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Identifying remaining socio-technical challenges at the national level: France

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Authors: Yannick Barthe, Morgan Meyer (CNRS)

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1 General introduction - historical overview

France isn't only a country known for its cheese… it's also a country of nuclear power. With its 58 nuclear reactors (63,000 megawatts), producing 79% of the country's electricity, France is arguably the world's leader in the production of nuclear energy. It is estimated that the relative contribution of nuclear energy to power production in France will decline to 70% in 2020 - the main reason for this being governmental investments into renewable energies. While France's reactors were all constructed between 1977 and 1996, two new reactors are to be commissioned in the near future: one in Flamanville in 2012 and one in Penly in 2017.

Two ministries, the Ministry of Ecology, Energy, Sustainable Development and Seas and the Ministry of Higher Education and Research are primarily involved in defining French nuclear policy today. The National Plan for Nuclear Waste Management (PNGMDR) defines policy at national level for radioactive waste management. Under this act, ANDRA (Agence Nationale pour la Gestion des Déchets Radioactifs) is in charge of radioactive waste management in the long-term (in the French nuclear fuel cycle, downstream activities are clearly divided, the main stakeholders being AREVA NC for treatment, MELOX for recycling and ANDRA for waste management).

It is in the beginning of the 1970s that the development of the nuclear industry intensified, with the launch of a large programme called *Messmer* programme (after the name of the prime minister at that time, Pierre Messmer). The implementation of this program was made without any national consultation and parliament has historically been left out of the decisions on nuclear energy, even though nuclear power has enjoyed and still enjoys today a fairly broad consensus among political parties (except for the Green party). Decision-making used to take place within the very confined circle of the "techniciens du nucléaire" (see Barthe, 2006). Indeed decisions were made by just a few people: prime ministers Pierre Messmer and Raymond Barre, people from the Corps des Mines, and from EDF and the CEA. The arrival to power of the socialists in 1981, rightly presented as a "turning point" in politics, did however not lead to a turning point in terms of energy policy: even though the government cancelled the project to build a new plant (in Plogoff in Brittany), it maintained the broad outlines of the Messmer program.

In 1979 a national agency (ANDRA) was created especially for the management of nuclear waste within the *Commissariat à l'énergie atomique* (CEA), the principal organism for research on nuclear issues in France. Besides carrying out research, the CEA advises the government and represents France at the IAEA. The CEA is also in charge of R&D needs for developing the 4th generation of reactors and is due to be transformed into the Atomic and Alternative Energy Commission (reflecting wider and governmental trends to focus on alternative, low-carbon energies).

The waste problem was thus taken charge of by ANDRA which took into account the choices made throughout the nuclear sector, such as the processing of irradiated fuels by another public agency, COGEMA (which later became AREVA) (the processing choices are made by the government). It also took into account the economic constraints of the financer of research, also the main producer of waste, Electricité de France (EDF), who manages the nuclear power plants.

Since reprocessing is now the set option, irradiated combustibles are not considered waste in France. Uranium and plutonium recovered via reprocessing operations are indeed re-used in the form of MOX fuel for existing power plants, or preserved for use in reactors of the fourth generation. These fourth generation reactors are scheduled for the end of the century. Meanwhile, it is the so-called third generation reactors that are topical, with the recent decision to implement an EPR in Normandy. Before finding a solution for final disposal, long-lived waste are temporarily stored at The Hague (the reprocessing plant of AREVA): they represent a volume of 47.000 m3 out of a total of 2 million m3 of radioactive waste, that is, 4.8%, in which 99.9% of all the radioactivity of waste was concentrated. Waste of low activity is stored above ground in two centres run by ANDRA: the Centre de la Manche (also close to the Hague, which is the oldest) and the centre of Soulaisne in the Aube department.

The issue of high-level and long-lived nuclear waste has been the major problem at the heart of many public debates on nuclear power over the past two decades. Since the late 1980s, it has given rise to many conflicts in the public sphere, in particular following the various prospecting campaigns conducted by ANDRA to find a geological disposal site.

At the end of the 1980s, following intense conflict sparked off by the implementation of a project to bury the most high level nuclear waste deep underground, the problem appeared on the political scene. The political framing was characterized by the intervention of actors that had traditionally been excluded from decision-making in this field (mainly members of parliament), by the opening of a public debate on the subject, and, finally, by an Act of parliament passed in 1991 – the so called "Bataille Law" – which redefined radioactive waste policy. This redefinition is characterized by 3 points:

- First, new procedures were established to improve information and debate. For instance, local information and consultation commissions - grouping together representatives of non-profit organizations and local councillors - were set up at the sites concerned by research on waste storage.

- Second, and more at a symbolic level, new ethical principles were asserted, such as the protection of nature, the environment and health, as well as the rights of future generations.

- Finally, and most importantly, the exploration of new research options became a requirement. In parallel with studies on irreversible and reversible geological storage, two other options were explored: processes of destruction of long-life elements in nuclear waste (separation and transmutation), and solutions for storage above ground.

In the last period, since the 1991 Bataille Law, the notion of reversibility – the possibility to revise past steps or chosen technical options – has come to occupy an increasingly central place in debates and decision-making concerning the management of high-level radioactive waste. In France, the requirement of reversibility has become a centrepiece of radioactive waste management policy and legislation. In 2006, a new law was passed that foresees a future vote by parliament of a "Reversibility" Act before granting any repository license, in order for the parliament to validate the reversibility approach of the proposed solutions.

The *Autorité de sûreté nucléaire* (ASN) (Nuclear Safety Authority) and the *Haut commitée pour la transparence et l'information sur la sécurité nucléaire* (High Committee for the Transparency and Information on Nuclear Security) were also created in 2006. The *Autorité de sûreté nucléaire* controls safety and radiation protection rules. It ensures compliance, advises the government, and communicates with the public. In fact, it is the Nuclear Safety Authority that decides on the (de)commissioning, safety and potential extensions of the lifetime of nuclear power plants. The other body involved in nuclear safety is the *Institut de radioprotection et de sûreté nucléaire* (IRSN), which looks into the protection of human and environmental health. It is the main (public) source for research on nuclear energy and risks in the country and ensures technical support for the government (i.e. ASN) and reports to several ministries. The 2006 law thus reorganises the links between politics, expertise and industry, i.e. through the ASN, which is named by the parliament and, crucially, by stating that only parliament can authorize geological disposal of waste. Some therefore talk of a « parlementarisation » of the nuclear problem (Huet, 2006).

However, the 2006 "Planning Act on the sustainable management of radioactive materials and waste" (PNGMDR) reminds us that geological storage is still the "reference solution" and proposed a schedule to implement it at Bure, in the East of France, a site that has been selected in the 1990s. The geological repository project is now named "CIGEO" (Centre industriel de stockage géologique). The site could be approved by the government in 2013 after a new public debate in 2013 and the License application for the construction of the geological repository could be granted in 2015/2016 after a Public inquiry and the Law on Reversibility (the facility is then due to open in 2025).

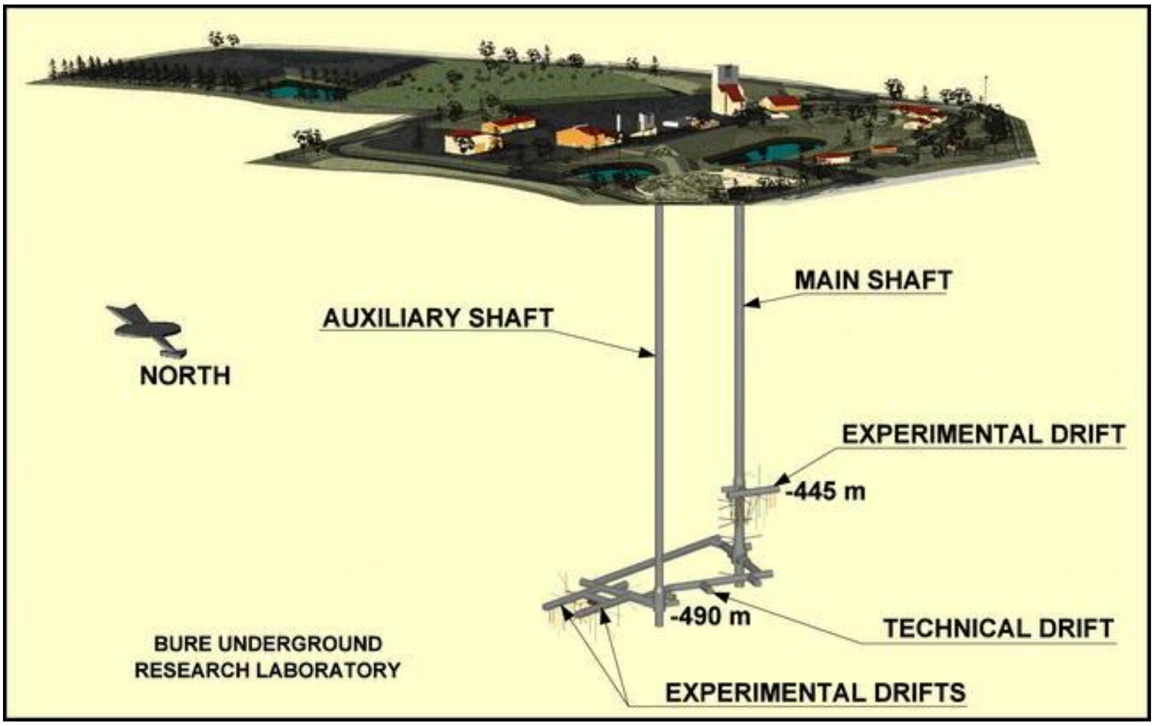


Figure 1: a schematic view of the general layout of the underground research laboratory in Bure.

Very recently, debates about nuclear power and nuclear waste have been particularly extensive. At the end of 2011, half a year before the French presidential elections, and at a time the Fukushima disaster still bears political consequences across Europe, the French Socialist party proposed a rethinking of the nuclear issue. The Socialist party signed a "Pacte" with the Green party, which, in case of a victory, they would carry out. The ideas of this pact include, for instance, to decrease the part of nuclear energy in power production from 75% to 50% by 2025 and to close down 24 of the 58 power reactors. In a joint press release issued in November 2011, both parties stated that:

> *we will strengthen the guarantees for the safety of French nuclear power and engage in a constant reconversion of employment in the sector of MOX reprocessing and the means for storing different types of waste, including the laboratory in Bure into centres of excellence for waste management and decommissioning.*

The plan was greeted critically by the political party currently in power (the right-wing UMP) as well as by the industry (EDF, AREVA, etc.). Both the UMP and industrialists are keen on the status quo in the nuclear domain and mobilise energy independence, competitive advantages, maintenance of jobs and low prices for energy as arguments against the Pact of the Socialists/Greens.

Also worth of being mentioned is that, following the stress tests after Fukushima, in January 2012 an audit report on the security of French nuclear installations was presented by the *Autorité de sûreté nucléaire* to French prime minister Fillon. Vast investments are recommended – the report says 'imposed' - in order to render the nuclear industry safer, especially in the case of natural events, or in the case of loss of water or electricity. The proposed ideas include, for instance, to create a "*force d'action rapide nucléaire*" capable of intervening in a site within 24 hours (and which should already operate by the end of 2012); a *groupe éléctrogène diesel d'ultime secours*, a "*noyau dur*" to assure the principal functions in extreme cases. Concrete figures are not yet provided, but a rough estimate says that it will amount to about 2 billion euro per nuclear power plant – the timeline for these investments to be made is 2018.

As we see, there have been important shifts since the mid-1970s, a time when geological (irreversible) storage was seen as the "optimal" solution for the management of long-lived and high activity radioactive waste. France's "technopolitical regime" (Hecht, 2009) has been substantially reconfigured in the past 2 decades. From a regime of "delegative democracy" there has been a transition towards a more "dialogical democracy" (Barthe, 2009, Barthe et al., 2010), and a shift from irreversibility towards reversibility as the guiding concept for nuclear waste management. In other words, a "reversibilisation" (Lehtonen, 2010) and a democratisation of the technopolitical regime took place over the past couple of decades. Two key "myths" about French nuclear power have started to break up, especially over the past year: that nuclear energy is cheap and that it is safe.

As waste augmented and as there were increasing demands for more transparency (especially in the aftermath of the Chernobyl fallout in which French authorities were accused of not being transparent and truthful to the public) new institutions, among which ANDRA, were created, or became entrusted with new missions. Policy-making and decision-making was to open up and become more transparent. For instance, Marie-Claude Dupuis, then-director of ANDRA, tellingly said in 2008 about work carried out at the Bure laboratory: "We will not take people by surprise. We will say everything what we will do". Yet, despite these efforts to make decision-making processes more transparent and more open, some criticise a certain "false transparency" on the nuclear issue and talk of a "pseudo-reversibility". During the CNDP debates (see appendix point B), people criticised that reversibility is a means to "*faire passer*" disposal and that it was an "alibi".

Today, then, deep geological storage of nuclear waste is at once a technical, public, political and institutional matter. Where and how deep waste is to be stored is an agencement of various actors and factors: rock formations, technical expertise, local municipalities and communities, the public, legal requirements and procedures, political constraints, France's specific nuclear history, the non-acceptance of irreversibility, European directives, etc.

1.1 Main sociotechnical challenges

- The issue of reversibility and retrievability. Today, France attempts to diffuse its concept of reversible geological storage as a “model”. Yet, numerous questions remain: for how long can reversibility be ensured? Is this principle compatible with the model of security based on irreversibility? And, finally, how to ensure reversibility on a decisional level?

- This last question refers to the issue of *alternatives* to geological disposal. If reversibility enables people to go back, one must indeed have other solutions. Hence, a number of questions need to be addressed: what is the degree of openness of research? Can the economic cost of exploring new options be supported? The attitude of EDF, which will finance storage facilities, has been ambiguous on this matter in recent years and the development of new options in the future may also result from the cost – which might eventually be judged as being too high - of geological storage.

- Related to the above points is, of course, the issue of the selection of the site for waste disposal. The French history of the selection of sites for geological storage has seen many, sometimes contradictory, developments. How are scientific criteria and political criteria taken into account in site selection? (How) are “geological feasibility” and “social desirability” concurrently negotiated and dialogues organised? How are a suitable political climate, a suitable rock formation, an interested local community, a favourable regional economic context interlinked?

- The question of the memory of the sites is also important (where and how waste is stored, and how to diffuse this information to future generations). Should we preserve the memory of the sites? If so, for how long? And should one focus on technical devices or draw upon social procedures?

- The variability of the definition of nuclear waste (see appendix point A). This variability is linked to the future of nuclear power, and to the political and economic choices that will be made about the future of the industry. For example, depending on the design of new reactors, the plutonium currently accumulated can finally be considered as waste that must be reprocessed.

2 Socio-technical challenge 1: retrievability/reversibility

As the debate about nuclear waste developed in France, the principle of the *reversibility* of solutions to be implemented to address the problem has gradually become an "obligatory passage point" in all kinds of discourses. Introduced by the 1991 law on nuclear waste as an option among others, the reversibility of storage is today presented as an essential requirement by most players in the field. Reversibility has become a governance principle in terms of radioactive waste management through the Planning Act n°2006-739 from June 28th, 2006. Indeed, this act calls for ongoing research in view of designing a high-level and intermediate-level long-lived radioactive waste (ILW-LL and HLW) reversible deep disposal facility. It assigned ANDRA the mission to complete those studies so that the licence application may be completed and filed in 2015, following a public debate planned for 2013, for a commissioning by 2025. It specifies that disposal reversibility shall be effective for a period of no less than one hundred years, and that a new act shall be required to set the facility's conditions of reversibility prior to a would-be licence (ANDRA, 2010).

ANDRA's framing of the term reversibility is important to highlight. ANDRA writes that reversibility "is not the direct result of a technical or scientific need, but of social demand and of a political choice, which engineers and scientists are duty-bound to accept" (ANDRA, 2010, 33). ANDRA further states that "the Agency must find socio-technical compromises, which means solutions that are robust both in technical and social terms […] the definition of reversibility can only be established on the basis of a dialogue between actors from both those fields" (ANDRA, 2010, 30).

The appearance of the theme of reversibility is directly related to claims being made during the 1990s by elected people and populations concerned by the research of ANDRA to find a storage site. These claims were widely discussed on a national level by a number of members of parliament and ministers. In their view, reversibility is essential as it should allow, in the case of scientific progress, at any future moment to recover waste to reduce its radioactivity. As early as December 1998, the French government announced that it was willing to clearly follow this logic of reversibility. The government recalled that "the condition of the acceptability of decisions is related to their reversibility" and that "it is crucial that future generations are not bound by the decisions already made and that they can be in a position to change their strategy according to any technological and sociological changes that may have occurred in the meantime". In 2002, ANDRA explored the motivations of using reversibility and identified three key issues: "Searching for openness in decision-making, "cautious" actions in an uncertain context, application of the precautionary principle and a scientific attitude of modesty".

The demands in favour of reversibility, usually made by the opponents of geological storage, did not lead to eliminate this option. But the introduction of this principle of reversibility has nevertheless led to redefine the initial approach concerning storage, which, until the mid-1980s, was an approach emphasizing irreversibility and "passive safety". Thus, the reference option is now that of a "reversible geological disposal."

However, despite the unanimity which the principle of reversibility now seems to enjoy, a certain number of ambiguities remain. And the manner in which this principle is respected appears to be a key socio-technical challenge. In the current debate, differences are noticeable as to the role that reversibility can or should play in the overall policy of nuclear waste management. Broadly speaking, it is possible to distinguish two competing conceptions of reversibility: on the one side, a conception that can be qualified as "restricted" in the sense that taking into account reversibility does not necessarily lead to a change in the hierarchy of solutions proposed so far, on the other, a conception which we can call "extended" in the sense that reversibility is instead seen as a fundamental change of "doctrine" that should lead to change this hierarchy.

2.1 "Reversible geological disposal" or the "restricted" conception of reversibility

According to the experts of the National Commission of Evaluation (CNE) of research in this domain, "reversible geological disposal" may be considered as a "necessary compromise between the technical constraints and the ethical requirements expressed by public opinion." (see Barthe, 2006).

(The CNE is a commission which was put in place by the 1999 law; it evaluates research in the nuclear domain, it consists of independent experts who are nominated by the government). While seeking such a compromise, this solution also appears to be a good translation of a "restricted" conception of reversibility (see Barthe, 2006). This conception is restricted, first, because the reversibility of a potential geological storage would necessarily be limited in time. Even if the research undertaken by ANDRA suggests the possibility of ensuring the reversibility of storage over several centuries, many doubts are raised about the reality and the effectiveness of what appears to be primarily a discursive argument: it seems that, indeed, the eventual recovery of waste will be increasingly difficult to undertake as time elapses.

Degradations due to the geological evolution, but also other problems, such as hydrogen, render the application of the principle of reversibility difficult or even impossible in the long run. In the minds of many actors, reversibility can actually only be applied to a limited period of time, roughly corresponding to the so-called "exploitation" period of the repository, that is to say a period from the moment the first waste is stored up to the point where the decision is made to close the repository after a certain period of time (about fifty years). In this perspective, reversibility inevitably leads, after this period, towards final and irreversible storage. Therefore reversibility is often denounced by opponents of geological disposal as a "*sham*", designed primarily to make people accept the solution presented in the late 1980s - namely irreversible geological disposal - as inevitable.

Second, this conception of reversibility is also restricted, since the reversibility of a potential geological storage is essentially considered by operators in terms of *monitoring*: the key issue being to maintain physical access to waste if certain problems were to appear, rather than considering an effective recovery of waste to benefit, for example, from progress made in other avenues of research (see Barthe and Gilbert, 2006). In other words, reversibility, from this perspective, allows foremost the establishment of a monitoring phase of deep disposal, before its final closure. But it does *not necessarily* mean that research into other methods of treatment be continued. And, also, this monitoring also represents a substantial burden for future generations and implies that these future generations have to consider how to preserve the memory of the disposal sites.

It is actually conceivable, according to this conception, to decide for a reversible storage without, however, engaging in the exploration of other options, which means that the decision amounts to an irreversible storage previously seen as reversible. Moreover, the pursuit of vitrification as the method for packaging high-level radioactive waste is a clear hint for the fact that this restricted conception of reversibility is the dominant view among those who promote geological storage. Vitrification is indeed a process that is essentially irreversible, the recovery of vitrified batches in view of separation and transmutation are to date either impossible, or at least uninteresting in terms of managing waste. Under these conditions, the reversibility of geological storage of vitrified waste can hardly been considered as a means of preserving the possibility to choose other options to treat these residues… Rather than taking about reversibility, actors then often prefer to speak of “récupérabilité” (retrievability) to describe this conception.

According to this first conception, reversibility only introduces a temporal shift in the implementation of the solution initially envisaged, yet, the horizon of irreversible geological disposal remains. Generally speaking, reversibility is, in this view, a secondary and limited principle: far from fostering a change in priorities amongst the various solutions, it is a means to “accommodate” irreversible geological storage: by inscribing the creation of such a repository into a longer temporality, it allows for a “de-dramatization” of this type of decision and to render it more acceptable.

2.2 Towards an "enlarged" conception of reversibility?

The opponents of geological storage generally argue in favour of another option that would, in their eyes, respect reversibility much more: the idea would not be to store waste below ground, but to do so above ground. This option is rarely considered as a "real" solution by researchers who are working in this domain. They generally express reservations about this solution, for it: does not solve the problem in a definite manner; presents the inconvenience of introducing strong constraints for future generations in terms of surveillance; and, finally, it is generally presented as a risky solution (possibility of terrorist attacks, forgetting, etc.). However, in contrast to geological storage, this solution of storing waste above surface corresponds to an "enlarged" conception of reversibility (Barthe, 2006).

It is an enlarged conception, first of all, to the extent that storage above ground is by definition a reversible solution. While geological storage will, over time, inevitably transform itself into a definite and irreversible solution, the storage of waste above ground is by its nature a provisional solution: after a given period of time, corresponding to around 100 years, it will necessarily have to be renewed to ensure the confinement of waste, if no other options have been chosen. It is also an enlarged conception, since storing waste on the surface does not only allow people to permanently maintain the possibility to choose another option. This option also *obliges* people to continue to do research and to find other modes of managing waste. In other words, in the case of surface storage, the retrievability of waste is not one possibility among others, it is more or less considered a necessity. Reversibility, in this sense, thus supposes that additional or alternative choices are made possible in terms of management. It is therefore a more socio-technical conception of reversibility. Finally, it is also an enlarged conception to the extent that surface storage means "putting on the agenda" the problem of nuclear waste in the long run, which thereby remains a problem to enlighten, to review, discuss, etc. and, conversely, a problem that cannot be presented as being definitively "settled" or forgotten.

One understands perhaps better, therefore, why surface storage can be perceived as a "threatening" management option by the operators of nuclear power. To the extent that it turns reversibility into an absolute principle (and not a relative principle), this solution leaves open a space of possible choices, and encourages people to explore other options and, correspondingly, to question choices that are consistent with closure, such as the vitrification of waste or geological disposal. In this perspective, the notion of "reversible geological disposal", despite its appearances, can be considered as a way to limit the political consequences of the introduction of the principle of reversibility, especially to hinder the materialization of options such as surface storage that seem to be more in line with this principle.

Thus, if reversibility is a principle that is clearly stated and is now part of almost all discourses about nuclear waste in France, this idea still raises many questions and challenges. Many actors, particularly those from the nuclear milieu, do not consider any real alternatives to storage, which amounts to consider that reversibility is only one step before a kind of storage which will end up being irreversible anyway. For opponents of geological disposal, however, reversibility must, above all, maintain the possibility of recovering waste to benefit from progress made in other areas of research, such as transmutation. Therefore, some key questions remain: to what extent is reversibility, as envisaged, really designed to allow the examination of new options that may result from technical and scientific developments? Is geological disposal able to guarantee reversibility over long enough periods to allow for moving forward on new options to the point that it becomes interesting to recover waste? How to reconcile the idea of reversibility demanded by local populations and the traditional concept of safety in this area, a concept based instead on the idea of passive safety? This is a major socio-technical challenge of managing nuclear waste in France.

The concept of reversibility presents both benefits and drawbacks. One of the benefits is that in terms of decision-making, there is no single decision to be made, which would solve once and for all the problem of waste disposal, nor is there a succession of small decisions inevitably leading to a final solution. Rather, reversibility allows for an iterative process, a process that is not linear, but open-ended and flexible, a process that can become cyclical, repetitious, etc. Yet, the term reversibility is rather vague, which has both advantages and disadvantages. On the one hand, the exact "content" of the concept of reversibility is not something pre-determined or pre-given. Theoretically, at each stage in the disposal process, it can be decided a) to reverse, b) to change, c) to continue, or d) to reassess. Reversible disposal of radioactive waste thus involves several features: uncertainty, flexibility and irreversibility (Héraud and Ionescu, 2011: 11).

This definitional and decisional plasticity allows for a more open process and the inclusion of a larger number of actors to define the meaning of reversibility and to operationalize reversibility into a set of techniques, methods and procedures. It also means that reversibility has to be "realised", or brought into existence, that is to say, that those concerned with reversibility need to figure out "when" and "how" to enact reversibility. But, on the other hand, this flexibility and openness also has shortcomings: decisions are actually "non-decisions" or a way to postpone decisions, since they can be undone in the future; efforts need to be put into "demonstrating" reversibility, that is, making the case and showing concrete guarantees for reversibility; its alleged openness might actually hide a narrow technical vision, and a dismay for other options, eventually leading towards irreversible storage. Reversibility is thus a socio-technical challenge since it concurrently opens up a variety of debates: about the depth of storage, the methods of packaging waste, the degrees and duration of reversibility, the kinds of decision making, and so on and so forth. Even the kind of reversibility (which we have called "restricted" versus "extended") is open to debate and how to "demonstrate" and "show" reversibility is now high on the agenda.

3 Socio-technical challenge 2: site selection process

At the moment, France has selected one site to establish a centre for interim nuclear waste storage, located in Bure in the department of the Meuse in the East of France. Although the selection of a second site is currently not on the agenda, the history of nuclear waste management in France shows that the initial idea was however to select several sites in order to have a greater flexibility in terms of the final choice. Therefore the selection of storage sites remains a socio-technical challenge that could quickly become topical. This challenge can be qualified as a socio-technical challenge to the extent that this selection process has been in the past - and will probably be in the future - subject to two constraints that may not be aligned: on the one hand, to choose a site that fulfils the requirements in terms of geology and, on the other, a site that is also accepted by elected officials and the local populations concerned. The different selection processes of sites that have been implemented in France since the late 1980's have generally sought to address these two constraints, with varying degrees of success.

The 1991 law, which helped to redefine the policy of radioactive waste management is the result of conflicts arising in the late 1980s by ANDRA's research on geological disposal. The sites surveyed by

ANDRA at that time were selected only according to geological criteria and without any local consultation (see Barthe and Mays 2001). This led to fierce local opposition. At the four selected sites, the opposition of elected officials and of concerned residents was very violent, which led to the government's decision to end the policy of prospection and to impose from now on a consultation with people. In the 1990s, therefore, decision-makers reconfigured their communication strategy in order to channel and contain controversies. Thus, rather than being secretive, opaque, technocrat (which they had been criticised for), they were now keen to embark on processes that were more open, democratic, and based on dialogues with local stakeholders, politicians, and communities.

In 1993, in order to implement this consultation foreseen under article 6 of the 1991 law, a mission of "mediation" was assigned to the socialist MP Christian Bataille (the person who was also at the initiative of the 1991 law). The “mediator” was entrusted with the mission to expand the debate held in Parliament when the law was passed to a local level and to propose, as a result of his mission, two new sites to conduct research on deep geological disposal. To accomplish this mission, he had a very large freedom of action. No selection process was clearly defined by law. In addition, members of parliament did not provide any real legal substance to the notion of "concertation". As a consequence, since specific rules were absent, and in order to construct his approach, the mediator essentially built upon lessons learned from the previous period. Above all, the idea was not to repeat past mistakes. It is this principle that characterized every stage of the procedure, which explains that it was marked by a series of changes compared to the approach that was taken in the previous period. We can identify at least two main changes:

(i) The first important change concerns the hierarchy of selection criteria. By making a call for applications prior to the study of geological siting, the mission of mediation reversed the approach that characterized the previous phase. A previously defined decision was no longer imposed, but a call for volunteer regions was made and the social acceptability of projects became the main criterion for site selection. When taking office, the mediator clearly announced a change in method:

> *"I propose to test the geological feasibility of the projects proposed by the regions that are interested and not, as was done until now, try to convince the populations of the sites selected for their geological qualities" (Le Monde, January 14, 1993).*

The choice of sites to house an underground laboratory to test the feasibility of geological storage is no longer given in advance through the mobilization of predetermined technical criteria. The idea was primarily to interest local stakeholders and to draw a map of the "politically desirable" even before taking into account what's "geologically feasible." The process of selecting sites had thus to pass two trials of strength, one socio-political, the other techno-scientific. One of the lessons learned from past processes, was that site selection solely based on what's "geologically feasible" proved problematic and might actually strengthen or even give rise to an undesired actor, people-against-nuclear-waste. The new course of action to be taken was thus to be the following one: in order to – and, importantly, even before one could – consider geological formations, the formation and consolidation of a local community and a political climate accepting a storage site was fundamental.

(ii) The second major change was that compensation measures for the departments that would host an underground laboratory ware now made explicit. What used to be a discreet arrangement between the state and local officials was now being made public. The promises of economic development ware placed at the heart of the process of presenting the project.

To attract elected officials and encourage candidatures, the "accompanying measures" were explained, and they were made legitimate in the name of the effectiveness of the approach. Thus, in its call for applications launched in 1993 in a magazine destined to local representatives, the mediator identified the economic benefits associated to the implementation of a laboratory: a grant of 60 million French francs a year (during the entire period of operation of the laboratory, that is, about 15 years) to be distributed among the municipalities located within 10 km of the site; the creation of 150 jobs directly related to the construction and the operation of the laboratory; the possibility to implement "technological development centres" around the laboratories to benefit from the project in order to create a dynamics of economic and business development.

After the call for volunteers, the mission received about thirty candidates and/or requests for information on the project. Most of the candidates were municipalities from very small communes, in the rather structurally poor northeast of France. For those municipalities, the investment promised by the disposal site meant a very important economic prospect. But only eight departments were retained, departments for which the human, political and geological conditions seemed to overlap: the Allier, the Gard, the Indre, the Marne, the Haute-Marne, the Meurthe-et-Moselle, the Meuse and the Vienne. Thereafter, a second phase of the mission started during which the mediator sought to evaluate in more detail the applications received. In his report, which he presented to the Prime Minister in December 1994, the mediator noted that some of the departments that were consulted did finally not seem to be suitable for the establishment of a laboratory (the main reason being the lack of a political consensus). For others, on the contrary, he believed that there was a favourable, or even a very favourable, *a priori* towards the project. This led him to propose that work be undertaken on the geology in only four departments: the Gard (clay), the Vienne (granite), the Meuse and the Haute-Marne (both clay). The four departments selected to further carry out geological examinations were characterized by the combination of two criteria (Barthe, 2006). On the one hand, they were departments marked by an important political stability, particularly due to the presence of political figures - of "opinion leaders" - capable of heading and leading the majority of elected officials but also to influence decisions made by the government. On the other hand, the economic difficulties of these departments were another factor of "sustainability" that seem to have had its weight in the selection process.

In light of the economic depression, politicians tended to apprehend the laboratory project and its financial rewards as a way to restructure the department economically, to fight against "rural depopulation", or, in the case of the Gard, to compensate for the planned closure of several nuclear facilities at Marcoule. There were, in other words, efforts to rely on a political agreement and thereby to avoid the main drawback of this type of agreement, namely its transient character and the possibility of challenges in the course of turmoils during election times.

In order to be able to preserve the implementation process and to avoid the danger of challenges and contestations, four departments were ultimately recommended in the study – even though the law foresaw the construction of only two laboratories. In the framework of the Bataille mission, a careful approach was thus preferred: the idea was to dispose of a "margin of error" in the process and thus not to be stuck in the impasse to which previous phase had led. In addition, people also wanted to benefit from (the time of) the geological survey to consolidate, through information and consultation, the political consensus created around the project. In view of the violent opposition triggered by the work of ANDRA on geological disposal in the late 1980s, the approach taken by the Bataille mission of meditation thus introduced a striking contrast.

The concertation allowed to boost research into three new sites (the site of the Meuse and the Haute-Marne have been grouped together) and has, for a long time, been regarded as a frank success by policy makers in nuclear waste management. The concertation has even been presented - especially to foreign partners – as a "model" approach in nuclear waste management. But, in retrospect, it must be recognized that these were hasty judgments. The "results" of this mission do actually not seem match the expectations initially raised. There are two reasons for this. First, the extended temporality of the process proved to be a double-edged sword: in some cases, it helped to build and consolidate a broad agreement in favour of the project, such as in the department of Vienne. But in other cases, time also created uncertainties and allowed new oppositions to be built or be strengthened: this is typically the case for the site in the Gard were the opposition of wine growers to the project became more and more virulent. As we see, then, these more decentralised and transparent decision making processes favoured by the mission and the communication strategies about research programmes did not manage to contain all kinds of controversy. The fragility of such alliances is evident: they can be challenged and become subject to controversy.

Second, the disadvantages of an approach giving clear priority to political criteria at the expense of geological selection criteria were also revealed over time. Following a very reticent opinion of the National Evaluation Committee (a committee of experts) on the hydro-geological qualities of the site of Vienne, the latter was abandoned by the government despite the fact that local officials were keen on the project. In the end, only one site out of three was selected: the one in Bure in the Meuse. Bure is located in the Jurassic-age Callovo-Oxfordian argillites in Eastern France and was deemed interesting for ANDRA for several reasons: it is a stable rock formation and a “highly detailed mapping work and various oil drilling operations during the second half of the 20th century” was available (Delay et al. 2007). Natural characteristics (the permeability, stability, homogeneousness of the rock), historic and epistemic reasons (it is “geologically simple and well known”) and socio-political reasons came together in the selection of the site.

However, since only one out of four sites was selected, the Bataille mission can ultimately be considered a "half-success" or, conversely, a "half -failure" – and it must be recognized that the effect of the mission was to defer parts of the problem, namely the choice of a second site for the installation of an underground research laboratory, hence the idea to redo a selection process to find a second site. This was actually the objective of the "Granite mission of concertation" (“mission de concertation Granite”) established by the Government in 1999 in order to set up an underground research laboratory on nuclear waste in granite. The main issue at stake was then how to organize a new dialogue, after the Bataille mission of mediation, which could overcome the limitations of the latter while trying to preserve its main virtues. The design of the Granite mission thus occurred after an informal assessment of the whole process that had been embarked on since 1993. The concern to avoid a “scientific sanction", as in the case in Vienne after several years of work and consultation, led people abandon the Bataille approach by reversing again the hierarchy of selection criteria and by privileging now the "scientific rigor" of the process.

While one of the original features of the "Bataille approach" was to call for volunteering municipalities to select sites a priori in favour of the project, the procedure of the Granite mission was the exact opposite since the first phase of this new process consisted in determining at the national level those sites that might be suitable in terms of scientific criteria only. To do this, a study based on documents was carried out by ANDRA and the Bureau of Geological and Mining Research (BRGM) in 1999.[i] This study was then submitted to the National Review Commission in September 1999, which gave a favourable opinion from a scientific point of view. The geologists were thus able to draw a map of the granite sites that could, from a geological point of view, be suitable. Fifteen massifs were identified, involving 16 French departments.

One can interpret this inversion of sequences between "political acceptability" and "scientific acceptability" as a real step backwards since the approach strangely resembles the one that characterized the first campaign of exploration carried out by ANDRA from 1987 to 1990. With the same result: the mere announcement of the visit of emissaries from the government to the departments selected for their quality of geological subsoil triggered a real outcry almost everywhere from January 2000 onwards. This massive opposition led locally to the creation of numerous "anti-waste collectives", to the signing of petitions, to solemn votes for municipal deliberations, but also, of course, to the organization of public events, sometimes festive, at other times more stormy.

The French history of the selection of sites for geological storage has seen many, sometimes contradictory, developments. The inclusion of both scientific criteria and political criteria proves to be a key issue, above all, superimposing/juxtaposing the two is complicated. Campaigns where we observed the prioritisation of scientific criteria over political criteria, or vice-versa, have yielded mixed results at best and failures at worst. In both scenarios, the political or the scientific always seems to “strike back” when not sufficiently considered and taken into account. As we see, then, the site selection process is a socio-technical challenge for a number of reasons, amongst which: the necessity and difficulty of taking into account both “geological feasibility” and “social desirability” concurrently; the difficulty of organising dialogues, of finding a suitable political climate, a suitable rock formation, an interested local community, a favourable regional economic context. And, the challenge is also a procedural one, be it in terms of the (absence of) legal content of terms like “concertation”, of the entanglement of national, regional and local politics, or of participative decision-making in general.

At the moment, then, the situation is rather a fragile one, since there is, to date, only one site in which research on geological disposal is being carried out, namely Bure. For ANDRA, Bure represents a scientifically robust option. In June 2005, for instance, ANDRA released a report which concluded that “in principle, the feasibility of storage in clay formations is now acquired” in a zone about 200 km2 in the north and east of Bure and that “Since its deposit, the history [of the clay layer] has been very calm, which is a major argument to establish its homogeneity and its extreme stability”. Yet, despite this, having only one site leaves decision-makers with not much room for manoeuvre and flexibility in the near future, should there be no second or third site. Also, there have been voices against the Bure laboratory and the prospect of having a disposal site nearby. The Bure laboratory has been criticised because its “raison d’être” is not only to be a research laboratory, but also, in the eyes of some critics, a “Trojan horse” for geological disposal. Resistances against Bure have taken various forms, i.e. the book “Le site de Bure et les déchets radioactifs, Carnet de Bure 2001-2006” (2008) written by Bernard Fery on what local people make of the site; the collective “Bure Stop” which regularly organises demonstrations; as well as expertises or activities by the Commission de recherche et d'information indépendantes sur la radioactivité (Criirad) and the Sortir du Nucléaire network.[ii]

4 Socio-technical challenge 3: societal memory

> "You have to imagine very well the needs of those who should have access to this knowledge for centuries to come. [...] To consolidate these reflections on robust solutions over a large time scale, ANDRA is interested in the heritage inherited from previous centuries" (ANDRA).

The ways in which information about the location and the technical details of storage sites are to be safeguarded (or not) is an issue that is currently being explored. ANDRA's way to tackle the issue of 'memory' is subdivided into 5 "dispositifs". On the one hand, there are two short and medium-term dispositifs: informing the public and following the functioning of the site of storage. On the other, there are three long-term tools and devices: detailed memory such as documents, stored at the site and at the National Archives; synthetic memory in the form of a single volume, distributed to local and national decision-makers and the public; as well as "Servitudes ou tout acte inscrit au cadastre" (Easements or any act registered in the cadastre). For instance, the document *Préserver la mémoire des centres de stockage* (ANDRA, 2006) (Preserving the Memory of the Storage Centres) examines how, in the middle ages, manuscripts were stored or how the Académie Française archives its texts. In order to safeguard memory, several methods can in fact be used. Information can be printed, for instance, on permanent paper, a kind of paper that can preserve ink between 600 and 1000 years. Or, reflections about how to materialise memory over millenaries in various forms are examined: through art works, various kinds of objects, monuments like pyramids or the statutes on Easter Islands, and so on and so forth.

Yet, social memory does not only have to do with the materiality of the preservation of information. It also has to do with preserving certain practices, traditions, or procedures. Even after the closure of a site, several practices are to be maintained: "activities of communication of ANDRA (a journal of the site for example) and the bodies of concertation such as the local committees composed of representatives of the people and authorities concerned" (ANDRA, 2006). Preserving the social memory of storage sites also means having to deal with expertise that goes beyond mere technical expertise. "We will have to leave the world of the engineer, and to turn ourselves to past civilizations to examine how their culture has survived. We will work together with archaeologists, historians, anthropologists", the person in charge of sustainable development at ANDRA explains (Patrick Charton quoted in Farthouat, 2008). ANDRA has also organised open-days of some of its facilities, some commentators mocking these as being a form of "nuclear tourism" and something akin to a visit to "Nuclear Park" (du Roy, 2010).

The social memory of storage sites is a multifaceted socio-technical challenge as it brings together a number of issues: the materiality of the transmission of information, the envisaged time-span over which memory has to be stored, knowledge and assumptions about future generations, different kinds of expertise and technical know-how, weighting the benefits and drawbacks of making information available, the exploration of the effectiveness and forms of memory transmission of past cultures and, last but not least, the necessity to consider memory at once as written information, concrete objects, social practices, material techniques, oral traditions, political norms, institutional behaviours...

Appendix: The classification of waste in France

The 28 June 2006 law differentiates between radioactive waste and radioactive material that can be valorised (impoverished uranium, etc.). The PNGMDR classifies radioactive waste according to 5 categories: high-level, medium level and long lived, low level and long lived, low and medium level and short lived, and very low level waste. Two parameters are taken into account for this classification: the level of radioactivity (or activity) and the period of radioactivity (or half-life).

Figure 1: ANDRA's classification of nuclear waste (source: ANDRA)

Storage

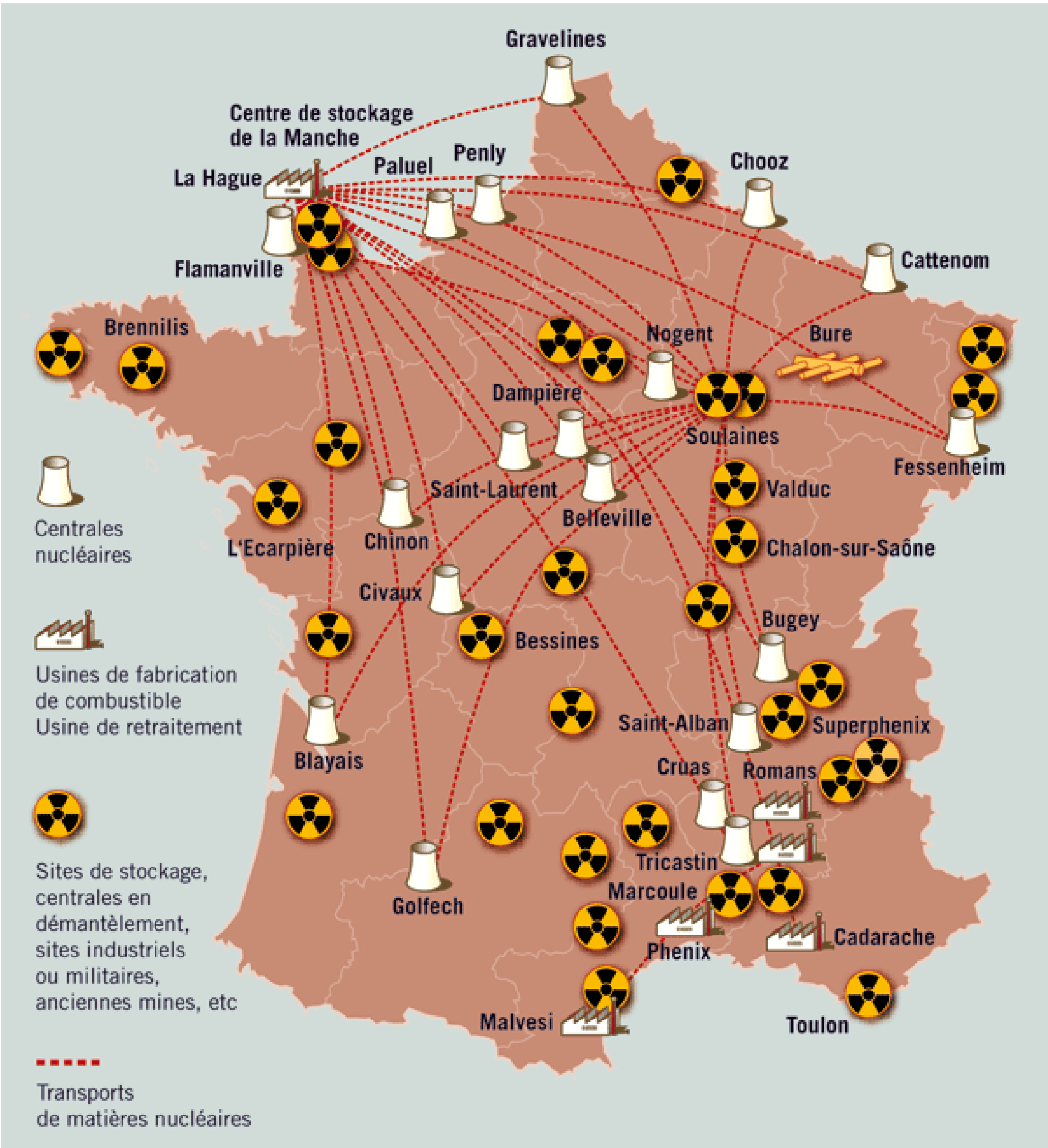
By the end of 2007, there were officially 1121 sites in which radioactive waste was stored. However, more than 90% of radioactive waste is concentrated in the sites of La Hague and Marcoule. Storage varies according to the kind of waste:

- HLW is stored at production sites (La Hague, Marcoule, Cadarache)
- ILW-VL-waste is stored at production sites (La Hague, Marcoule, Cadarache)
- LILW-SL are mainly stored at la Aube in Eastern France
- LLW are stored in several sites
- VLLW are stored at ANDRA's *Centre de stockage TFA* (Aube), in operation since 2004

As can be see also on figure 1, the management solutions range from surface disposal, in the case of very low-level radioactive waste up to deep disposal, for high level radioactive waste. While high-level waste is currently stored at Hague and Marcoule, the idea is, in the long run, to dispose of this waste in deep disposals in the north-east of France (in the Meuse and Haute-Marne departments).

Here is a timetable for deep disposal.

- 2010-2011 comprehensive survey of the interest zone
- 2012-2013 public debate
- 2013 final site selection in the interest zone
- 2015 application for construction licence
- 2017 start of construction (if authorisation is granted)
- from 2025 onwards disposal of waste containers



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[i] The Bureau de recherches géologiques et minières (BRGM) is the key public actor in earth science and management of resources and risks of sol and sous-sol. The BRGM has started to work with ANDRA in 1998 and has renewed a 4-year collaboration for 2011-2014. BRGM is one of the partners of the so-called “Group of Laboratories” (which also include EDF, Inéris, LAAS-CNRS, LCPC, LNE, PACT and the University of St-Etienne, UTT).

[ii] Here is a longer list of those actors involved against nuclear power and geological disposal of nuclear waste : Association des Écologistes pour le Nucléaire ; le Conseil National des Ingénieurs et Scientifiques de France ; les Collectifs Bure-Stop (CEDRA 52 et CDR 55) ; la Coordination Nationale des Collectifs contre l’Enfouissement des Déchets Radioactifs ; le Comité de Réflexion et d’Information sur la Lutte Anti-Nucléaire ; Greenpeace France avec WWF, Amis de la Terre, Agir pour l’Environnement et France Nature Environnement ; le Groupement des Scientifiques pour l’Information sur l’Énergie Nucléaire ; Sauvons le Climat ; la Société Française d’Énergie Nucléaire ; Sortir du Nucléaire.