Safety case for license application for a final repository: The French example

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The reversible repository in a deep geological formation is the French reference solution for the long-term management of high-level and intermediate-level long-lived radioactive waste (HLW and ILW). Twenty years of R&D work and conceptual and basic studies since the first French Act of 1991 led, in particular, to a feasibility demonstration in 2005. According to the French Act on Radioactive Waste of 28 of June 2006, Andra shall design a reversible repository in order to apply for license in 2015. In response to this demand, Andra developed the industrial project known as "Cigeo", a reversible geological disposal facility for HLW and ILW located in Meuse/Haute-Marne.

Two years before applying for authorisation, Andra's project is now focusing on three main targets: developing Cigeo's industrial design, preparing the authorisation process through increased exchanges with stakeholders and the preparation of a safety case to support authorisation application. The latter draws on the previous safety cases of 2005 and 2009, which give a sound basis to assess Cigeo's safety, both for the operational and post-closure periods. In this new stage of the project, the challenging issues for the preparation of the safety case are the following:

- to identify the various regulatory frameworks (nuclear and non-nuclear) and guides applicable to the facility;
- to ensure that the industrial design complies in particular with the safety requirements as presented in the safety case and its supporting safety assessment;
- to identify crucial inputs (R&D, tests,...) needed to support the authorisation application, in particular, to bring convincing arguments to assess the technical feasibility of the design and when appropriate its ability to meet the safety requirements;
- to ensure that all the requirements from previous regulatory and peer reviews (national and international?) are taken into account.

General schedule

Thanks to the first outputs of the industrial design, Andra was in a position to propose to the Public Debate National Commission, an independent body tasked with organising public debate on large infrastructure projects, to hold the public debate on Cigeo in 2013. The debate began in May and will end in December 2013.

Any changes made to the project following the public debate, along with the avenues for optimisation identified by Andra will be taken into account in the following study phase before the repository license application is filed in 2015.

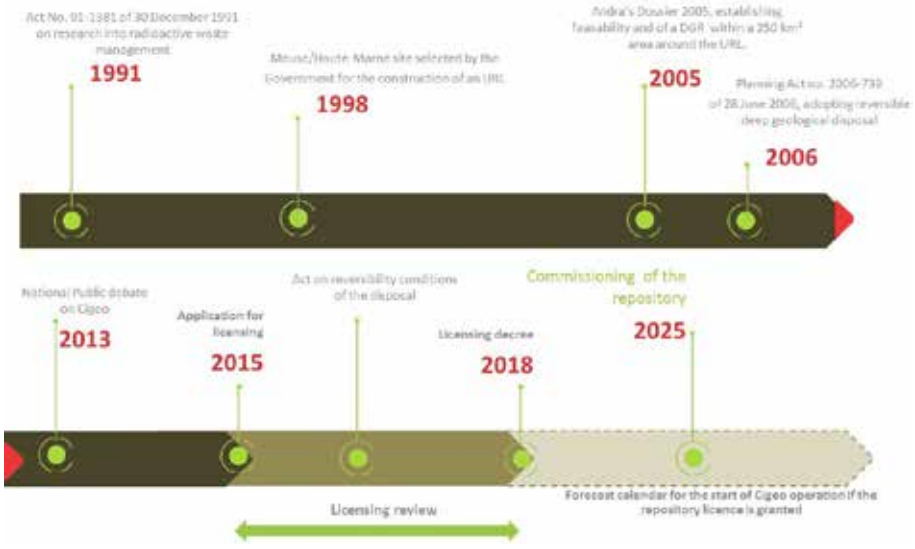
The content of the application file is defined by Decree (2 November 2007). It comprises various plans of the facility, the description of the solution envisaged for the closure of the facility, the preliminary safety case (operational safety, long-term safety, protection against malicious acts, management of accidents, preliminary acceptance criteria,...), the environmental impact assessment (health, transport, human activities, nature, patrimonial aspects,...). These elements shall be produced on the basis of a sufficiently detailed design, so that the safety authority can fully grasp their industrial feasibility and their required performance.

The regulatory review process consists of many evaluations and decisions: The license application is examined by the National Assessment Board, Nuclear Safety Authority; local authorities are consulted. An assessment is carried out by the Parliamentary Office for the Evaluation of Scientific and Technological Choices. An Act shall be passed on the disposal reversibility conditions. Afterwards, Andra shall update its license application to take into account this new law, before the review process is achieved: examination by the Nuclear Safety Authority and its technical safety organisation (TSO), the Institute of Radioprotection and Nuclear Safety (IRSN) and public inquiry will be carried out prior to the "Conseil d'Etat" decree granting the repository license for Cigeo.

According to French regulation, a creation decree will authorise the construction of the facility and then the nuclear operations to be performed. An explicit and unequivocal safety demonstration has to be provided for these operations in the license application. In the case of Cigeo, the authorisation for operations foreseen in the far future may be granted on the prerequisite that complementary dedicated files be transmitted in the future. This regulatory mechanism may be generalised to all operations for which complementary elements are found necessary by the regulator.

According to the planning Act of 26 June 2006, the commissioning of the facility is planned by 2025. The nuclear operations will start with the reception of the first waste package provided the commissioning of the repository is authorised by the safety authority. At this stage, the commissioning encompasses only the first portion of the facility. Beyond 2025, construction and equipment work will be carried out concurrently with nuclear operations in the previously commissioned portions.

Figure 1: General schedule for French deep geological repository Cigeo



Cigeo's general layout

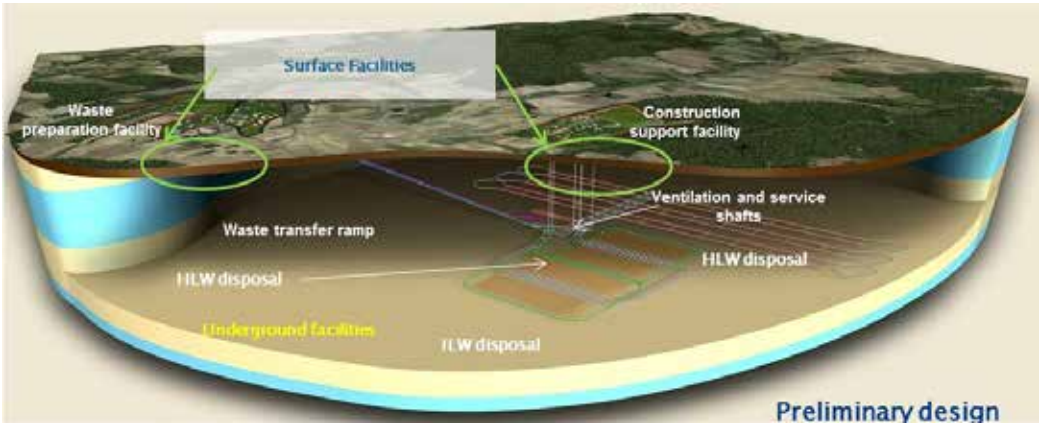
Cigeo will consist of surface installations for operations such as waste package receipt, inspection and preparation, an underground disposal installation, and an infrastructure that will connect the underground installation with the surface. The repository will operate for more than 100 years and be built according to a step-by-step planning process over time. To guarantee its role and ensure that waste is confined over very long time periods without the need for human intervention, the underground structures at Cigeo need to be closed up. This closure will take place gradually.

Located at a depth of around 500 meters, the Cigeo underground facility will be expanded over the course of its operations. It will consist of separate disposal zones for HLW and ILW-LL, connecting drifts and technical facilities. By its 100th year of operation, Cigeo's footprint will be around 15 km². Robots will emplace waste packages in horizontal tunnels, known as cells, excavated in the heart of the Callovo-Oxfordian layer. HLW will be emplaced in metal-lined cells measuring a few hundred meters in length and around 70 cm in diameter. ILW-LL will be emplaced in horizontal disposal cells measuring a few hundred meters in length and around ten meters in diameter. The disposal zones will be modular in design to allow waste disposal tunnels to be built according to a step-by-step planning process over time.

Two types of infrastructure will connect Cigeo's surface installations with the underground facility. Vertical shafts will be used to transfer workers, construction equipment and materials, and ventilate the underground facility. Waste packages will be transferred by means of a funicular along an access ramp.

Cigeo's surface installations will be split across two sites (ramp zone and shaft zone) located a few kilometres apart. The ramp facility will be built in the zone already prepared around the current URL and integrated with the site's physical features.

Figure 2: Cigeo's general layout after 100 years of operation



Upon arriving at Cigeo, waste packages will be transferred to buildings where they will be taken out of their transport casks and inspected (absence of contamination, dose rate, etc.). These buildings will also be used to manage flows of waste packages prior to their transfer into the underground facility. These facilities do not intend to replace waste producers' own storage facilities, particularly those playing the role of cooling HLW sufficiently prior to transfer and emplacement into the repository. Waste packages will then be placed in disposal containers. Disposal packages will be placed in a cask to shield against radiation. The cask will be loaded onto a funicular that will slowly descend all the way to the galleries. The cask will then be transferred to the cells and the emplacement of waste packages in the cells may be remotely controlled. The transfer cask will dock

with the interface door of the cell in order to create a containment system while the door is open. The door will not be able to be opened until the transfer cask is correctly docked. The handling system will then transfer the waste packages into the cell and the door of the cell will be closed in order to protect workers from exposure and to fulfil containment requirements.

Safety case in the industrial design phase and preparing for licensing

The 15-year period from 1991 to 2006 was mainly dedicated to research activities, especially thanks to the underground repository laboratory (URL) constructed at the border between the Meuse and the Haute-Marne districts, at the Bure location. Following the 2006 Planning Act, work progressively focussed on the siting process for Cigeo and on preparing for the project's industrial development.

In late 2009, Andra submitted the so-called "Dossier 2009" to the French government. The Dossier included proposals concerning the siting and design of Cigeo, as well as an intermediate preliminary safety case focused on operational safety.

After the review of this file and decisions taken by the government on the siting, Andra decided to launch the industrial design phase in 2011. For this new stage of the project, Andra set up a dedicated industrial structure for Cigeo project development. To reinforce the engineering resources of the project team, Andra engaged a prime contractor, the Gaiya group formed by Technip and Ingerop. An industrial outline was developed in in 2012. A detailed design will be established from 2013 on. In its position of implementer and future operator, Andra shall ensure a robust technical control of the project throughout its existence. Andra has thus reinforced its engineering skills (project management, design and handling of disposal packages, infrastructure engineering, economic assessment), by creating a specific division for engineering and managing the Cigeo project, with a view to ensuring the operational follow-up of subcontracts on studies.

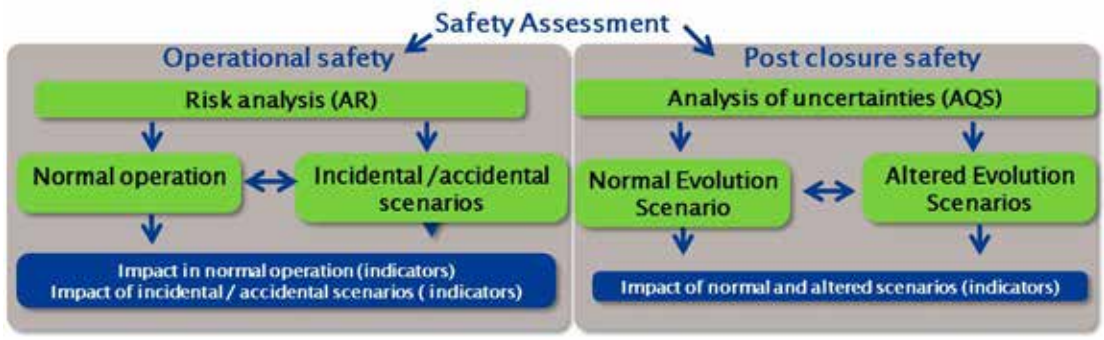
This new organisation imposes specific measures to ensure that safety requirements established on the basis of previous safety cases are still met during the development of the industrial design. To achieve that target, Andra has established and characterised functions to be fulfilled by the components of Cigeo and also frozen design choices, in order to leave space for optimisation of the industrial design but at the same time to preserve critical safety parameters. Short-term and operational requirements are expressed mainly on a safety functional basis (for example: to meet workers' radiological protection targets against potential exposure); on the contrary, technical solutions to long-term issues, which are out of scope of classical nuclear engineering, are in some cases imposed and specified along with functional requirements. These technical solutions to fulfil post-closure safety functions were established thanks to Andra's 20 years' experience in long-term radioactive waste management. For example, the location and length of seals are imposed, but the choice of the material is left open, provided an overall performance is achieved (permeability, swelling pressure).

To establish those requirements, Andra also had to analyse applicable regulatory frameworks, guides and practices, in order to identify potentially conflicting regulations and practices (e.g. nuclear versus mining) or a lack of references. For example, specific requirements on fire risk were identified in order to take into account the combined constraints of "conventional" underground facilities (tunnels, mines) and nuclear facilities. Andra was thus obliged to establish specific guidelines on handling fire risk for the underground nuclear facility, as no existing guidance was directly applicable. Other specific requirements during the operational period have been identified and concern, for instance, enabling proper management of the containment systems or the co-activity (co-existence of conventional and nuclear activities in the underground facility).

On the basis of the developed industrial design, Andra is preparing the safety case in support of the license application. As previously said, the safety case shall be produced

on the basis of a sufficiently detailed design, so that the safety authority can fully grasp its industrial feasibility and its compliance with the required performances. To do so, Andra draws on the iterative process employed up to now, which provides a sound methodological basis. Concerning operational safety, the Cigeo safety case will follow standard practices for risk management for classical nuclear facilities in accordance with French regulations. Therefore, Andra will apply a classic risk analysis scheme in its assessment of normal, incidental and accidental scenarios. Concerning post-closure safety Andra is considering the development of a Qualitative Safety Analysis which would define normal and altered evolution scenarios. This methodology would be strengthened through the integration of preceding reviews' outcomes and of recent developments in international standards, guidance and best practices. For example, to improve the comprehensiveness of the safety case, the synergy between FEP and functional analysis will be deployed at the outset of QSA.

Figure 3: Structure of the safety assessment



An operational safety case was outlined in the "Dossier 2005" and more thoroughly assessed in the "Dossier 2009". Central issues such as the definition of containment systems, fire risk management and co-activity management were identified, so that Andra was able to designate relevant requirements pertaining to these issues as input for the industrial design. Cigeo's ability to meet legal performance requirements will be assessed on this basis.

Regarding the post-closure phase, it was thoroughly developed in the "Dossier 2005". The main tasks for the safety case supporting the license application are manifold:

First, a formal process must define what the inputs for the safety case are: what is the state of knowledge, what is the waste inventory considered for safety assessment, what is the reference design? This task is all the more important so that during the industrial design development phase, the layout of the facility may be optimised and design options may be closed or left open. The impact of such evolutions on the safety must be controlled. To do so, formal intermediate reviews in line with the planning of the industrial design development are organised throughout the preparation of the safety case.

On this basis, Andra must establish the evolution of knowledge and the remaining uncertainties, after ten years of supplementary work in R&D and experiences in the Bure URL since the publishing of the "Dossier 2005". Andra must also consider the evolution in design since 2005, and thus reassess whether remaining uncertainties are managed by technical components or by scenarios.

Finally, Andra must bring convincing arguments to assess the technical feasibility of the design and its ability to meet the safety requirements. To do so, R&D results have been completed by a large set of technological tests and developments of various topics (e.g. mining, mechanical, waste containers, sealing systems) in the underground laboratory in Bure as well as in surface laboratories in order to verify parameters, develop equipment, optimise disposal solutions and tackle potential emerging issues. A programme of

technological tests and demonstrations, identifying the results needed for the license application, has been developed, and further tests are planned over the long term to confirm, if needed, performance of components with full-size tests in the facility before its commissioning. From the outcomes of those tests, Andra also aims to provide a solid and documented technical outcome as a back-up to the Cigeo licensing application, responding to themes and issues identified by evaluators in previous reviews. In particular, given the importance of seals for the post-closure safety of the facility, a number of tests have been implemented to demonstrate their industrial feasibility and performance.