SITE SELECTION PROCESS FOR A HLW GEOLOGICAL REPOSITORY IN FRANCE

A convergence approach

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ABSTRACT

On December 1991, the French National Assembly passed the French Waste Management Research Act, authorizing and initiating a 15 year research program along three options for HLW long term solution: separation and/or transmutation, long-term storage, and geologic disposal.

On June 2006, the "Planning Act on the sustainable management of radioactive materials and waste" sets a new framework and new aims to the above mentioned options.

This paper deals only with the geologic disposal research program. In a step by step approach, this program has been broken down into three phases, each having intermediate objectives: site selection for an Underground research Laboratory (URL), disposal feasibility demonstration, reversible disposal design.

The first step of the research program aimed at URL site selection. From 1994 to 1996, Andra carried out geological characterization surveys in four French districts, leading to the Request for Licensing and Operation of laboratory facilities on three sites. During this phase, boreholes, 2D seismic campaigns and outcrops geologic studies were the main sources of data. The result was the selection of Bure area, the most suitable site for the implementation of an underground laboratory. Main results on Bure URL will be presented in the paper.

In the second phase the research program targeted the safety and technical feasibility of a reversible disposal site, located in Meuse or Haute Marne districts, as selected by the government in 1998. Andra conducted geologic survey during the URL shaft sinking and experiments in drifts at depths of 445 and 490 m. This program allowed consolidating the knowledge already acquired: geological environment, stability of the rock and the regional geology, and containment properties. The 2005 Progress Report presents the results of this phase. The main conclusion is that a potential disposal facility may be safely constructed over a zone with geological characteristics similar to those investigated at the URL, called transposition zone (about 250 km^2). The paper will present the most important results in this phase.

From 2006, the third phase of the program, the activities were oriented, inside the transposition zone, to determine a smaller zone in which a potential disposal facility could be located. In 2009, Andra issued a proposal for such a zone to the French authorities. In this paper, the main results of this phase will be presented.

Finally, the next steps towards a final implementation will be described.

1. INTRODUCTION: THE FIRST LEGAL FRAMEWORK

In 1991, the French National Assembly passed the first Waste Act which laid down the framework for HL-LL, IL-LL radioactive waste management, from 1991 to 2005. The scope was large enough to study different possible solutions that would require

Three complementary R&D avenues:

a. partitioning and transmutation of long-lived elements,
b. reversible disposal in deep geological formations,
c. Long term storage

In the second avenue, the Waste Act stipulated that several formation types had to be studied in different geological contexts by means of underground laboratories.

Andra, in charge of the second avenue implementation, scheduled a progressive approach for licensing underground research laboratories (URL). Andra also had to set a research program to carry out research to assess the potential of French geologic formations for radioactive waste disposal. This scientific and technical challenge will be discussed in this paper.

The public acceptation of the research facilities was another aspect to consider. This is not shown here.

2. FIRST STEP: SELECTING SITES FOR UNDERGROUND RESEARCH LABORATORIES

In 1993, MP Christian BATAILLE conducted, by Government's decision, a site selection process. This process started with a call to potential candidates to apply in order to host the URL facility. Thirty five communities (regions, districts, municipalities or townships) were interested. The outcome of Christian BATAILLE selection process, by the end of 1993, was four districts in which preliminary investigations had to be carried out (See figure 1): Vienne district, Gard District, Meuse and Haute-Marne Districts. In these four districts only three different geologic formations were represented.

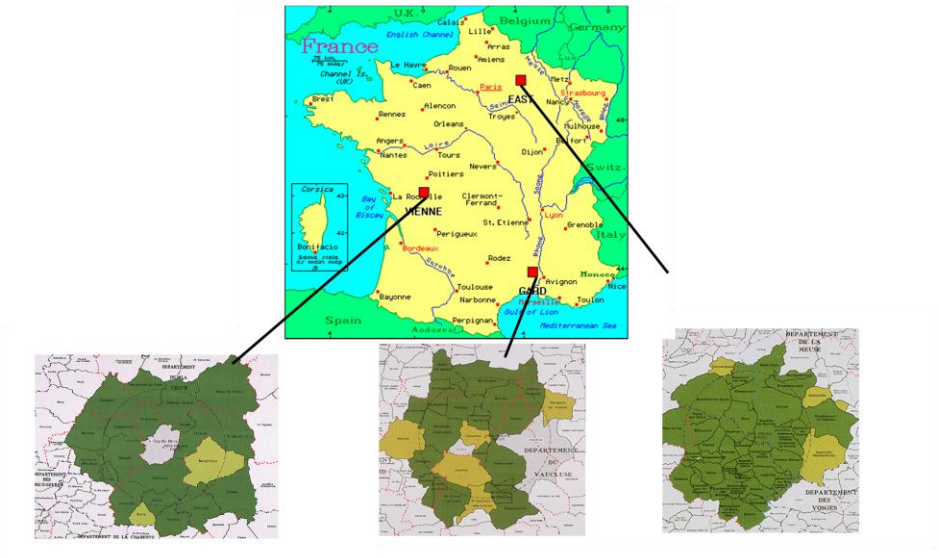

Figure 1: BATAILLE's outcome districts: Vienne (left), Meuse and Haute-Marne (middle), and Gard (right)

For these three sites, the government authorized Andra to apply for licensing three URL. Some characteristics of granite in Vienne, siltite in Gard and claystone in Meuse-Haute Marne were already referenced in the available bibliography. The aim at this step was to demonstrate to evaluators (the Safety Authority mainly, but also stakeholders) that the geologic formations had enough relevant radionuclides containment properties to allow construction of an underground laboratory facility.

From the surface of the three selected sites, from 1994 to 1996, Andra made geologic and hydro-geologic studies, sample measurements of rock properties, migration modeling for safety assessments, etc (see [1], [2] and [3]). At the end of this phase Andra applied for three Underground Laboratories, one in each geologic formation.

By the end of 1998, the government decided to license the URL facility in Meuse/Haute-Marne Districts next to a little city of Bure. Also, the decision to continue site seeking in granite formations was taken. A consultation mission was set to carry out this.

Andra started the construction of the facility and defined a research program intending to evaluate, in the Jurassic layer, the possibility of construction, operating and monitoring of a reversible repository in complete safety for man and the environment.

3. SECOND STEP: THE URL WORKS AND STUDIES. FROM DISTRICT AREA TO TRANSPOSITION ZONE.

Andra built an underground research laboratory [URL] (Figure 2) with a view to studying *in situ* the properties and the behaviour of a clay layer dated from Callovo-Oxfordian (about 150 million years). The underground structures of the URL consist of a 40-m experimental niche located at a depth of 445 m and of about 600 m of drifts at a depth of 490 m. They hosted various phenomenological and technological experiments to confirm the very promising characteristics of the Callovo-Oxfordian formation for the potential implementation of a waste repository.

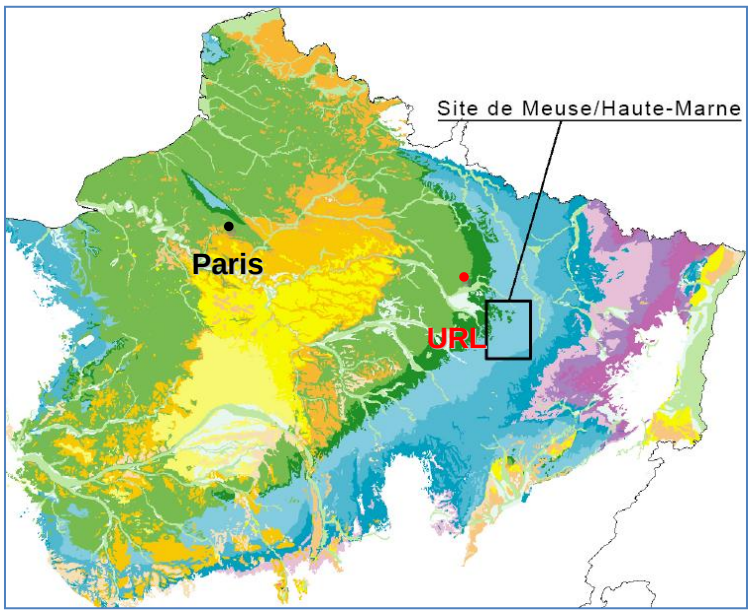

Figure 2: The Meuse/Haute-Marne Underground location

3.1 Works and studies, conducted from 1998 until 2005 on the feasibility of a deep geological repository

Several kinds of works and studies were made in order to reach the aim of repository feasibility.

3.1.1 From the surface:

- Analysis of regional seismic profiles,
- drilling of deep boreholes and measurement of mechanical properties, permeability and diffusion,
- drilling of deviated boreholes to survey, at large scale, the geological layers,
- 2D and 3D geophysical survey campaigns (underground auscultation with seismic waves),
- hydro-geological monitoring,
- seismic (earthquake) monitoring network.

3.1.2 Within the URL:

- While sinking the shafts: layer survey, water collection and flow-rate measurements in limestone layers overlying the Callovo-Oxfordian formation, wall deformation measurements, real-time monitoring of rock mechanical behavior (via sensors), and assessment of rock damage by excavation.
- Inside the drifts: wall deformation measurements, thermal conductivity measurements, monitoring of chemical perturbations, permeability and diffusion measurements for water and radioactive substances, and performance tests on grooves filled with swelling clay.

3.1.3 From safety assessments and repository design:

- Several scenarios analysis taking into account the main expected long-term evolutions
- Calculations of impact on man and the environment
- Design studies of disposal facility architecture and operation
- Studies on reversible management of the repository

3.1.4 R&D Outcome

After 10 years of research, in 2005, Andra had acquired sufficient knowledge of the geological environment at both local and regional scales to fully demonstrate that the Callovo-Oxfordian layer of the Meuse Haute Marne Districts has favourable properties for HLLL waste repository.

In the course of its investigations, Andra delineated a 250-km² transposition zone (TZ) in which the properties and characteristics of the clay layer may be considered as equivalent to those observed in the URL (Figure 3). In that zone, the characteristics of the clay are suitable for the implementation of the underground structures of the waste repository.

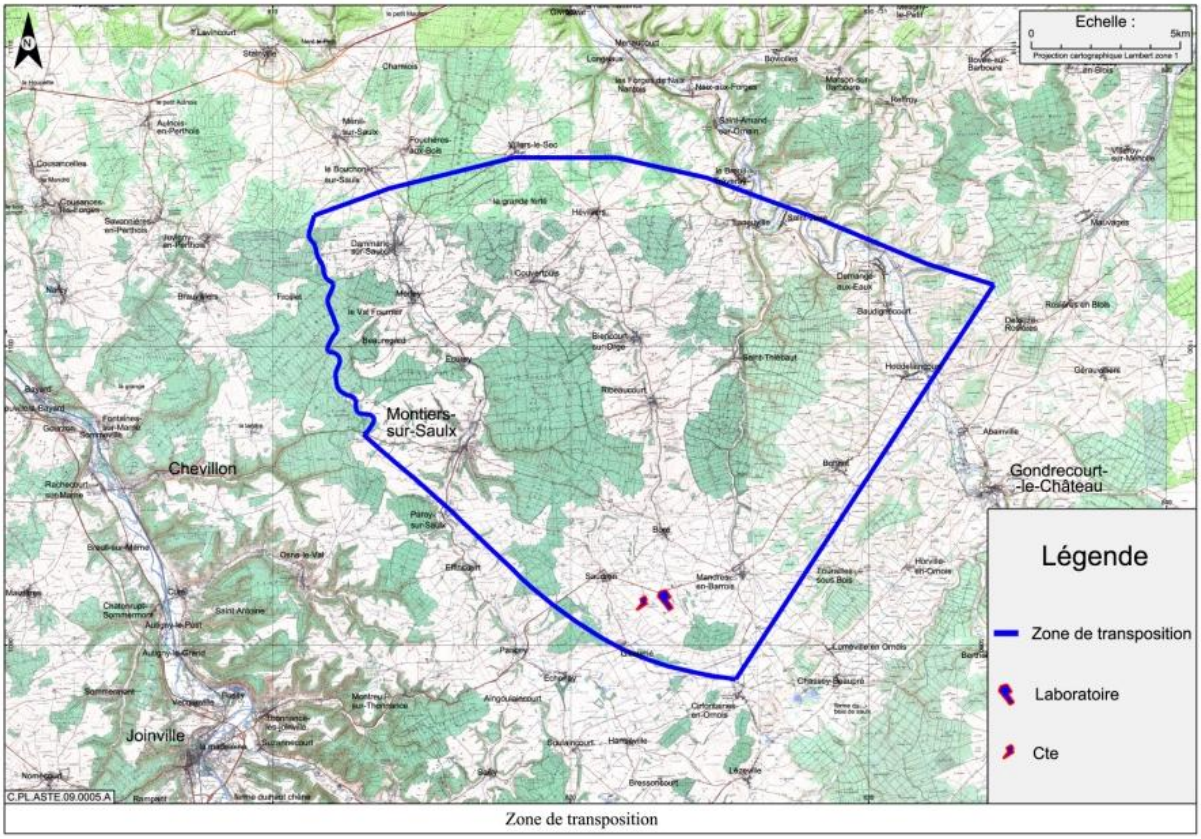

Figure 3: The transposition zone spreads over a 250-km² area to the north of the Underground Research Laboratory

The criteria used in 2005 in order to delineate the TZ are exclusive in nature:

- geometrical criteria:
  - implementation depth for underground structures set at 630 m (thus limiting the TZ to the west);
  - thickness of the upper layer set at 130 m (thus limiting the TZ to the southwest);
- structural criteria:
  - distance of over 1 km from major faults (zone of diffuse fracturing, Marne faults to the south and Gondrecourt Rift to the east), and
- lithological criteria:
  - thickness of the upper level ("R0") of the clay layer (richer in smectites) exceeding 65 m, and
  - silt proportion not exceeding 20-30%.

This TZ was an important issue in the 2005 milestone of 1991 Waste Act, showing the site convergence in progress.

4. THE SECOND FRAMEWORK

The reversible deep geological disposal has been recognised by the Planning Act No. 2006-739 Concerning the Sustainable Development of Radioactive Materials and Waste of 28 June 2006 as the reference solution for the long-term management of high-level and intermediate-level long-lived radioactive waste. The Act entrusts upon Andra to continue studies and investigations with a view to selecting a site and to designing the future deep geological waste repository in time for the creation-licence application to be reviewed in 2015 and, subject to its approval, to commissioning that facility in 2025. The repository must be implemented within a deep geological formation that must have been studied through an underground research laboratory.

The implementation approach for the deep geological repository is divided into several steps:

- in 2009, the selection of an interest zone to carry out a comprehensive geological survey and the definition of implementation scenarios for surface installations to be reviewed in preparation for the public debate;
- the presentation of the results of the comprehensive survey and of the development studies during the public debate scheduled in 2013,
- the selection of the implementation site after the public debate.

The 2009 milestone is the only one shown below.

5. THIRD STEP: FROM TZ TO ZIRA

The transposition zone (TZ) is the investigation start point in 2006. The aim is to delineate a smaller zone of interest in which more detailed studies would be carried out for a possible disposal implementation. This zone is called ZIRA (Zone d'intérêt pour la reconnaissance approfondie).

5.1 Implementation of underground structures

In order to pursue studies and investigations and to prepare the proposal for an implementation site, it is essential to reduce the investigation perimeter to a smaller interest zone in the order of 30 km² (i.e., about twice the size of the proposed underground structures). That will help Andra conducting new and more detailed surveys at a reasonable scale with intensive investigation techniques, such as 3-D seismic.

In accordance with the National Management Plan for Radioactive Materials and Waste, the interest zone was proposed to the government before the end of 2009.

Since the National Review Board (*Commission Nationale d'Evaluation* – CNE) emphasized that the geological quality must be a determining criterion, Andra undertook the most comprehensive review of the geological criteria to be taken into account. Contrary to the approach that led to the definition of the TZ by means of exclusion criteria, the criteria for defining the interest zone aim at delineating a potentially more promising area within the TZ from a technical or scientific standpoint in order to implement the underground structures.

The results from the different geological-survey campaigns showed a remarkable lateral continuity and homogeneity of the clay layer and of the containment properties of the rock throughout the TZ.

Consequently, the properties of the rock (permeability, mechanical properties, etc.) do not constitute, at this stage of the project, adequate criteria for the actual location of the interest zone.

Nevertheless, by relying on the ALARA principle with regard to long-term safety, it is possible to recognise that:

- the thickness of the Callovo-Oxfordian layer, with limited amplitude in variations, remains an objective and relevant parameter, and
- the zones likely to host the highest vertical hydraulic gradients, appear less favourable for the implementation of underground structures under heavily degraded hypothetical conditions..

With respect to the optimisation of operating and operational-safety conditions, it should be noted that the amplitude of excavation-induced damages appears to be much more significant beyond a depth of 540-590 m. Additionally, zones with a small dip of the layer are preferred as it allows keeping the design of the repository simple.

As a complement to those elements, the delineation of the interest zone will rely on the exchange and dialogue approach, using social or politic parameters. In fact, such an approach may partially shape the Andra proposal by allowing the expression of preferences, either positive (preference given to a certain type of surface environment for specific reasons) or negative (not allowing underground structures below certain locations for specific reasons).

The more comprehensive surveys performed in 2010 throughout the interest zone will contribute to the proposal regarding the location for the underground structures of the future waste repository.

5.2 Implementation of surface installations

Surface installations will be implemented in close association with the construction of underground structures.

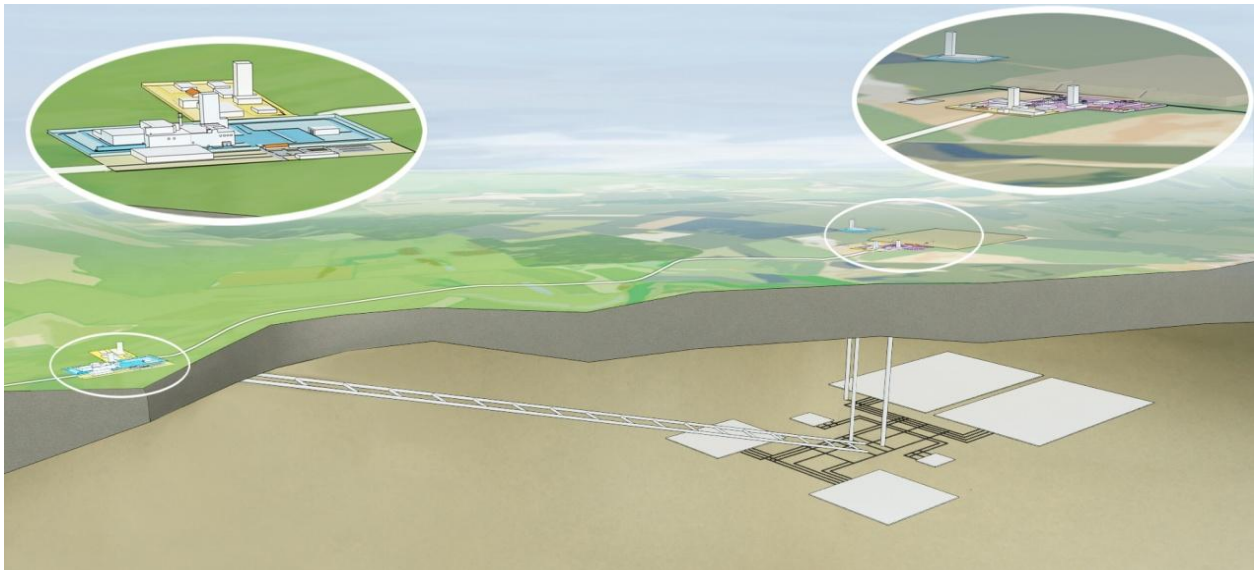

Figure 4: A proposed geological repository architecture

In 2005, Andra submitted a concept in which surface installations are located vertically directly above the underground structures, thus imposing heavy constraints on the surface installations.

Studies have shown that some concept choices offered more versatility than others for implementation purposes. In fact, the use of more or less inclined inclines or a combination of shafts and inclines would actually decouple surface and underground installations, allowing a distance of several kilometres between them (e.g., about 5 km for a 10% dip) (Figure 4). Flexibility for the location of the nuclear surface installation is allowed this way. The access/non nuclear part of the installations will remain directly above the underground structures for technical reasons (air-return shaft) or industrial reasons (e.g., industrial excavation-related activities). In order to pursue the reflection on the implementation of surface installations, Andra will complement its proposed 30-km² interest zone with several implementation scenarios for surface installations (such zones are called, in French, ZIIS which stands for Zones potentielles d'Implantation des Installations de Surface).

In order to define those scenarios, it is essential first of all to consider the various constraints to which the industrial project is submitted. Those constraints, which are often non-crippling, but constraining to various degrees, include notably the integration of the following components:

- elevation: zones with a low dip are preferable for implementing surface installations;
- easily-flooded zones, damp valley bottoms and protection perimeters of drinking-water catchments, as well as criteria with a potential impact on the size of the surface nuclear installations (air-crash risk and flood hazards, etc.);
- urban areas, isolated dwellings and historical monuments,
- outstanding natural sites, such as environmentally protected zones (Natura 2000), natural zones of ecological interest (ZNIEFF), etc.

In parallel, it is necessary to examine connection possibilities with transport infrastructures (road, railroad, navigable waterways) and to take into consideration the local socio-cultural and tourism-inducing heritage.

Lastly, the implementation scenarios for surface installations under study and the proposed interest zone must be consistent.

As it is the case for underground structures, the definition of implementation scenarios will rely on the exchange and dialogue approach.The 2009 Report

By the end of 2009, with all the elements briefly described above, Andra made a proposal for the ZIRA and ZIIS zones. The ASN (French National Safety Authority) and the CNE (National review Board) issued a favorable opinion on this report. The CLIS (Comité local d'information et de suivi du Laboratoire souterrain, Local Commission for information and the follow-up of URL) also sent its remarks and suggestions to the government.

The government authorized, by the end of March 2010, to continue the investigations in the ZIRA zone. Andra started those investigations on April 2010. Figure 5 shows the ZIRA situation inside the transposition zone (TZ).

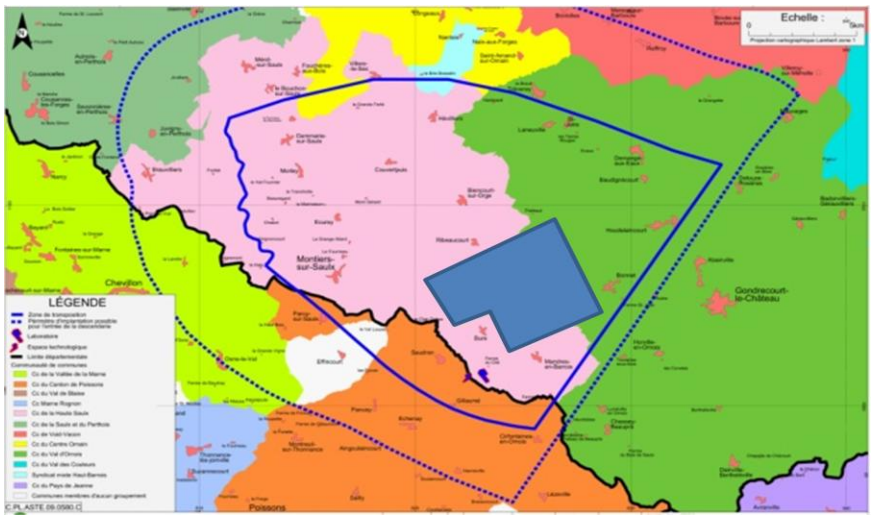

Figure 5: The ZIRA inside the TZ

5.3 The site convergence process goes on

Figure 6 shows what the next steps are a continuation of the process initiated in 2005. Each step is underpinned by new works and progress reports, substantiating the scientific evaluations and the public debates, paving the way for the act authorizing the construction of the site, planned in 2015 and one year later for a law on reversibility.

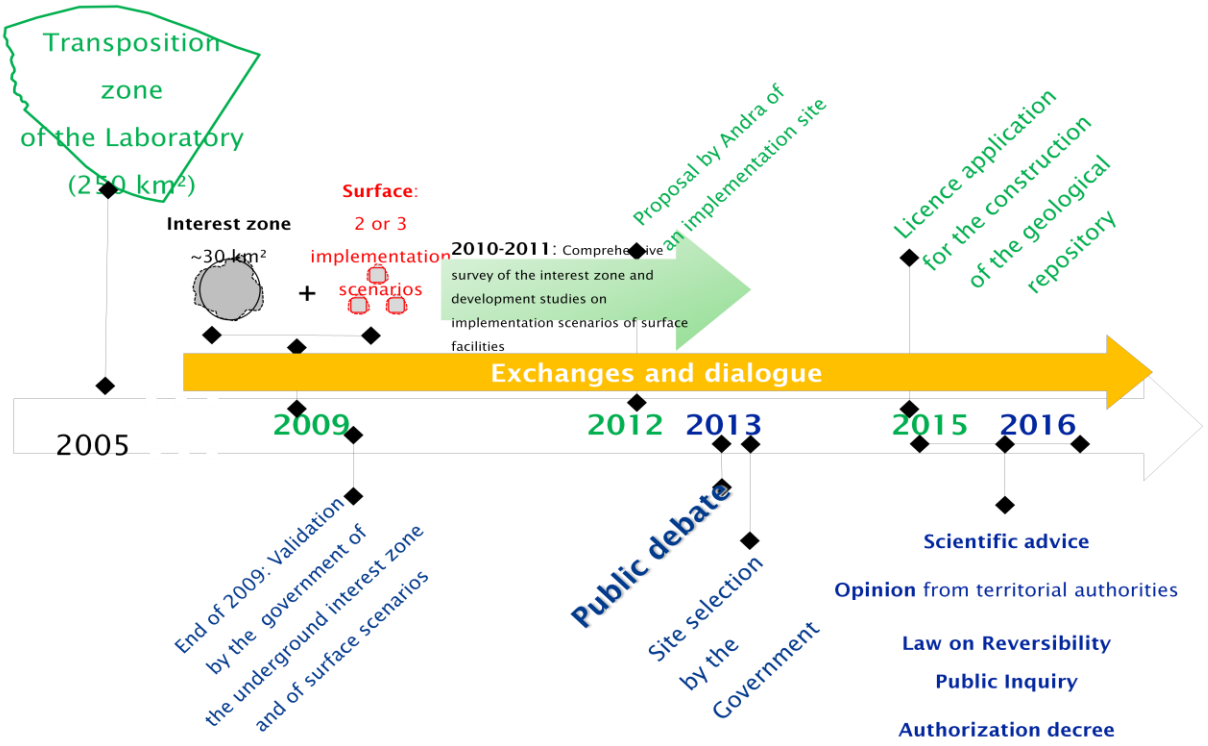

Figure 6: The convergence process in the 2006 Planning Act framework.

REFERENCES

1. Etude du Massif de Charroux-Civray. Actes des journées scientifiques CNRS/Andra. Poitiers, October 13th and 14th, 1997. Edited by EDP Sciences.
2. Etude du Gard Rhodanien. Actes des journées scientifiques CNRS/Andra. Bagnols-sur-Cèze, October 20th and 21st, 1997. Edited by EDP Sciences.
3. Etude de l'Est du Bassin Parisien. Actes des journées scientifiques CNRS/Andra. Bar-le-Duc, October 20th and 21st, 1997. Edited by EDP Sciences.
4. Dossier 2005. Andra report for the 2005 milestone of the 1991 Waste Act. In French. www.andra.fr.
5. Proposition d'une zone d'intérêt pour la reconnaissance approfondie et de scénarios d'implantation en surface (in French). Octobre 2010.