The Proposed Operations Master Plan of Cigéo-17013

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ABSTRACT

The **proposed operations master plan of Cigéo** describes the so-called "reference progression" of the Cigéo project as envisaged by Andra at the end of the preliminary design studies. It aims at clarifying the objectives of the industrial pilot phase and present the choices offered by the reversibility for the management of the Cigéo project.
The reference progression includes the inventory of the waste to be disposed of in Cigéo used for the dimensioning (73 600 m3 of ILW-LL and 10 100 m3 of HLW). Cigéo is designed to store the waste already produced and those that will be produced in the future by the existing nuclear installations and those whose creation was authorized, until the predictable end of their operation and their dismantling. All spent fuel is assumed to be reprocessed.
The reference progression also includes the duration and the projected milestones of the construction and operation phases of Cigéo until termination. Across the operating life of Cigéo, the extensions of the Cigéo repository areas proceed by successive incremental phases, from the start of the industrial pilot phase (2025) to the final closure operations planned by 2150.
Reversibility is defined as the ability to offer to the next generations different choices in terms of radioactive waste long-term management. The implementation of the reversibility principle is based on both governance and technical project management tools.

INTRODUCTION

High-level (HLW) and intermediate-level (ILW-LL) long-lived waste cannot be disposed of in surface or near-surface facilities due to the fact that it remains hazardous for tens or hundreds of thousands of years. The 2006 Planning Act [1] charged Andra with the task of designing and building a reversible disposal facility for this final waste. This facility is known, as the Cigeo geological disposal facility. The depth, design and construction of this repository in a stable geological formation (an impermeable argillaceous rock) will make it possible to protect radioactive waste from human activities and natural surface phenomena (such as erosion) and confine these substances over very long periods of time. The facility will no longer require human intervention after it is closed up. This means that the waste contained in Cigeo is protected and the burden of its management is not placed on future generations.

The proposed operations master plan (in French “Plan Directeur pour l’Exploitation” - PDE) [2] describes the reference progression of the Cigeo project, i.e. the waste inventory to be emplaced in it and the consecutive steps in building the industrial, operational and closure facilities as envisaged by Andra based on studies conducted up to 2015.

This document is not intended to be a technical document. It is the forerunner of a project governance tool whose purpose is to be periodically updated with decisions taken throughout Cigeo's operation lifetime. The technical aspects (architecture, plans, technical definition of equipment, optimization, etc.) and figures (dates, number of cells, number of packages, etc.) included in the PDE may change during, as well as after, the detailed engineering design phase (APD) depending on the studies and exchanges to be held with the stakeholders.

INVENTORY OF THE WASTE TO BE DISPOSED OF IN CIGEO

The purpose of Cigeo is to dispose of waste that has already been and will be generated by existing nuclear facilities as well as nuclear facilities that have been granted a building license (those are presently under construction), including up to their expected date of decommissioning and dismantling [3].

The typical useful service life of all nuclear reactors, including the Flamanville EPR under construction, is 50 years. It is assumed that all spent fuel will have been reprocessed. The longevity of the fuel cycle facilities is commensurate with that of the nuclear power plant fleet. The research facilities (CEA reactors and laboratories) currently in operation, as well as the Jules Horowitz reactor currently under construction, have an expected service life of 50 years. The ITER reactor is expected to operate for only 20 years.

The waste intended for disposal at Cigeo is intermediate-level long-lived waste (ILW-LL) and high-level waste (HLW). Cigeo has a reference inventory of 73,600 m^3 for ILW-LL and 10,100 m^3 for HLW.

ILW–LL contains significant quantities of long-lived radionuclides, and its level of radioactivity is generally between 1 million and 1 billion of becquerels per gram. HLW has a radioactivity level of several billion of becquerels per gram and gives off heat. Some of the radionuclides contained in it have very long half-lives. A distinction is made between HLW0 waste, which has a moderate heat output, and HLW1 and HLW2 waste, which has a higher heat output.

HLW1 and HLW2 waste require storage to decrease their activity and decay heat before they can be shipped and disposed of in Cigéo. No HLW1 or HLW2 waste packages will be shipped to Cigeo before 2075. Between Cigeo's commissioning and 2075, only ILW-LL and HLW0 waste packages will be emplaced in the repository.

OVERVIEW AND DESIGN OF CIGEO

Based on previous studies and on their assessments, Andra embarked in 2010 on an initial design phase in order to draw up a preliminary industrial project of Cigeo. The outline studies of the facilities were finalized in early 2013 [4] and the engineering design studies then started. Andra is scheduled to apply for a construction license (in French “Demande d’autorisation de Création” - DAC) in 2018. Once the DAC is filed, the work for the technical definition of Cigeo will be continued by project design and construction studies, the aim of which will be to prepare, if the construction license is granted, the construction of the first buildings and infrastructures.

The Cigeo reversible geological repository [5] includes a number of facilities that constitutes a nuclear installation (Figure 1). It comprises:

- Surface facilities divided into two distinct sets:
  - ✓ A zone (referred to as the 'ramp zone') for receiving, inspecting, and preparing HLW and ILW-LL primary packages for disposal. In this zone, the first facility that will be built will be used to receive HLW0 and ILW-LL packages. The second facility will be used to receive HLW1 and HLW2 packages. This zone is adjacent to the underground research laboratory, which is currently authorized to operate until 2030.
  - ✓ A zone (referred to as the 'shaft zone') for underground work support activities. This zone includes the entrances to the vertical shafts and muck piles for storing rock extracted from below ground during the excavation operations.
- An underground facility comprising:
  - ✓ Ramps (slanted tunnels) for lowering waste packages into the repository via a funicular, and vertical access shafts for staff and for lowering equipment and materials during the excavation work.
  - ✓ Repository zones containing waste-package disposal cells and drifts. Specific zones will be dedicated to HLW0, ILW-LL and HLW1/HLW2 packages.
  - ✓ A logistics support zone.

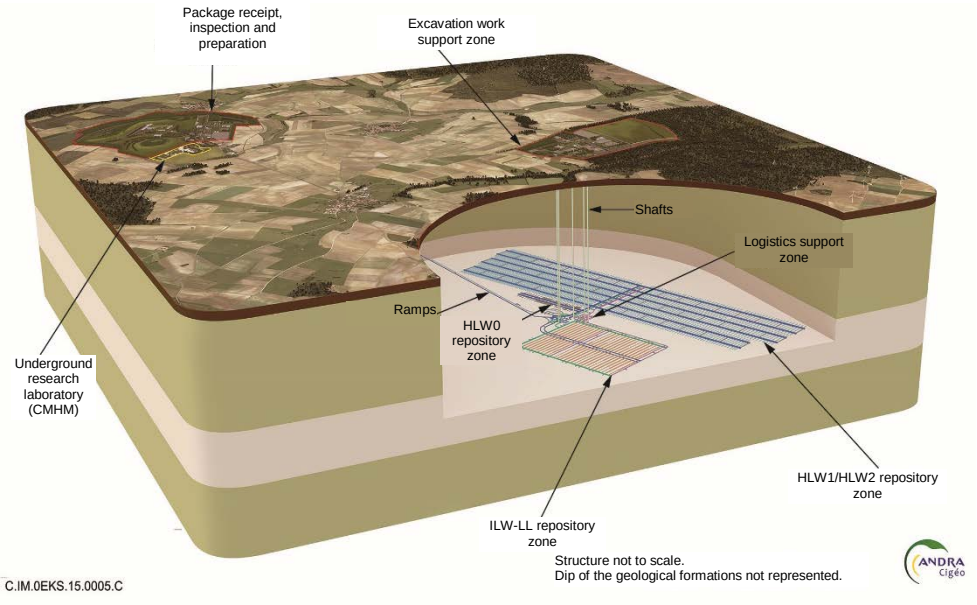

Fig. 1: 3D view of Cigeo's surface and underground facilities (diagram at the end of the preliminary engineering design).

THE INDUSTRIAL PILOT PHASE

The industrial pilot phase is a period of the Cigeo project. Its objective will be to conduct all the testing operations, to set up the demonstrators (e.g. for the sealing of cells) and to verify all the operation and equipment (e.g. monitoring tools) that will be necessary to successfully take Cigéo forward to full routine operation [6].

The industrial pilot phase will begin with the start-up tests of the facility and end when Cigeo makes the transition to routine operation. It is estimated to last for around 10 years (Figure 2). It will be documented in a report to be sent to the national safety authority (ASN) and submitted to the Parliament and to the project's stakeholders. The transition to routine operation will follow a process associating ASN and the project's stakeholders. The industrial pilot phase will comprise a phase of inactive start-up tests (conducted on dummy packages), commissioning tests conducted on waste packages, and the gradual and careful bring-up to full operation (Figure 2).

The aim of the industrial pilot phase is to confirm, under real conditions and in addition to tests conducted in the underground research laboratory:

- ✓ Risk management under operating conditions.
- ✓ Performance of industrial equipment.
- ✓ The ability to retrieve waste packages from their disposal cells.
- ✓ The ability to monitor repository structures.
- ✓ The ability to close off or seal cells, drifts, and ramps.
- ✓ Avenues of technical and economic optimisation.

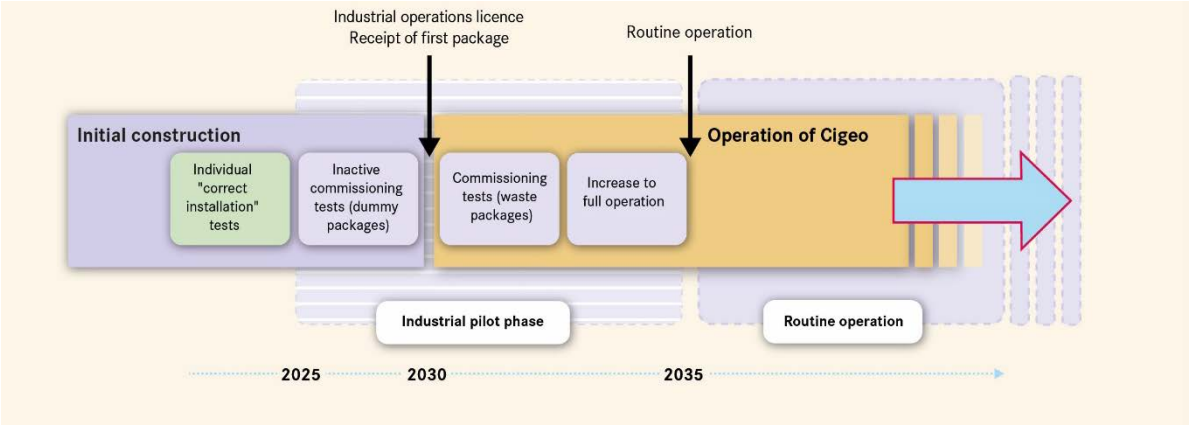

Fig. 2: Diagram showing the sequence of steps in the industrial pilot phase and the initial construction and operation phases.

INITIAL CONSTRUCTION

The initial construction phase (scheduled to start in 2021) includes building the facilities, structures, equipment, and systems that will make it possible to receive the first waste packages in Cigeo's surface facilities and then dispose of them (Figure 3). Its aim is to make the first phase of Cigeo (T1) operational for the industrial emplacement of waste packages in 2030. Operations of the industrial pilot phase will be conducted in the structures built during this phase.

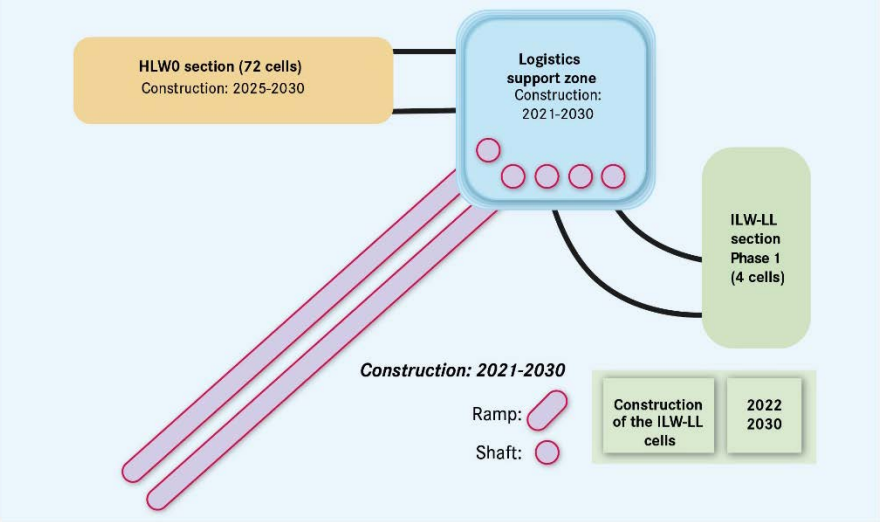

Fig. 3: Schematic diagram of the steps involved in the building of the underground structures during the T1 phase.

These structures will be the first to be commissioned for the emplacement and disposal of packages. Some of the structures built during this phase — such as the ramps, shafts and logistics support zone ('operation' and 'construction' portions) — will be used throughout Cigeo's operation. It is therefore important that they will be dimensioned in order to enable, and not to limit, the development and construction of the subsequent phases.

OPERATION

Once Cigeo's operating license is issued by the National Safety Authority (the operating license enables the reception of the first waste packages), scheduled for around 2030, the structures built during the initial period will be used for the disposal of packages (Figure 4). The repository zones will gradually be extended to match the disposal needs. The first extension, which will correspond to the second investment outlay (T2), will be to the ILW-LL section (addition of six cells). Construction on this extension is scheduled to be commissioned in 2040.Then, over the course of Cigeo's service life, the underground facility will be regularly expanded in order to be able to contain all of the waste packages in its inventory. Ten new phases (T3 to T12) will thus in turn be built and commissioned up to Cigeo's completion, i.e. when all the structures enabling the disposal of all the packages in its inventory have been built (Figure 4). The repository zone for ILW-LL waste packages will mainly be built first, followed by, around 2070, the repository zone for HLW1 and HLW2 packages. Each construction phase will take around no more than 10 years to more easily accommodate Cigeo's incremental development.

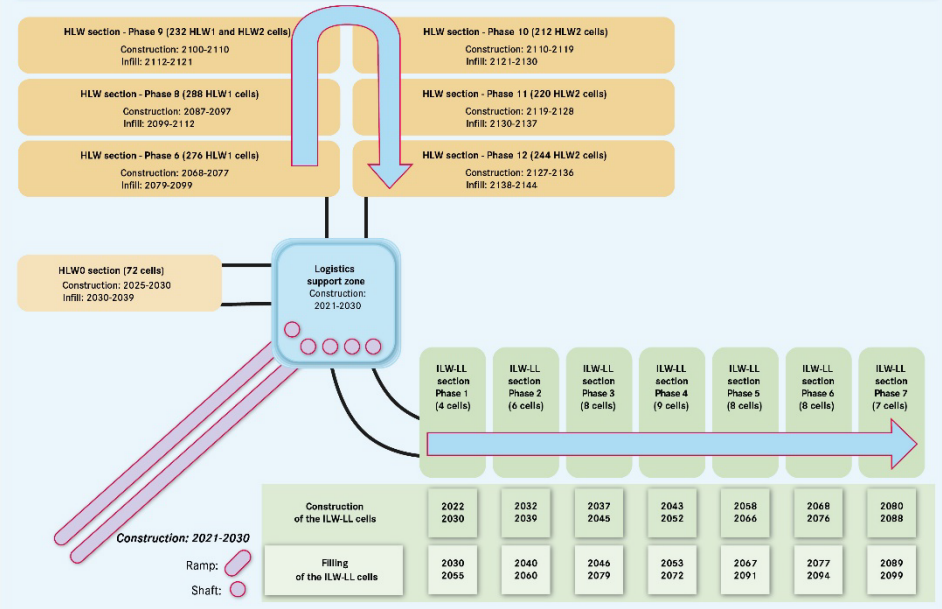

Fig.4: Schematic diagram of the steps involved in the building and operation of the underground structures up to completion

GRADUAL AND FINAL CLOSURES

Cigeo's underground structures will have to be closed off in order to ensure that the waste emplaced in it remains undisturbed for a very long period. This closure will be carried out gradually, according to a specific licensing process. A series of 'partial' closure operations will be carried out, zone by zone, within the repository (Figure 5). They will consist of dismantling equipment used to build and operate the structures. Each closure operation will increase the degree of effort required to retrieve waste packages, should such a decision be taken.

The purpose of partial-closure structures is to close off the disposal cells, backfill the drifts and seal off the drifts. The drifts will be backfilled with the clay removed during the excavation of the repository and stored on the muck piles on the surface. The studies conducted at this stage have found that the optimum closure scheme (Figure 5) in line with the aforementioned objectives consists of:

- Closing the HLW0 section at around 2070 (approx. 40 years at the highest level of monitoring and retrievability).
- Closing the ILW-LL section at around 2100 (approx. 70 years at the highest level of monitoring and retrievability).
- Closing the HLW1/HLW2 sections at around 2145 (based on the sections up to approx. 60 years at the highest level of monitoring and retrievability).

The surface facilities will be dismantled once they are of no longer use. The main dismantling operation planned before Cigeo's final closure is that of the EP1 building, occurring at the end of the filling and closure of the ILW-LL section (around 2100).

At final closure, the last shafts in Cigeo's logistics support zone and ramps will be sealed and backfilled. The surface facilities will be dismantled. According to the current schedule, Cigeo will close definitively around 2150.

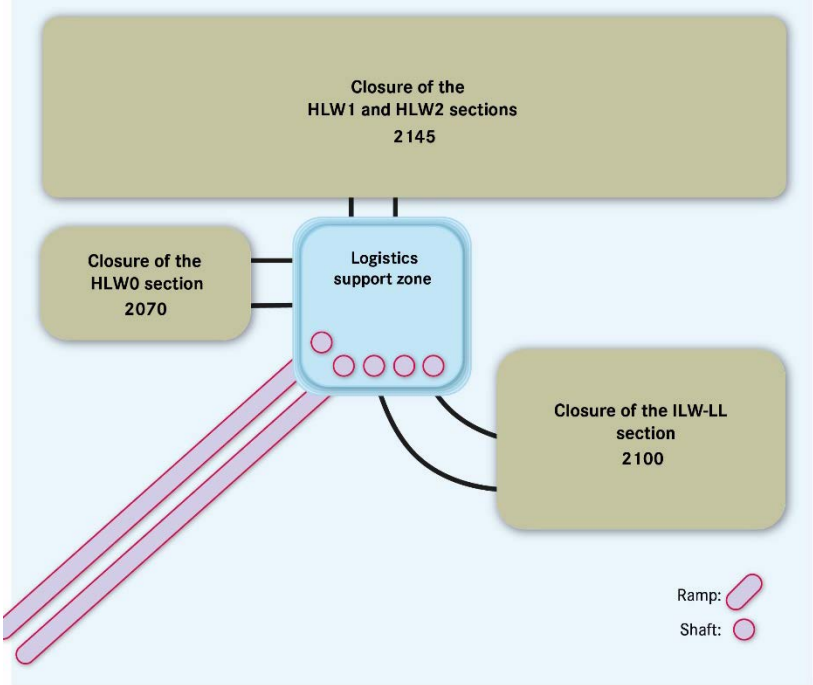

Fig.5: Schematic diagram of the steps involved in the partial closure of underground structures

PROJECT MANAGEMENT CHOICES OFFERED BY REVERSIBILITY

Ethical concerns for reversibility originate in the time scale required to manage the most harmful radioactive waste and especially Cigeo's century-long service life [5]. Disposal reversibility is the ability to leave future generations options regarding long-term management of radioactive waste. In practice, its implementation is based on governance tools and technical project management tools [7].

The tools of governance are as follows:

- Continuous improvement of knowledge on the management of radioactive waste.
- Transparency and transmission of information and knowledge.
- Involvement of society, assessment and supervision by Parliament.
- Control by ASN.

The project management tools are:

- Incremental development and gradual construction of Cigeo's facilities.
- Operational flexibility.
- Adaptability of the facilities.
- Waste package retrievability.

The 'incremental development' of Cigeo gives future generations the possibility to accelerate or delay Cigeo's construction. It promotes the inclusion of future phases of construction and all improvements made possible throughout the project's century-long service life by scientific and technical advances and feedback. Optimization opportunities that have already been identified but which have not yet reached a sufficient degree of technology maturity for

inclusion in the construction license application to be filed 2018, may, if their licensing is granted in the future, be integrated into subsequent stages of the project.

Operational flexibility gives future generations the possibility to delay or accelerate (within certain limits related to equipment performance, equipment usage rates, and operator availability) the flow of packages emplaced within Cigeo. Acceptance of waste which conditioning has been modified will be facilitated by this flexibility. It also makes it possible to amend the reference closure scheme to foresee or delay partial closure operations.

The adaptability of Cigeo's facilities makes it possible to modify the project following changes in its initial design assumptions, such as its reference inventory (number and type of waste for which Cigeo has been initially designed). Namely, Cigeo's design can be adapted to the potential disposal of spent fuel (if such a National policy change happened to be taken within its service life) or for waste that is currently intended for near-surface disposal facilities (eg. low-level long-lived wastes).

Retrievability gives future generations the possibility to reconsider the decision to use deep geological disposal as a way of managing all or part of the radioactive waste packages emplaced at Cigeo.

The cost of technical measures taken to ensure reversibility is factored into in the project, meaning that current generations are providing future generations with easier options for acting on the disposal process. However, should future generations decide to exercise these options, for example, to modify the repository to allow the emplacement of new types of waste or remove waste packages, they will have to take responsibility for their decisions.

FUTURE STEPS OF DEVELOPPEMENT OF THE OPERATION MASTER PLAN

The objective of the operation master plan is to become the concrete medium for the reversibility of Cigéo. It is a document that is intended at tracing the decisions that will be taken within the governance process of the facility throughout its service life.

In order to consolidate and to complement the proposed operation master plan that constitutes the first version of the document, Andra will engage into a broad concertation process with the stakeholders and the society. The aim is to produce a solidified and shared version of the operation master plan may be joined to the license application in 2018.

The primary subjects on which the concertation will focus are:

- The PDE itself (format, content, accessibility) to verify that it is an adjusted tool to facilitate and trace decisions;
- The governance process of Cigéo (Who is implicated? When? How? On what basis?) with the objective to formalize a commonly understood mechanism that would then be submitted to the Parliament.

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