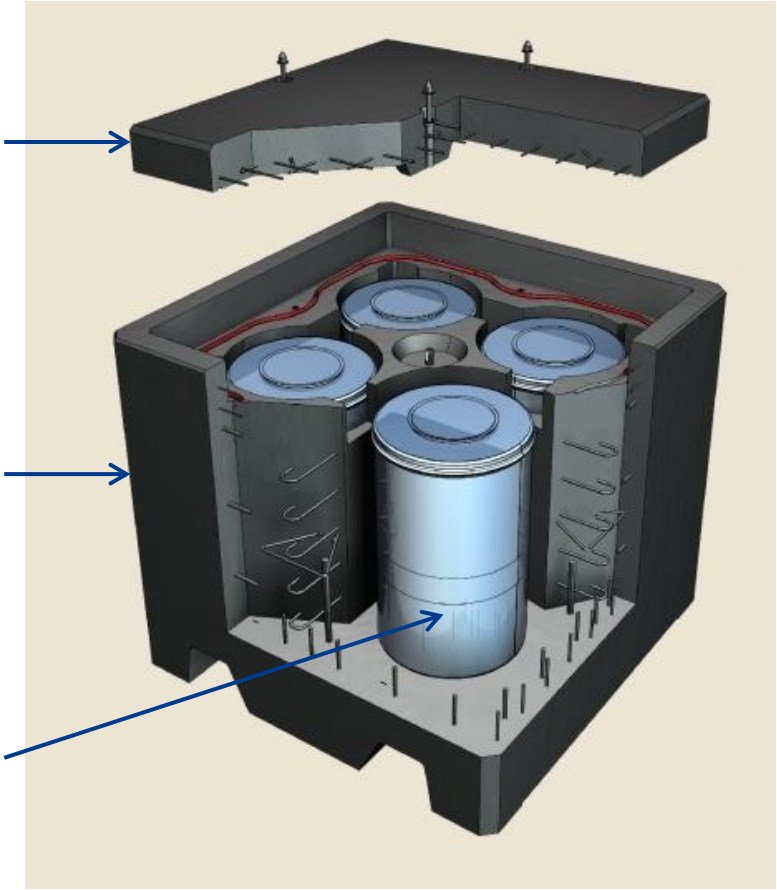
Steel sleeve



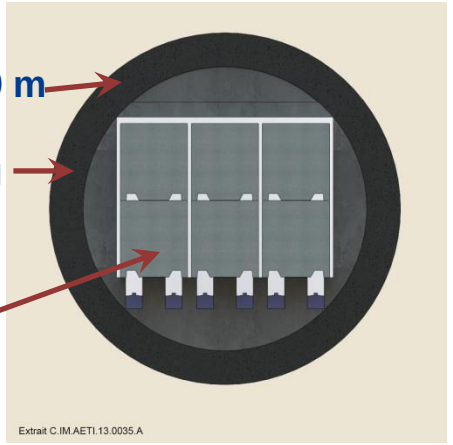
Steel overpack

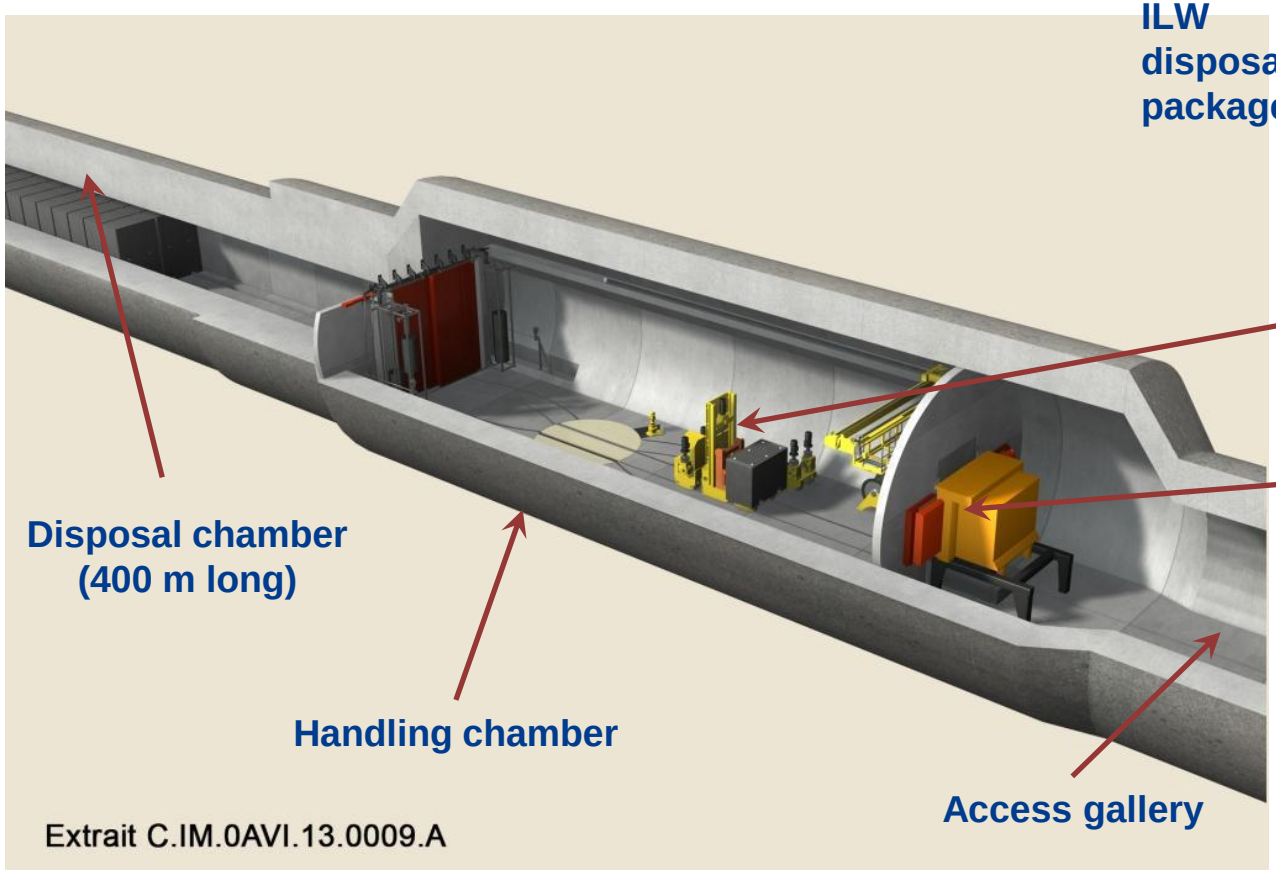
IL-LLW disposal packages

Intermediate Level – Long lived Waste will be placed in precast reinforced concrete containers



IL-LLW will be disposed of in horizontal tunnels





Construction and operation

Cigéo Project

Cigéo is a unique project

Large underground facility (120 km tunnels, 160 km microtunnels)

Will be constructed, operated and closed over a very long period (~120 years)

Construction and operation will take place simultaneously

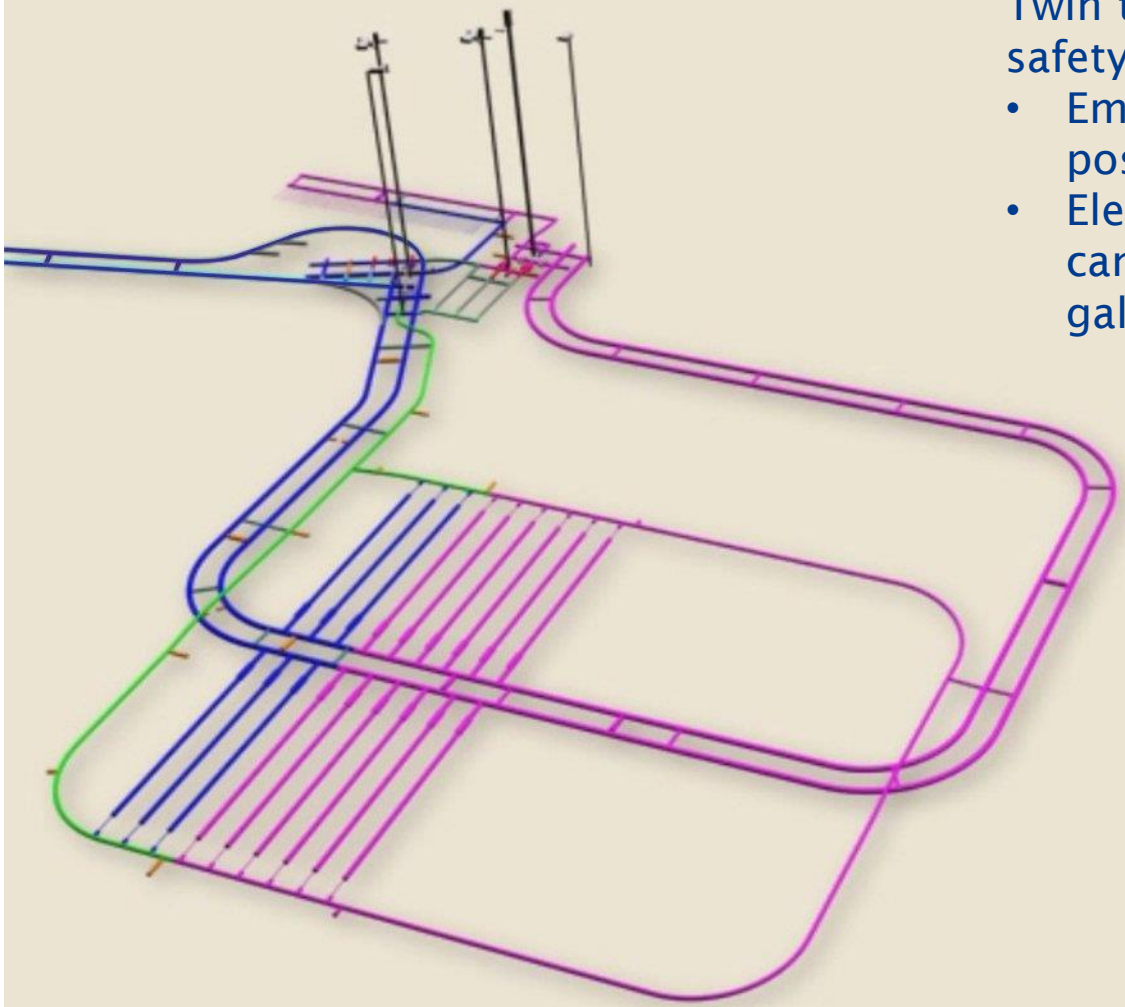
Operation is a nuclear operation with highly radioactive material (use of steel shields >10 cm thick)

- **Reversibility**
  - Ability to retrieve waste packages for at least 100 years
  - Step by step, flexible development

Main design principles

- **Each category of waste in a separate zone**
  - HLW
  - IL-LLW
- **Keep construction area and operation area separate**
  - Separate access facilities
  - Separate power and information network
  - Separate ventilation system
  - Generally speaking, an incident in one area should have minimal consequence on the other area

Development of project



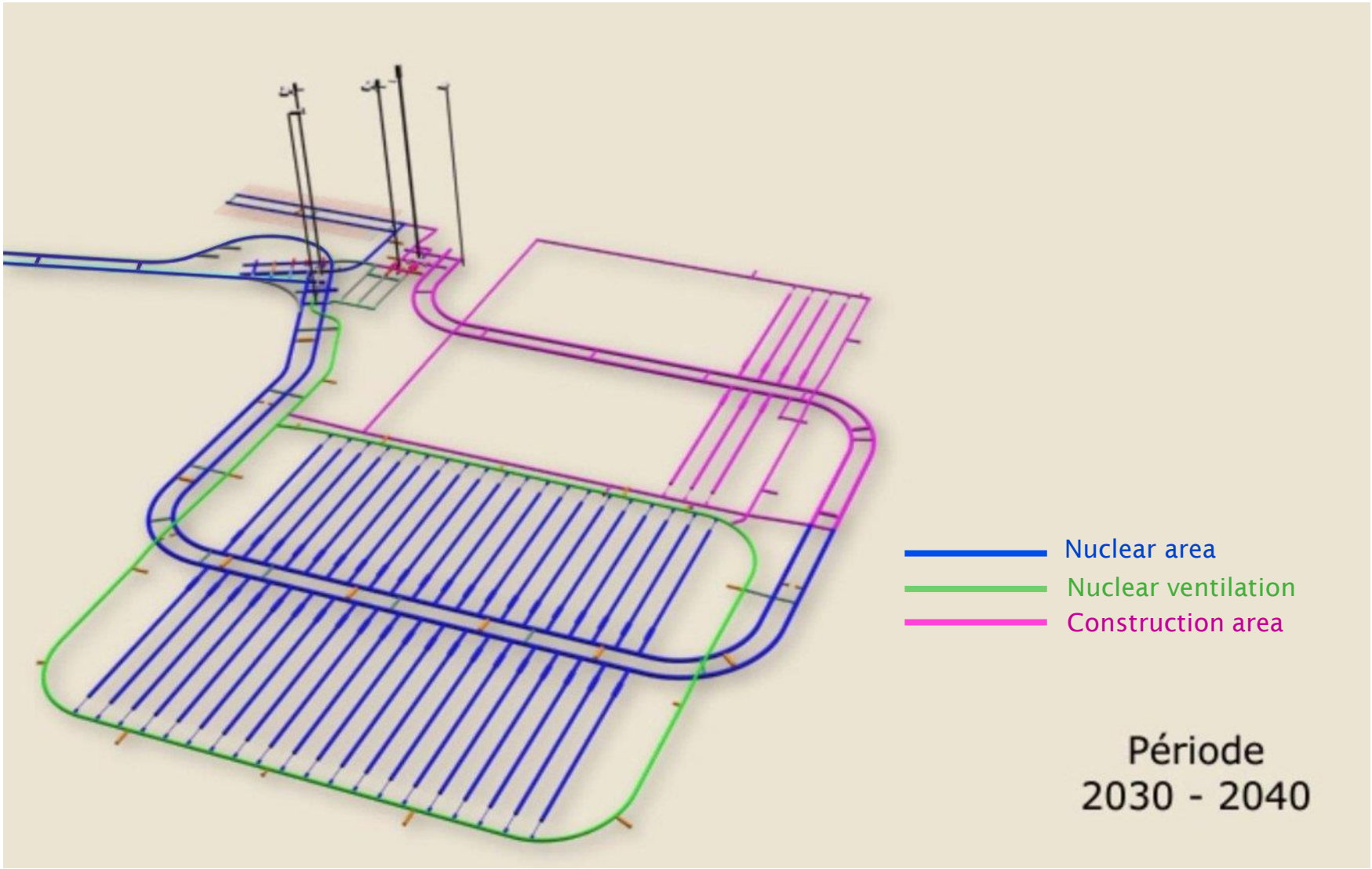
Twin tube design for higher safety and service

- Emergency access and exit possible within each area
- Electrical and data network can be doubled in separate galleries

Nuclear area
Nuclear ventilation
Construction area

Période
2025 - 2029

Development of project



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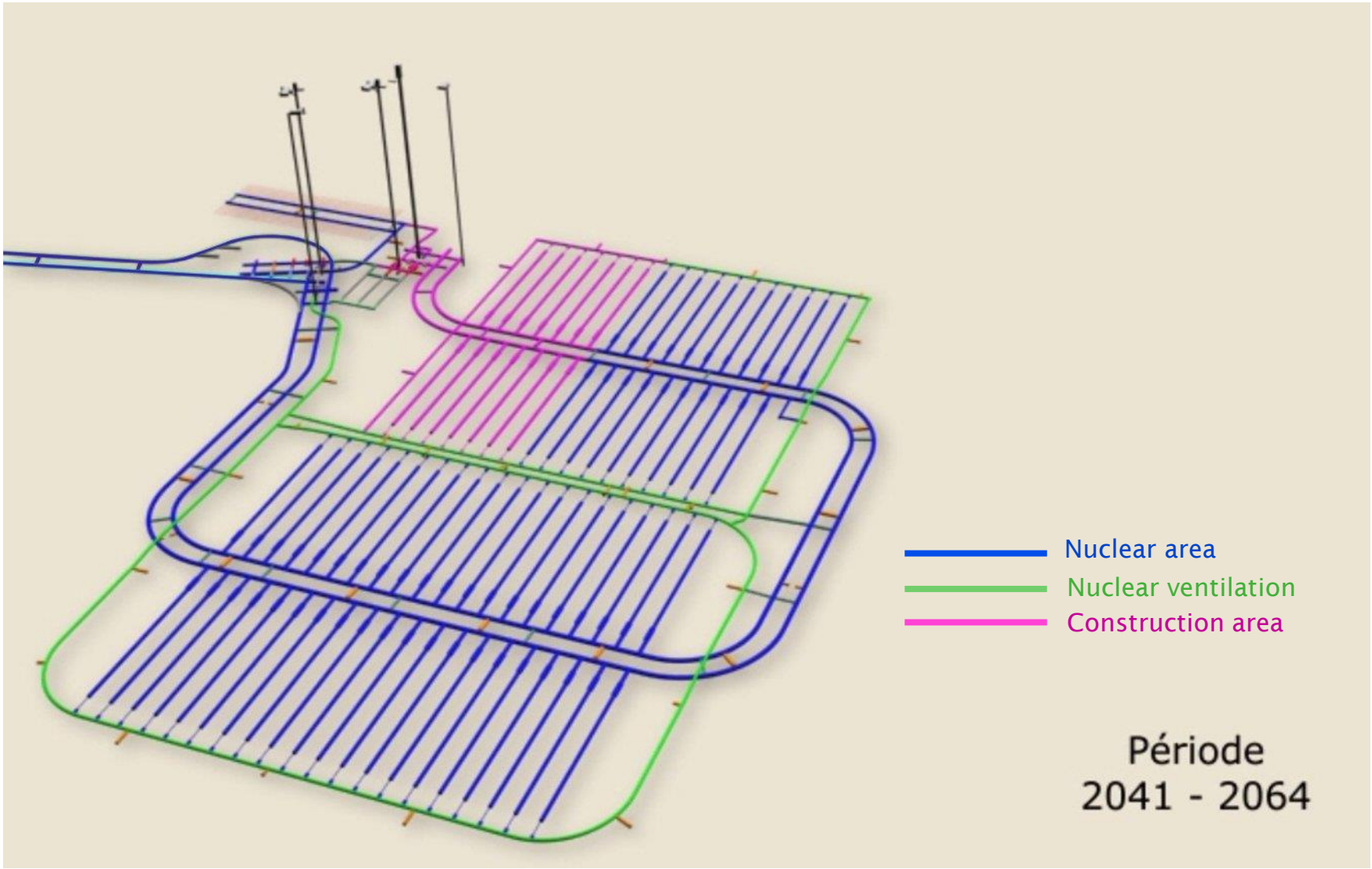

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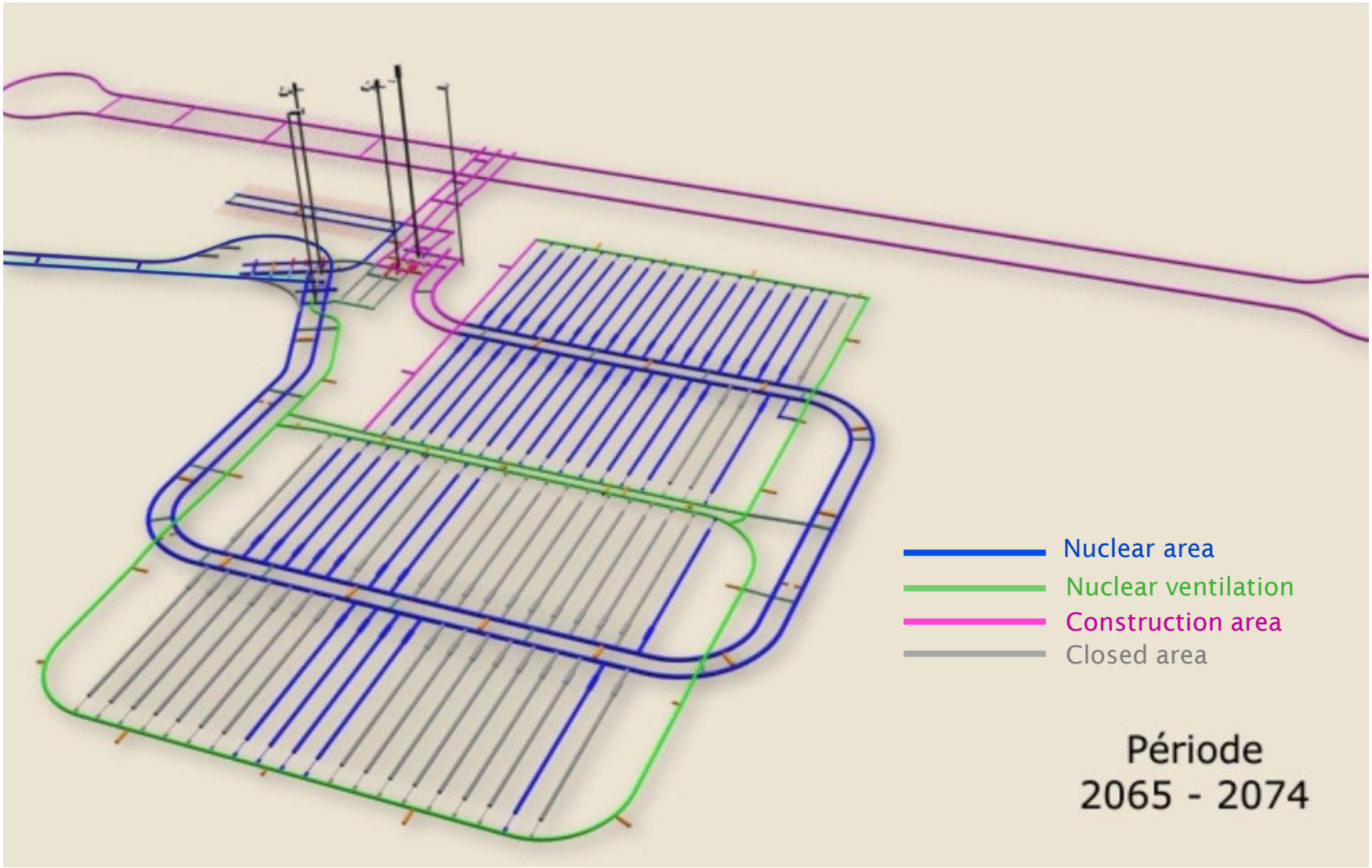

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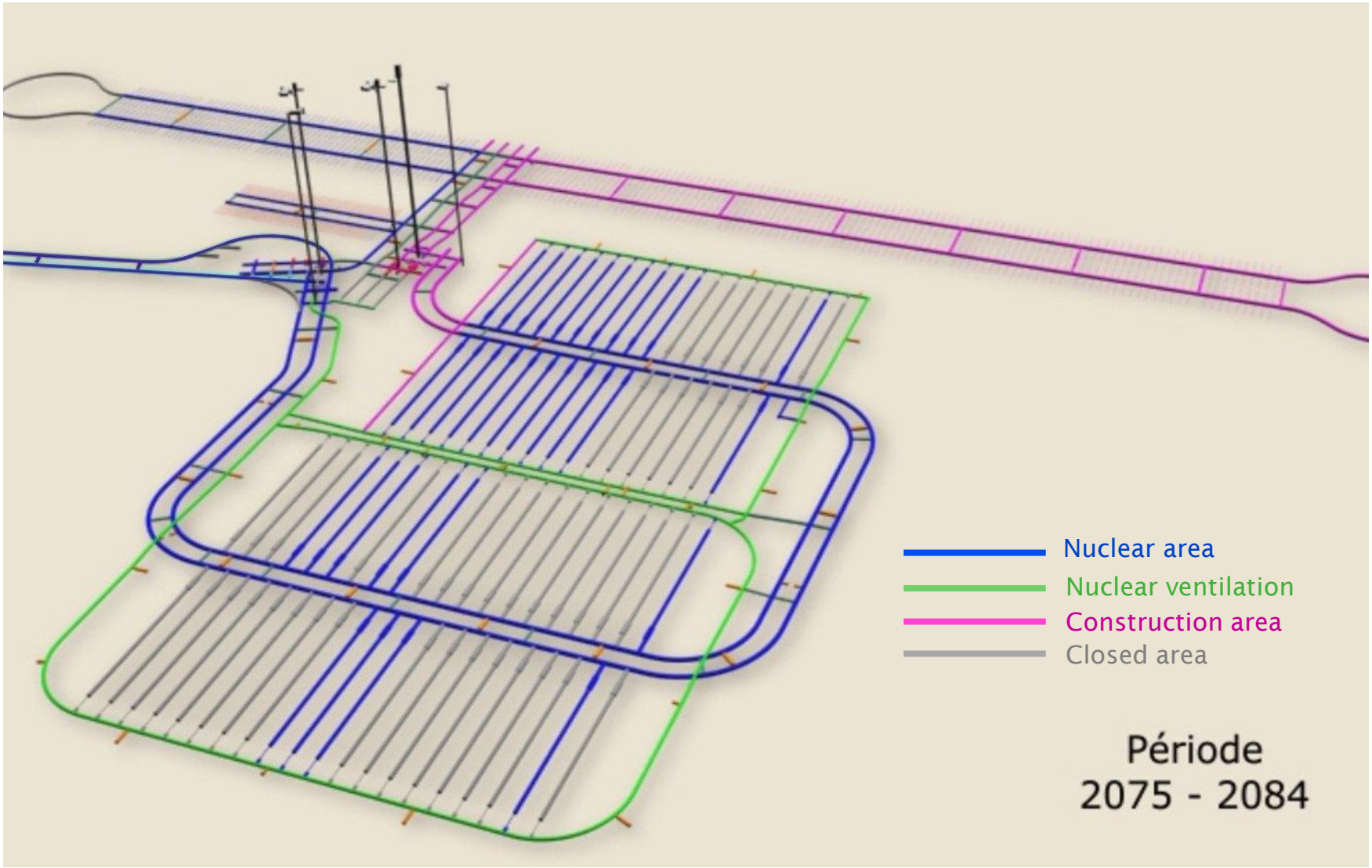

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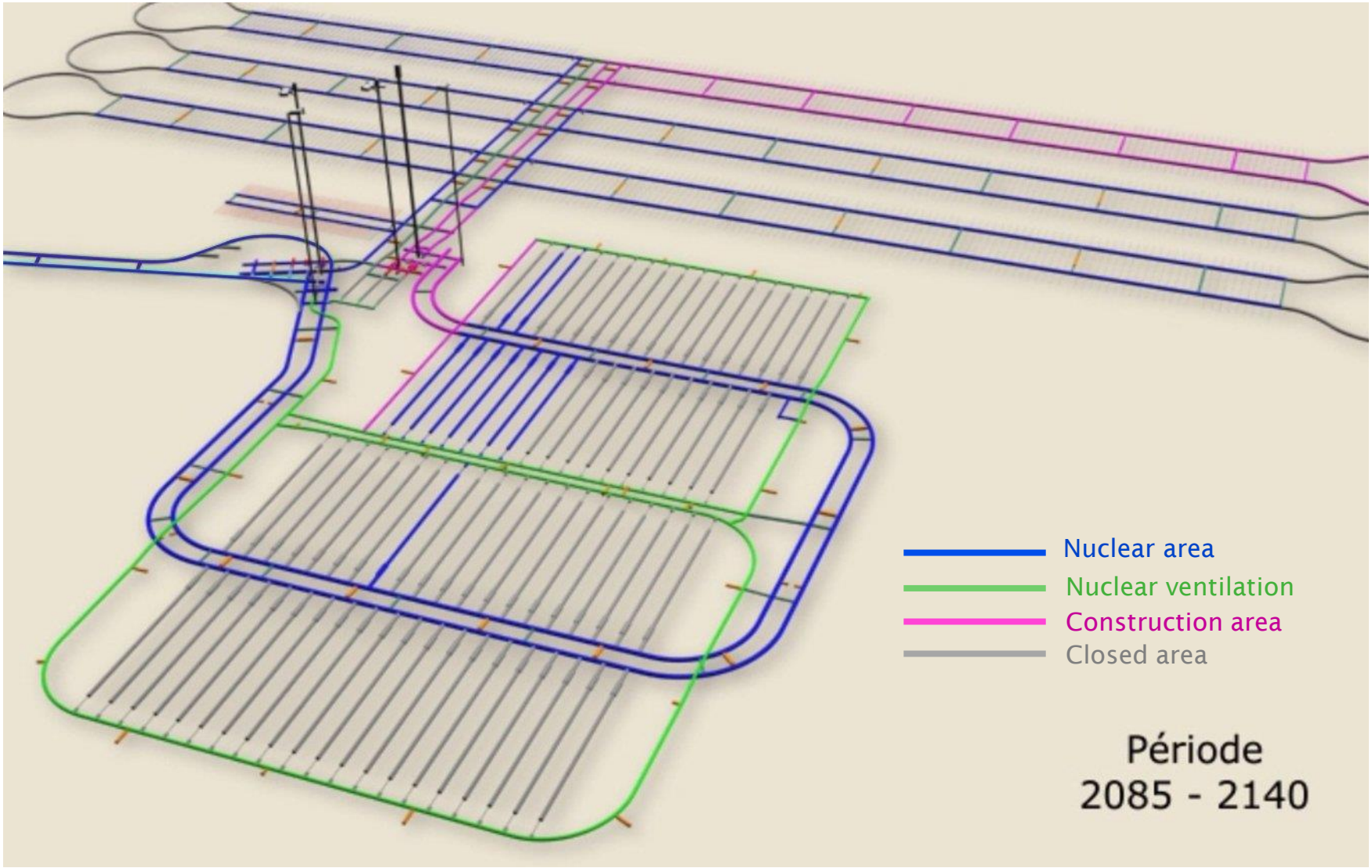

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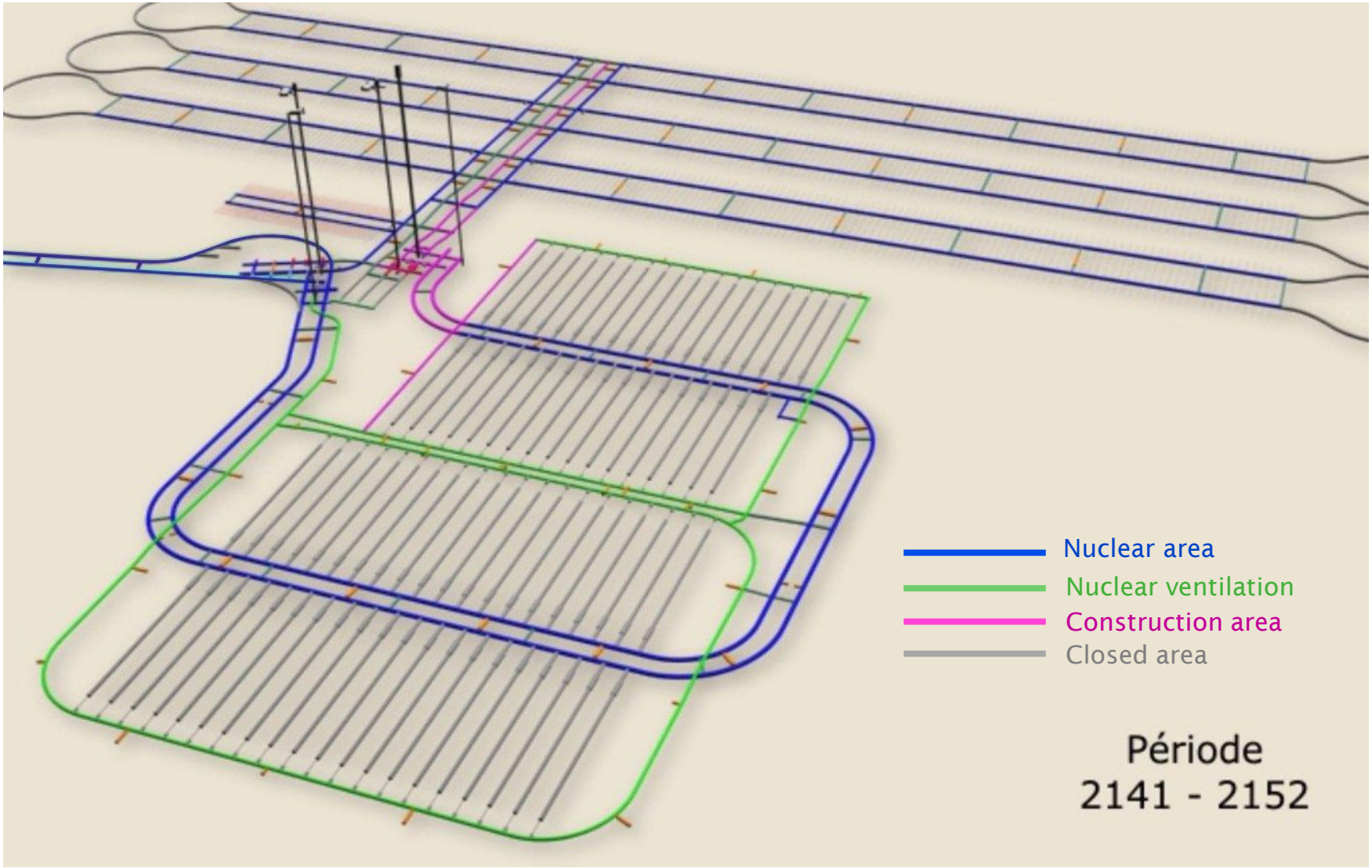


Operational Safety

The Cigéo Andra Fire Guidelines

The fire risk : Cigéo fire guidelines

- **Two apparently "divergent" approaches :**
  - Nuclear approach
    - Fire + presence of Toxic, Radioactive, Flammable, Corrosive, and Explosive products
    - => Fire barriers and confinement to prevent contamination by dangerous products
  - Underground construction/tunnel approach
    - Fire + presence of persons
    - => Smoke extraction to allow evacuation of persons and action of firemen
- **No existing regulation covering all aspects of Cigéo fire risk**
- **Necessity of reconciling these two approaches to draw up the Cigéo fire guidelines**
  - The guidelines have been set up by Andra with the contribution of fire experts from nuclear operators (AREVA, CEA, EDF) and from various bodies including the institute for industrial risks (INERIS), the center for tunnel studies (CETU) and firemen.

Objectives and Functional Requirements to be reached

Objectives

- OS 1: Protection of the live and health of the persons present in the installations
- OS 2: Preservation of the environment (including protection of the nearby population)
- OS 3: Maintaining safety functions
- OS 4: Maintaining the industrial activities and the installations

Declined into sub-objectives and associated requirements

Performance criteria are proposed for each of the identified requirements

Wherever possible, a specific reference value is used.

- It is issued from
  - Applicable regulations, if available,
  - Or the other guideline texts,
  - Or the feedback from experience and the experts' opinions.

For example

- Requirements in connection with personnel
  - possibility of evacuating,
  - distance of evacuation (400m maximum),
  - fire resistance of the galleries
    + *more than the evacuation duration in terms of structures resistance, flame and warm gas tightness*

In the absence of complete applicable regulations, all theses reference values will have to be justified to the regulators (Nuclear Authority, Civil Protection Authorities)

Further Requirements to Take into account the Specificity of the Cigeo Underground Installations

Apply the principle of *defence-in-depth* commonly used in the nuclear industry

1st line of defence : minimize the risk of any start of fire and its spreading :

- Limitation of the fire load when designing the fixed and mobile equipments,
  - For example, transfer of nuclear waste using
    - + *Cable car in the ramp*
    - + *Electrically powered Rail system in horizontal galleries*
- Limitation of the areas having a high fire risk
  - For example limitation of underground maintenance shops and storage areas as much as practically achievable

2nd line of defence : detection of fire and early fire fighting :

- Implementation of detection devices as close as possible to the potential hazard sources (in order to have a reduced time of reaction)
- Implementation of fire-fighting systems to limit the spreading of fire
  - For example, in board automatic fire fighting system on vehicles

3rd line of defence : control of fire and limitation of its consequences :

- To be implemented according to the reference fires and the selected “envelope” scenarios :
  - Ventilation and smoke extraction systems, managed from a central control room
  - Presence of fire compartments, especially for areas entailing a risk of radioactive substances dispersion or for areas presenting a major fire hazard
    - + *electrical rooms for example, which feature major fire loads and ignition sources*
  - Presence of passageways to evacuate persons and to enable access for fire-fighting and rescue teams

Ventilation

Cigéo Project

Design Principle Applicable to Ventilation

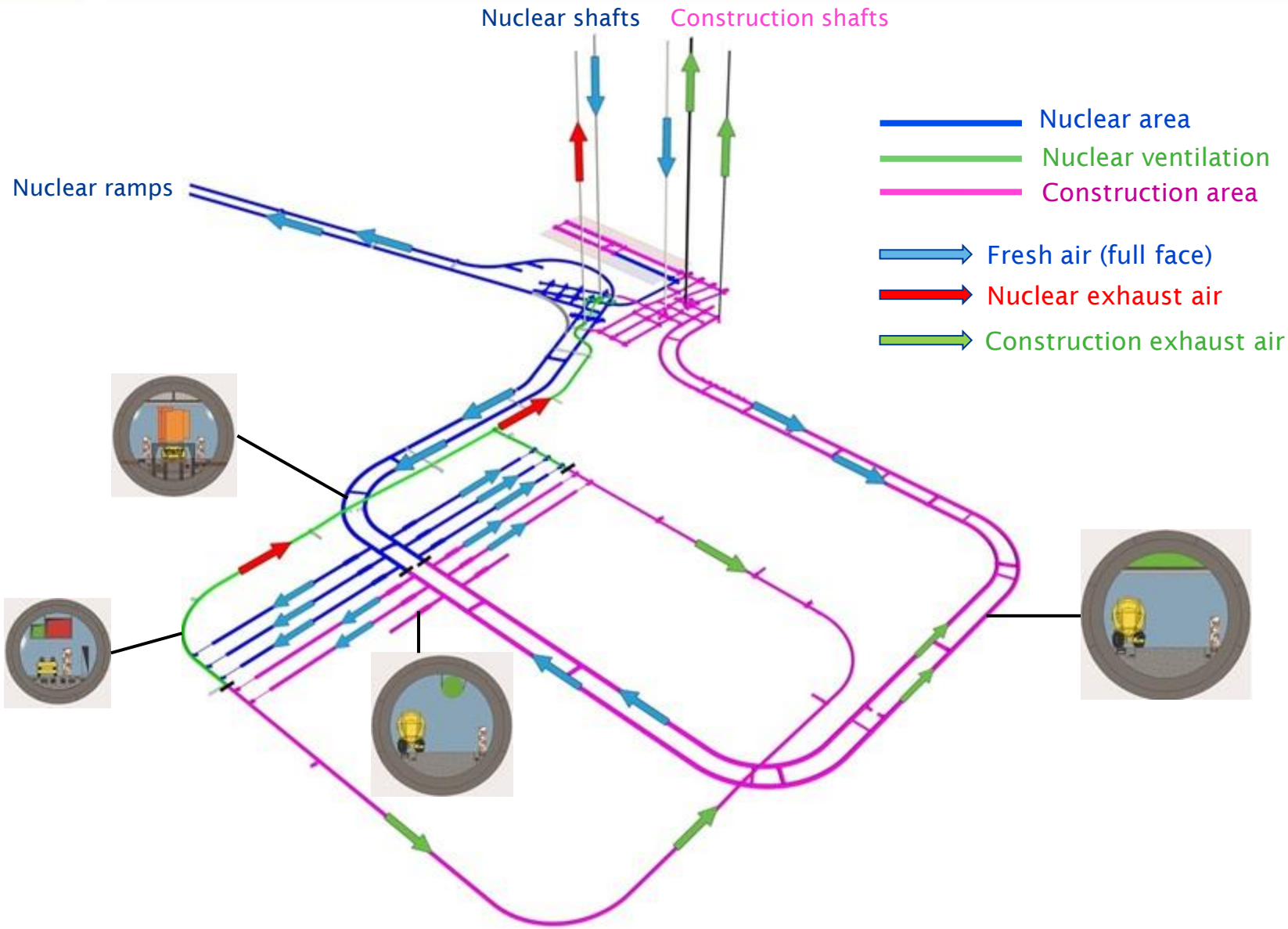
- **General**
  - Separation of ventilation flows between « construction area » & « nuclear area »,
  - Main ventilation plants near the head of shafts and ramps,
  - IL-LLW* Disposal Cells have been classified « Containment Class C2*** » as a function of the risk of accidental dispersion of radioactive material
    - → filtration and separation (air duct) of ventilation flows exhausted from the cell

- **In normal operation**
  - "nuclear area":
    - air intake provided through full section of galleries
    - air exhausted through air duct (HLW** zone) or dedicated gallery (IL-LLW zone)
  - "construction area":
    - air intake provided through full section of galleries + secondary air ducts
    - air exhausted through air ducts

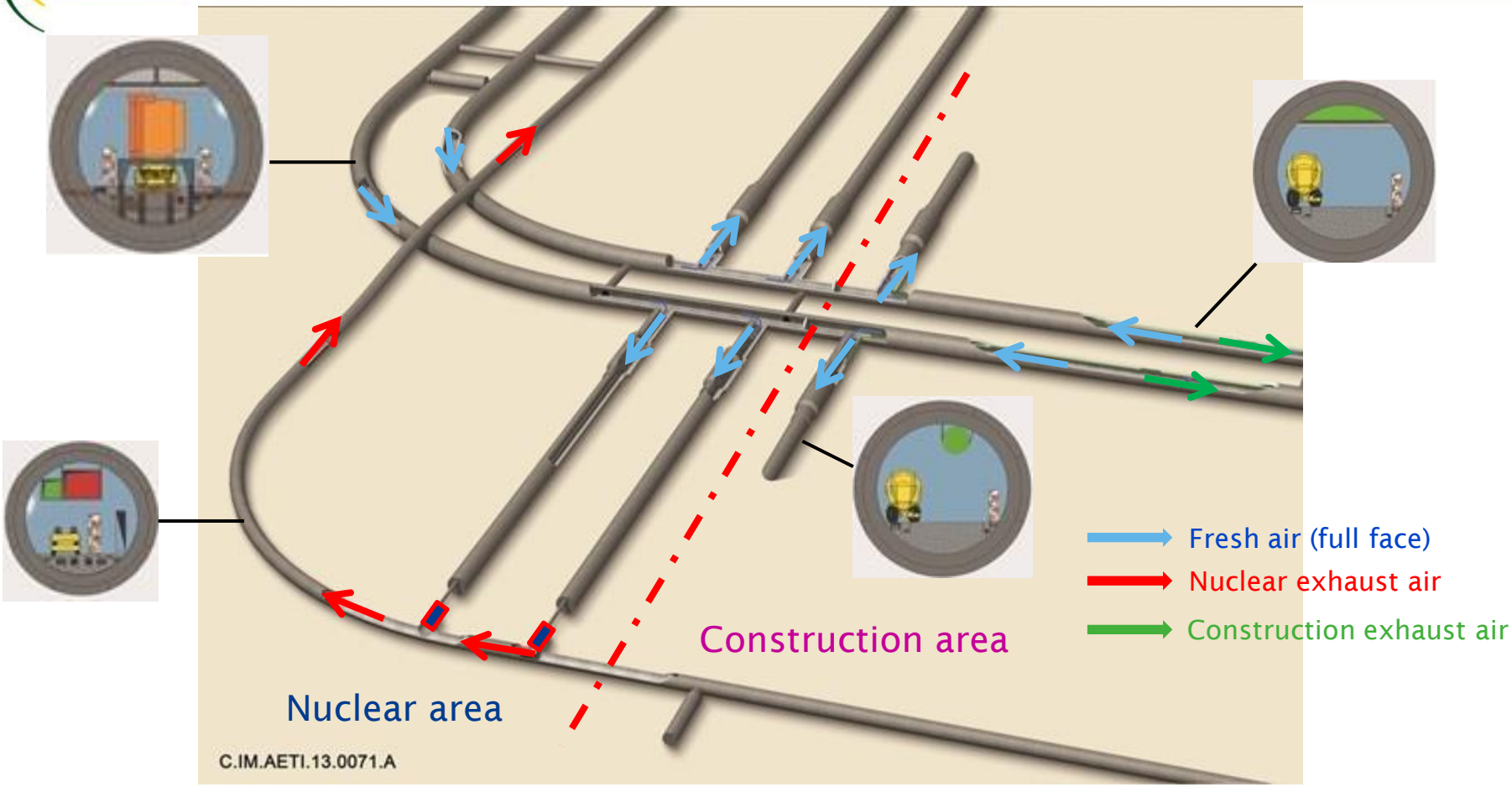
- **In case of fire**
  - Underground design includes patterns of parallel galleries. These galleries are interconnected, thus providing a smoke free escape route to the personnel and access for firefighting and rescue operations.

**Intermediate Level Long Life Waste,*
***High Level Waste.*
****Containment Class C2 implies the use of HEPA (High Efficiency Particular Air) filters*

Ventilation General Design (nuclear and construction areas)



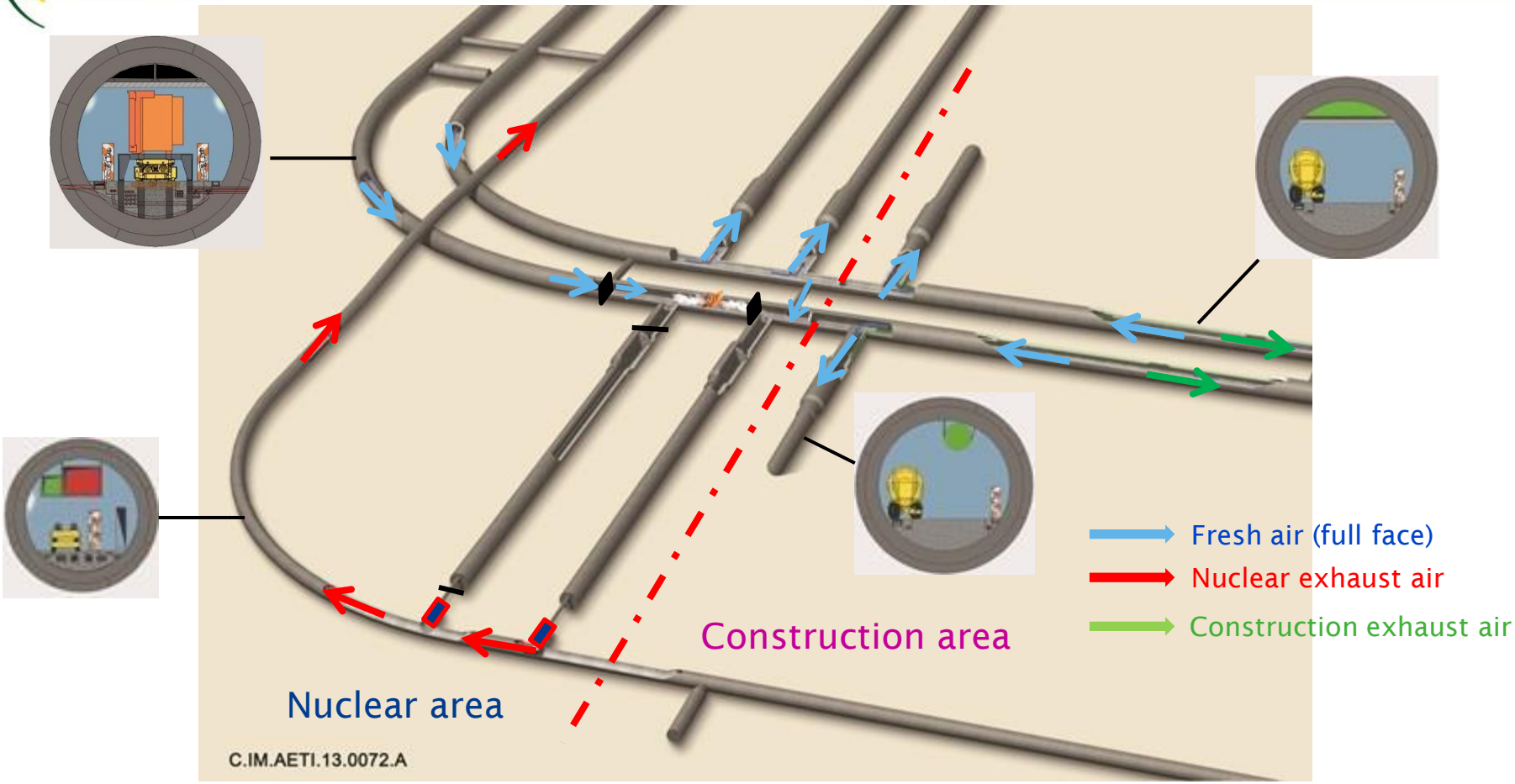
Ventilation in normal operation in IL-LLW zone (nuclear area and construction area)



- Separate air flows for Construction area and Nuclear area
- Full section ventilation
- Air from the disposal cell cleaned by HEPA[1] filter
- Air exhausted through ventilation gallery surrounding the disposal zone & linked to a central exhaust air shaft

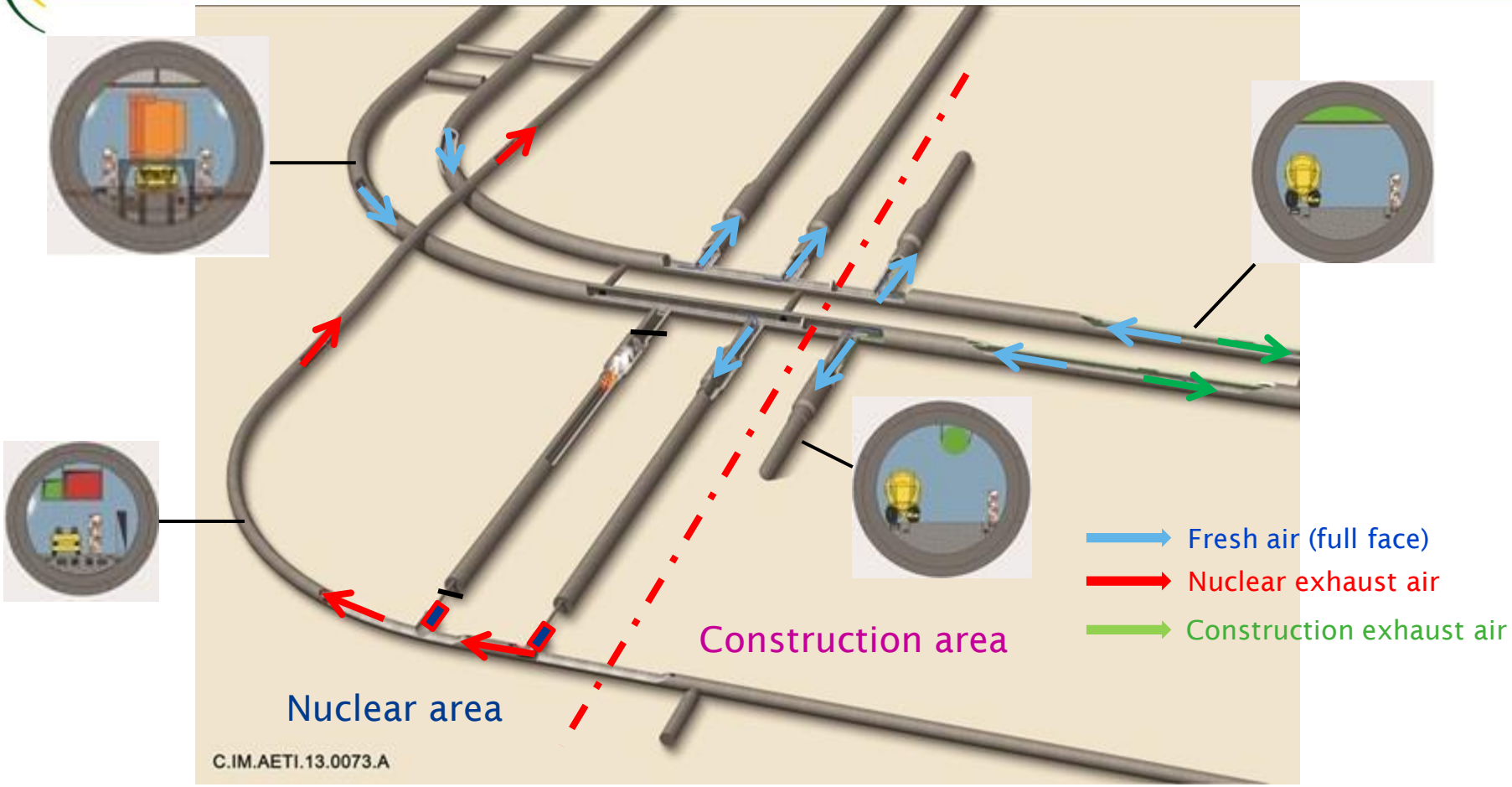
[1] *High Efficiency Particulate Air*

Fire case study (access gallery in nuclear area) in IL-LLW zone



- Subdivision of gallery in compartments using fire doors (maximum length of compartment 800 m)
- Ventilation stopped in neighbouring disposal cells
- Smoke extraction via duct installed at the top of each gallery
- Air intake through door and/or connection gallery
- Escape of personnel through connection drifts into smoke free gallery
- Access of firemen through door and/or connection gallery

Fire case study (disposal cell) in IL-LLW zone



- Scenario : fire in disposal cell
  - No personnel in disposal cell
  - No access for firemen in disposal cell
- Closure of air shutters at inlet & outlet of disposal cell in order to contain the fire