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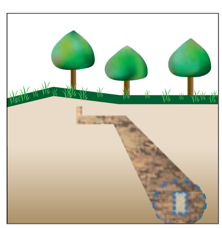
Reversibility and Retrievability in Planning for Geological Disposal of Radioactive Waste

Proceedings of the "R&R" International Conference and Dialogue
14-17 December 2010, Reims, France



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Organisation for Economic Co-operation and Development

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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Foreword

In 2007 the OECD Nuclear Energy Agency (NEA) Radioactive Waste Management Committee (RWMC) launched a four-year project on the topics of reversibility and retrievability in geological disposal. The goal of the project studies and activities (www.oecd-nea.org/rwm/rr) was to acknowledge the range of approaches to reversibility and retrievability (R&R), rather than to recommend a specific approach, and to provide a basis for reflection rather than to lead towards a particular conclusion. The NEA Working Group on Reversibility and Retrievability enjoyed participation from 15 countries and 2 international organisations. The project benefited from exchanges among an ever-widening group of interested parties that culminated in the International Conference and Dialogue on Reversibility and Retrievability in Planning for Geological Disposal of Radioactive Waste held in Reims, France, in December 2010.

The members of the R&R project prepared the three-day conference and dialogue in order to open the discussions to a larger audience. The objectives of the conference included allowing and recording as many points of view as possible, discussing and better understanding commonalities and differences, testing and refining the findings of the draft NEA R&R project report, and refining the international R-scale, a tool for dialogue that has been developed within the framework of the NEA R&R project.

The event was open to all interested parties and featured participation from civil society stakeholders, implementers and scientific researchers, regulators, policy makers and social scientists. Some 180 persons attended, making or hearing plenary presentations, and dialoguing in breakout round-table sessions.

Among the key points that emerged were:

- The development of any geological repository for radioactive waste will take place over many decades and should be open to progress in science and technology, to evolving societal demands and to fixing potential implementation errors. In this regard, selecting technologies that are as reversible as possible is a prudent approach. There is interest in a number of countries to show that retrieval of the waste is feasible during the period of waste emplacement or even during a certain period after closure of the repository.
- While countries differ in their plans to study retrieval before or after closure of a repository, the Retrievability Scale developed by the NEA R&R project is a useful communication tool across contexts. It shows that even if geological disposal is intrinsically a reversible technology, ease of retrieval through the various stages of repository implementation can only be a matter of degree.
- There is strong societal interest in reversibility of decisions or retrievability of waste, as indicated by legal provisions in many countries. In France, for instance, reversibility is at the core of the current technical and societal debate framed by its stepwise waste management process. There is universal agreement, however, that R&R provisions are never to interfere with long-term safety. R&R only add value to a final management solution that rests on passive safety.
- Reversibility of decisions and retrievability of waste are complex subjects that cannot be considered in isolation from safety and societal issues. Further reflection and dialogue are needed, in particular to harmonise vocabulary and to define key terms such as

"disposal", "storage", "waste" and "closure". Because there is no "one size fits all", each concept should be adapted to its national context.

These proceedings contain the conference presentations, the reports from the round-table sessions and the poster abstracts. All are published under the responsibility of their authors.

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R&R IN PLANNING FOR GEOLOGICAL DISPOSAL OF RADIOACTIVE WASTE, ISBN 978-92-64-99185-9, © OECD 2012

Executive Summary

The International Conference and Dialogue on Reversibility and Retrievability in Planning for Geological Disposal of Radioactive Waste took place at the *Centre des Congrès* in Reims, France on 14-17 December 2010. The conference was organised by the OECD Nuclear Energy Agency (NEA) in co-operation with the International Atomic Energy Agency (IAEA), the European Commission, and the International Association for Environmentally Safe Disposal of Radioactive Materials (EDRAM). It was hosted by the French National Radioactive Waste Management Agency (Andra), with support from the Swedish National Council for Nuclear Waste (KASAM), the United States Nuclear Waste Technical Review Board, Germany's Nuclear Waste Management Commission (BMU), Japan's Advisory Committee on Geological Repository Safety (NSC), Japan's Institute of Applied Energy, the French association *Décider Ensemble*, the UK association NuLeAF, France's Local Information and Oversight Committee of the Meuse/Haute Marne Laboratory (CLIS de Bure), and the French Universities' network *Groupe des Écoles des Mines*. The conference was chaired by Mr. Claude Birraux (MP), President of the French Parliamentary Office for Technology Assessment (OPECST).

Over 180 participants from 16 countries around the world, including policy makers, civil society stakeholders and experts from academia and from implementing and regulatory organisations took part in the conference by means of invited presentations, panel sessions, round-table discussion sessions and poster sessions. Simultaneous English-French translation was provided. Session topics included national policies on the subjects of reversibility and retrievability, messages from the social sciences, the perspectives of implementing organisations, expectations of local stakeholders and non-governmental organisations, optimal choices and duties to future generations, and the place of reversibility and retrievability in regulatory policy.

The NEA had established a working group on reversibility and retrievability in 2007, and this "R&R" Working Group acted as programme committee for the conference and prepared documents that were made available to conference attendees. One of these was a "retrievability scale" that has already been used as an aid to communications in a number of countries. The full report of the working group, including this scale in annex, has been published by the NEA.[1] The scale is also available as a stand-alone leaflet. A short brochure with key messages from the R&R initiative has also been published.[2] The project website, from which these and other publications may be downloaded, is *www.oecd-nea.org/rwm/rr*.

During the opening session, welcoming addresses were given by Mr. Jacques Meyer, Deputy Mayor of the City of Reims; Mr. Luis Echávarri, Director-General of the NEA; Mr. François-Michel Gonnot (MP), Chairman of the Governing Board of Andra; Mr. Piotr Szymanski, Director, DG-ENERGY, European Commission; and Ms. Irina Mele, Head of the Waste Technology Section of the IAEA.

It was noted by Mr. Meyer and Mr. Gonnot that the conference was of particular interest in France because of the longstanding importance of reversibility as a requirement in the French disposal programme. The conference was also timely because of the upcoming decision making on a disposal project for high- and intermediate-level waste expected in 2016.

1. Nuclear Energy Agency (NEA), "Reversibility and Retrievability (R&R) for the Deep Disposal of High-level Radioactive Waste and Spent Fuel", OECD/NEA, Paris (2011).
2. NEA, *Reversibility of Decisions and Retrievability of Radioactive Waste; Considerations for National Geological Disposal Programmes*, OECD/NEA, Paris (2012).

From an international point of view, reversibility and retrievability have been subjects of discussion and comparison for several years, among these an earlier international conference held in Sweden in 1999, an international summary report on the subject published by the NEA in 2001,[3] and subsequent projects undertaken by each of the three international organisations represented at the conference.[4]

The second session was intended to set the scene and consisted of addresses by the conference Chairman, Mr. Birraux, and by Mr. Claudio Pescatore, Principal Administrator in charge of decommissioning and radioactive waste management at the NEA and manager of the NEA's current international project on reversibility and retrievability.

Mr. Birraux described the parliamentary oversight of the French radioactive waste disposal programme. He expressed his pleasure that representatives of French civil society and in particular the CLIS de Bure were participating in the meeting.

Mr. Pescatore presented the major findings to date of the NEA's reversibility and retrievability project. He noted that reversibility is a decision-making feature that is part of a sensible approach to any large complex project. The idea of reversibility is not necessarily to make reversal easy, but merely not to make it unduly difficult. Reversibility is also a means to promote dialogue. As for retrievability in geological disposal, retrieval of the disposed material is always possible; the question is, how difficult should it be to retrieve? Retrievability is thus a matter of degree, not an absolute yes/no issue. Regardless of what position is taken on retrievability, safety must not depend on retrievability, and retrievability must not undermine safety. Mr. Pescatore also noted that in discussing the subjects of reversibility and retrievability, clarity on terminology is important. There are differences in the way various terms are used in different countries, or even by different communities of interest within a single country.

The third session, focused on country situations at the policy level, was chaired by Ms. Kathryn Shaver, Vice-President, APM Engagement and Site Selection, Nuclear Waste Management Organization (Canada). This session consisted of short presentations by senior representatives of national disposal programmes in Finland (Ms. Jaana Avolahti, counsellor to the Ministry of Employment and the Economy); Switzerland (Mr. Michael Aebersold, Head, Disposal of Radioactive Waste, Federal Office of Energy); Germany (Mr. Georg Arens, Head, Division for Fundamental Aspects of Nuclear Waste Management and Final Disposal, Federal Ministry of the Environment); the United States (Ms. Catherine Haney, Director, Office of Nuclear Material Safety and Safeguards, Nuclear Regulatory Commission); Belgium (Mr. Philippe Lalieux, Director, Long-term Management, ONDRAF/NIRAS); Sweden (Ms. Ansi Gerhardsson, Deputy Director, Ministry of the Environment); and Japan (Mr. Seiji Shiroya, Commissioner, Nuclear Safety Commission). These presentations made evident the wide range of approaches to the subjects of reversibility and retrievability in different national programmes.

Following a lunch break, the fourth session focused on key messages from the angle of policy studies and the social sciences. The session was chaired by Mr. Daniel Metlay of the United States Nuclear Waste Technical Review Board.

Mr. Luis Aparicio (Andra) presented the work of the social sciences programme set up by Andra as part of the development of its mission in France. Under French legislation, Andra is responsible for preparing robust social as well as technical arguments in support of its disposal programme. One of the main aspects of this work so far has been the building of bridges between the engineering and social sciences communities. Mr. Carl Reinhold Bråkenhielm (University of Uppsala and Commissioner, Swedish National Council for Nuclear Waste) described the work of the council and the role of social sciences in this work, including surveys of opinions and attitudes as well as broader work on the relationships between science and society. Mr. John Whitton

3. NEA, *Reversibility and Retrievability in Geologic Disposal of Radioactive Waste – Reflections at the International Level*, OECD/NEA, Paris, November (2001).

4. These and other works may be identified by consulting the "Selected International Bibliography on Reversibility and Retrievability to Support the Current NEA Project" [NEA/RWM(2010)11, OECD/NEA, Paris (2010)].

(National Decommissioning Authority, UK) spoke of NDA's history of engaging stakeholders, and how stakeholders perceived the dialogue to influence the NDA decision-making process. Ms. Sandrine Spaeter (University of Strasbourg) described an economist's view of reversibility from the point of view of the Real Options Theory. Mr. Walter Wildi [University of Geneva and head of the Swiss working group "Concepts of Nuclear Waste Disposal" (EKRA) in 2000-2002] described the role of social and ethical considerations in the development of the Swiss disposal programme. Mr. Gerrit Raauws (Director, Health Programme of the King Baudouin Foundation) presented the results of the Citizens Conference conducted by the foundation in order to identify the concerns and wishes of Belgian citizens with respect to disposal. Ms. Claire Mays [Social Sciences Consultant to the NEA Forum on Stakeholder Confidence (FSC)] described the FSC's work of relevance, including work on the symbolic dimension of waste management, and on the role of reversibility and retrievability in regard to societal participation in stepwise decision making on waste management.

This session was followed by six parallel breakout round-table discussions, in which participants in mixed groups were encouraged to discuss topics such as key messages from the social sciences and the future role of social sciences in decision making on disposal. A rapporteur from each breakout group gave a brief summary of the discussions at the beginning of the following day's session. Perhaps the most important outcome of these discussions was recognition of the importance of continuing dialogue throughout the societal process of repository development.

The sixth session, "Perspectives on R&R from Institutional Players", gave the floor to technically-oriented organisations involved in the implementation of disposal programmes, with presentations from the United States (Mr. Steve Wagner, Sandia National Laboratories, Waste Isolation Pilot Project), the European Community's ESDRED project (Mr. Jean-Michel Bosgiraud, Andra), Sweden (Mr. Erik Setzman, SKB), the United Kingdom (Mr. Brendan Breen, Nuclear Decommissioning Authority), Japan (Mr. Hiroyuki Tsuchi, NUMO), France (Mr. Jean-Michel Hoorelbeke, Andra), Belgium (Mr. Walter Blommaert, FANC) and Germany (Mr. Jürgen Krone, DBE). Once again these presentations highlighted the wide range of approaches to reversibility and retrievability in different programmes, at both the technical and the policy level. The session was chaired by Mr. Bernd Grambow, *École des Mines* (France).

The next session, on "Expectations Expressed by Local Stakeholders and Non-governmental Organisations" (NGOs), was chaired by Ms. Eva Simic of the Swedish regulatory authority. Presenters included Mr. Jean-Paul Lheritier and Mr. Roland Corrier (CLIS de Bure), Mr. Fergus McMorrow (West Cumbria Managing Radioactive Waste Safely Partnership), Mr. Martin Donat (Atomausschhuss Lüchow Dannenberg), Mr. Johann Swahn [NGO Office for Nuclear Waste Review (MKG)], and Mr. Thomas Flüeler (Department of Public Works, Canton of Zürich). The presentations brought home the wide range of attitudes towards the topic, from the view that reversibility and retrievability are essential components of any programme to the view that discussion of reversibility and retrievability may primarily serve to obscure the intent of disposal in order to make it more palatable.

This session was followed by another set of parallel breakout round-table sessions. Again it was noted that not only programme policies, but also societal attitudes towards issues like reversibility and retrievability differ greatly between countries, and perhaps also with time even within a country. The actual position adopted by a programme on the subjects of reversibility and retrievability appears to be less important than ensuring continuing dialogue and discussion about these topics, as well as about disposal more broadly. The importance of reversibility may thus be seen not simply as a means of ensuring flexibility, but also as a means of guaranteeing a continuous dialogue regarding the justification of decisions throughout the life cycle of a programme. Reversibility and retrievability are not goals in themselves, and discussion about them cannot be separated from discussion of other issues related to the programme. The most important requirement is the building of trust. If trust is absent, reversibility and retrievability will be seen as "Trojan horse" tactics and viewed with suspicion.

The last session on the second day was a panel discussion on "Optimal Choices and Duties to Future Generations". The session was chaired by Mr. Michael Sailer of the Oeko Institute in Germany. The panellists were Mr. Pierre Bérest (*École Polytechnique*), Mr. Carl Reinhold Bråkenhielm (University of Uppsala), Mr. Bertrand Pancher (*Décider Ensemble*, France), and Mr. Erik Van Hove (retired, University of Antwerp). One topic that emerged was the difficulty of deciding on the balance between ensuring future safety and guaranteeing future freedom of choice. Clearly this will continue to be an important and difficult question. Another increasingly important issue is the balance between participatory democracy and centralised decision making. This in turn raises the question of how to communicate difficult technical issues meaningfully, not only at present, but between present and future generations. One point of view expressed was that over a long enough time, retrieval becomes nearly inevitable, regardless of whether it was originally intended or not. From this point of view, the question is not retrievability versus irretrievability; rather, it is how to minimise the risk when retrieval inevitably occurs.

After the rapporteurs' feedback from the break-out discussions of the second day, much of the third morning was devoted to a panel session on the place of reversibility and retrievability in regulatory policy, chaired by Ms. Carmen Ruiz (CSN). Panellists included Mr. Daniel Schultheisz (United States Environmental Protection Agency), Mr. Hiroyuki Umeki (Advisory Committee on Geological Repository Safety, Nuclear Safety Commission of Japan), Ms. Marie-Pierre Comets (ASN), Mr. Peter Hufschmied (Swiss Nuclear Safety Inspectorate), and Mr. Risto Paltemaa (STUK). Much of the discussion related to how regulatory agencies respond to and enforce the reversibility and retrievability policy requirements that have been established by governments in several countries. Open questions in this respect include that of how a future decision to retrieve would be taken, and how safety and security would be assured at that time. It was pointed out as well that unforeseen reversals can take place in any programme, and an important question to consider would be whether such reversals should take place within a predefined process or not. For some regulators, communication is an important part of the process, and more work is needed in this area.

Mr. Jean-Noël Dumont (Andra), a member of the NEA R&R Working Group, gave a presentation on the retrievability scale (R-scale) that had been developed during the project. The purpose of this R-scale was to support and improve communication on reversibility and retrievability issues by demonstrating how the relationship between ease of retrieval and passive and active safety evolves during the development of a repository. This is illustrated graphically in a four-page leaflet that is intended to support discussions. Draft versions of the leaflet have been used and tested at meetings with stakeholders in France and Scotland and referenced by the Swedish National Council. It is hoped that the scale will prove useful for describing the evolution of retrievability during repository development in other national programmes as well.

To begin the final stock-taking session, Mr. Pescatore summarised the previous three days from the point of view of the NEA working group. The discussions had been valuable to the working group in a number of ways. A number of the observations and findings of the working group had been developed further during the meeting, and several new insights had also been presented and developed during the discussions. His presentation was followed by a general discussion in which many of the participants made further remarks in light of the exchanges in the previous sessions.

Mr. Uichiro Yoshimura, Deputy Director for Safety and Regulation at the NEA, thanked the participants for their fruitful discussions. He noted that the final report of the NEA working group would take the conference discussions into account, and that the NEA's Radioactive Waste Management Committee would be studying the working group's report and making decisions on future work.

At the conclusion of the conference, the conference Chairman, Mr. Birraux, surveyed the key points emerging from the conference and the most important areas where consensus or divergence were revealed. In his remarks, he noted that while there were differences among programmes, there were also some convergences, notably on the importance of democratic processes and on the importance of assuring safety. The conference had brought together a broad, diverse audience, and had benefited from active participation from many different groups. The past three days had been an example of horizontal exchanges between different disciplines and communities of interest, which represents an important stage and marks the first steps along a path we will all follow together in the coming years.

Overall, it can be concluded that reversibility and retrievability are tools which help implement repositories in a manner that is professional and responds to ethical and precautionary obligations. They add societal and technical value to repository development plans by helping to close down options in a considered manner. R&R practices are not essential to long-term safety, but provide extra assurance that long-term safety will be achieved. It was concluded at the conference that: "R&R are not a destination, but a path to be walked together".

NEA Perspective

Reversibility and retrievability (R&R) respond to the guiding principle of preserving options for future generations. "How should options be preserved?" and "For how long a time is it considered reasonable or desirable to preserve these options?" are questions that arise or will arise. The answers depend upon technical, political and social factors, and are therefore variable from country to country. Some of the trade-offs that may need to be considered could include:

- improved acceptance, decreased risk of project failure due to lack of acceptance vs. delays, costs and the risk of perception of inadequacy of disposal as a result of invoking retrievability;
- ability to correct operational faults vs. potential safety impacts and increased cost of postponing closure or backfilling;
- ability to change strategies as appropriate vs. an increased need to take an active role in continued control;
- safety benefits as well as retrievability vs. increased cost of more robust containers and underground structures;
- benefits of improved knowledge vs. increased cost of R&D to support retrievability, risk of increased perception of problems;
- benefits of retrievability vs. increased difficulty of safeguards;
- the need to ensure safety without imposing a burden of control vs. ability to access materials that may become valuable at a future time.

In addition to depending on such technological factors as the nature of the waste (spent fuel containing known energy resources vs. HLW) and the geological surroundings (which affect both the likelihood and consequences of radioactive materials reaching the environment as well as the ease of retrieval), there are also societal factors that have a major influence, e.g. societal attitudes towards freedom of choice vs. assurance of safety, and the degree of optimism with respect to future technological developments. *It is reasonable to expect that the points of balance among these competing factors will differ from one country to another and even from one time to another in a given country*.

Reversibility and retrievability are not requirements for long-term safety. They are about implementing a process that responds to ethical and precautionary obligations without compromising safety. Passive, long-term safety remains the first priority and ultimate goal. On the other hand, safety-first or safety-only is not a sufficient message to advance repository development. Dialogues on reversibility and retrievability can contribute to the understanding and eventual ownership of the concept by a larger part of society. Through this process, R&R can provide extra assurance that long-term safety is being achieved.

Reversibility and retrievability are not to be invoked simply in order to quell fears. Rather, they should be viewed as opportunities for continued dialogue, co-ordination and shared decision making. They should also be seen as tools that contribute to optimisation of the system of disposal. An open question is, indeed, how can R&R be factored in when discussing optimisation and can they augment the chances of protection and in what way. For instance, it is realistic to assume that mistakes will be made during implementation and operation. The ability to fix mistakes (reversibility) and the ability to retrieve canisters (retrievability) where necessary must exist. Reversibility and retrievability can be seen as "best available techniques" to help respond to such situations. There are, however, limitations on retrievability and reversibility, and limits to their application. It is important not to raise unrealistic expectations about the ability to reverse actions once taken. Retrievability requirements may also result in significant difficulties in carrying out a disposal programme. Clearly, the cost of implementing such requirements needs to be proportionate to the benefit that retrievability provisions may help achieve.

For regulatory and policy decisions to be credible, they have to be reversible or modifiable, in the light of new information, to the extent that this is practicable. The reversibility of a planned decision should probably be discussed ahead of time. In real life, reversibility exists, whether expected or not. The question is whether it should be incorporated within a defined decision-making process or left to arrive as a surprise, which can lead to loss of confidence in the foresight and adequacy of programme arrangements. Moreover, when decisions are reversed by authority in an ad hoc fashion, this may be seen as arbitrary and create mistrust. The conclusion should be that reversibility must be framed by a transparent, predefined process.

Reversibility and retrievability are complicated, multi-faceted topics of which our understanding continues to evolve with experience. The discussions at this conference have demonstrated some of the ways in which this evolution is taking place. The open communications and dialogue among participants with a very wide variety of backgrounds and interests are evidence of a shift in approach to the subject of disposal, in which social and ethical aspects of the discussion are assuming increasing importance.

There is a desire for shared definitions in order to facilitate communication. In keeping with the earlier work of the NEA, the R&R project definitions focus on decision making (reversibility) and on actual technical provisions (retrievability). For the most part, these definitions were used during the conference.

The retrievability scale developed during the project can also be a useful tool, and may be seen as a means of providing a shared language for discussion. It has already proven itself to be useful in a number of programmes.

Because they touch on freedom of choice and its relationship to safety, the concepts of R&R link societal and technical considerations, and tend to be central in the debate on "disposal" when, besides the technical audiences, the public and society at large are involved. Continued interest and new projects in these topics can be expected. The results of the OECD/NEA R&R Project (2007-2011) and the Reims 2010 conference proceedings will provide a solid basis for further exploration of these two concepts.

Setting the Scene

Findings from the NEA R&R Project and Personal Observations

Claudio Pescatore
Nuclear Energy Agency
Co-ordinator of the NEA R&R Project

Introduction

In 2001 the NEA published a report entitled *Reversibility and Retrievability in Geologic Disposal of Radioactive Waste: Reflections at the International Level* (NEA, 2001). As a follow-up, in 2008 the NEA's Radioactive Waste Management Committee (RWMC) established a project to study the issues of reversibility and retrievability in geological disposal of radioactive wastes. This project is supported by contributions from member organisations. Participants from 17 countries, international organisations and other RWMC groups (the FSC, IGSC and Regulators Forum) have contributed to the project.

Major milestones in the project have been the conduct of a bibliographic survey, a survey of NEA member countries' positions and discussions within an ever increasing group of interested parties to refine a leaflet on current international understanding of R&R. The project will culminate shortly following this conference. The project documentation is downloadable from the web page: *www.oecd-nea.org/rwm/rr*. An overview of the project findings so far is provided in the rest of this paper.

Before presenting the findings, it should be noted that some of the terms used in the context of the project are used in different ways in different programmes. For our purposes, we will use these terms as follows:

- *Reversibility* describes the ability *in principle* to reverse or reconsider decisions taken during the progressive implementation of a disposal system. Reversibility requires conceiving and managing the implementation process and technologies in such a way as to maintain as much flexibility as possible so that, if needed, reversal or modification of one or more previous decision(s) in repository planning or development may be achievable without excessive effort.

- *Retrievability*, in waste disposal, is the ability *in principle* to remove and recover waste packages after they have been emplaced in a repository.

- *Retrieval* is the actual action of removal of the waste packages, whereas retrievability is the potential for retrieval. Retrieval, if carried out one day, would be a major decision: it would be costly and would pose safety hazards. It would be a regulated activity and would require the same high-level regulatory scrutiny and authorisations that were needed originally to permit the emplacement of the waste packages in the repository. Retrieval would require justification and optimisation, just as for any other practice involving radiological exposures.

Project findings

Key observations

- From a technical point of view, flexibility in implementing a large project such as a repository is a recognised management approach. Retrievability is thus subsidiary to reversibility and flexibility, i.e. it is a means to implement reversibility that can be exercised if the need arises.
- There are variations in the approach to retrievability and reversibility:
  - In various countries around the world retrievability is: *i)* required by law; *ii)* required by government policy; *iii)* required neither by law nor by the government, but is built into the design by the implementer nonetheless; *iv)* part of the current national debate; *v)* not a current issue in a national debate, but even in these countries it is recognised as a potentially important issue by various players.
- There is general agreement across different programmes and nations that waste should be emplaced in a final repository only when there are policy and regulatory decisions ensuring that:
  - The "waste" is actually waste and not a resource to be used in the foreseeable future (disposal implies no intention to retrieve; if there is a clear intention to retrieve, the situation calls for interim storage, not final disposal).
  - The regulations on the protection of man and the environment are always complied with (the ability to retrieve is not an excuse for moving forward on a disposal project if passive safety has not been demonstrated convincingly).
  - Stakeholders have been appropriately involved (starting well before the construction of the repository).
- A final repository has to be declared safe without consideration of retrievability:
  - While some national programmes require retrievability before closure for operational safety reasons, none require retrievability after closure for basic safety reasons, i.e. as a fundamental safety feature of waste disposal. Accordingly, the regulations for these programmes do not require that retrieval be demonstrated in practice. They require only that retrieval could be exercised in principle.
  - On the other hand, an extended ability to retrieve the waste may be seen as providing further assurance of safety, in the sense that intervention is possible to correct problems during the operational phase. In the near term, retrievability provisions may be considered to be good engineering practices that contribute to safety, e.g. in helping to manage accidents during operation.
  - There is a trend, independent of regulation, to confirm experimentally that retrieval of disposed-of waste packages will be possible. Experiments have been devised and run successfully. Additional R&D is being performed in several countries.
- In the national programmes that include retrievability as a declared feature in implementing a final repository, the goal is not to make future retrieval easy or cost-free; it is simply to ensure that it is feasible, assuming a future society that is both willing and able to carry it out:
  - Those programmes that require retrievability mention three main reasons: *i)* having an attitude of humility towards the future; *ii)* providing additional potential assurance of safety; *iii)* heeding the desires of the public not to be seen as taking an "irreversible" decision from the start.
  - Because retrieval would be a major endeavour, especially post-closure, it is in no one's interest to use retrievability as an excuse to implement an immature programme.

- Safety considerations impose limits on the degree to which retrievability can be incorporated into a repository programme:
  - Maintaining retrievability for longer than the minimum time period required for operation could have negative impacts on safety (e.g. continued risk of industrial and mining hazards, dose to personnel, etc.), and the pros and cons will need to be balanced in each programme.
  - In the very long term, attempting to provide for retrievability by keeping a repository fully accessible could even make it impossible to meet safety requirements.
- A reversible approach in repository development should not be taken to imply a lack of confidence in the ultimate safety of disposal. It should be regarded rather as a way to make optimum use of available options and design alternatives during the evolution of the programme:
  - When considering the question of reversibility, two complementary ethical principles may be invoked: an internationally-agreed principle of not placing undue burden on future generations, which is mentioned in international safety fundamentals and can be interpreted as requiring the removal of all future responsibilities for safe-keeping of the waste as soon as possible; and on the other hand, a guiding principle of not depriving future generations unnecessarily of the possibility to exercise choice, which is found variously in the literature – including national positions – and can be interpreted as involving a more progressive release of controls. Reversibility facilitates such a progressive release of controls.
  - In any event, while reversibility can provide added degrees of freedom to a repository programme, there is agreement that retrievability provisions should never be achieved at the expense of safety of current and future generations.
- Geological disposal, as currently envisioned in all national programmes, is in principle never completely irreversible. Waste recovery would be possible over time scales that extend over millennia, albeit likely at great effort and expense:
  - The policy of concentrating and confining radioactive waste in a final repository, as opposed to a policy of dilution and dispersion, creates *de facto* a situation where waste could be re-accessed over very long time scales. Some critics indeed object to the fact that geological disposal, as currently envisioned, is never completely irreversible.
  - After the demise of present-day societal institutions, retrieval would be a major but possible engineering endeavour. It would be more difficult than during the period of societal continuity (loss of institutional memory). It would require resolve, resources and technology.
  - Although the long-term safety case must be able to stand on its own without post-operational institutional oversight, specific oversight provisions, such as monitoring and memory keeping, may nevertheless be decided upon. If so, these may further contribute to decision making relative to retrieval post-operation, and to the freedom of choice provided to future generations.
- When considering incorporating retrievability into a repository programme, it is understood that during the lifetime of a repository, retrieval would become successively more difficult as the repository takes on its final shape and function.
- To the extent that retrievability is about retrieving whole waste packages, means exist to enhance retrievability, e.g. by implementing more durable containers and waste forms. Other approaches may rely on longer times before emplacing backfill materials or sealing galleries and the whole repository:

  - There is, however, a delicate balance to consider, whether this may or may not jeopardise safety, both for present and for future situations. Cost is also a factor, as more durable containers may be more expensive, and the longer a facility is kept open, the higher the costs.

- It is possible that social pressures for reversibility and retrievability may be more in the direction of avoiding irreversible steps rather than of specifically requiring ease of retrieval:
  - In addition to the ability to access materials that may become valuable at a future time and the ability to continue to directly monitor conditions in the repository, it appears that the motivations for such social pressures in favour of retrievability may include unfamiliarity with (or lack of maturity of) the disposal technology and discomfort with the concept of purely passive safety without any means of oversight or active control, as well as a desire to avoid making decisions today that might preclude different actions in the future. A number of these drivers may decrease over time as the level of familiarity and trust in a programme increases over time. An extended period of control may also increase familiarity and willingness to accept passive/intrinsic safety.
  - In this context, the inclusion of reversibility and retrievability provisions may be seen as mitigating a risk, namely the risk that a repository project will not go ahead and that the wastes will be left in a state that may be untenable in the long term.

Personal observations

On the eve of this conference, the work so far leads the author to a number of questions and suggestions for consideration during the conference:

- It was mentioned earlier that geological disposal is never truly irreversible. An analogy to waste recovery is the mining of very high-grade uranium ores. For example, the gamma exposure rates from shafts drilled directly into 20% ores, such as some deposits in northern Saskatchewan (McArthur Lake, Cigar Lake), can be on the rough order of 1 mSv/h. Mining of this ore from a depth of 500 meters must be done entirely remotely, with no human access into the ore body, and the mining process is complicated by the low strength of the encompassing rock and the presence of large volumes of groundwater. The challenges posed by these ore bodies seem similar in scale to those that would be posed by attempting to recover high-level waste or spent fuel disposed of in a geological repository. In view of this, is there such a thing as truly irreversible disposal?
- If reversibility is a feature of a programme, the societal criterion for choosing reversal (the societal reason for introducing reversibility) should not be to make reversal painless; it should be "if you do determine you need to reverse, the amount of effort to do that is reasonable" (Commissioner Peterson, Blue Ribbon Panel).
- Even though disposal is carried out without the intention to retrieve waste packages, it certainly appears to be a good idea: *i)* not to preclude retrievability unnecessarily; *ii)* to apply reversibility as a management principle throughout the development process. Namely, the implementer should adopt an attitude of questioning whether the barriers or the construction materials and geometries would not constitute unnecessary obstacles to retrieval, if that was later decided (clearly some materials are more easily removable than others, etc.). The key is to consider any choices that could facilitate retrieval if it was ever required but to continue to ensure that that the integrity of the facility is not jeopardised by these choices; the decision maker should identify hold points at which a deliberation should be made whether to retrieve or not, and the resulting decision recorded. Criteria for this decision ought to be agreed to ahead of time.

Final remarks

Overall, it seems that the nature of the process of implementation and decision making is vital. In a long-term project such as a repository for high-level waste or spent fuel waste, what we started with will not necessarily be what we shall end up with; there must be continuous research and continuous questioning and, because of that, adaptability to new learning. Intermediate decisions must be, to some degree, reversible if they are to be credible.

The sensible approach to this situation is a step-wise process of learning, testing, questioning, implementation and more questioning. Reversibility is an intrinsic part of this process, and retrievability is a technical expression of the reversibility process. Reversibility and retrievability are thus characteristics of the process, not its end goals. Reversibility and retrievability are part of the journey, they are not the destination.

Reference

Nuclear Energy Agency (NEA) (2001), *Reversibility and Retrievability in Geologic Disposal of Radioactive Waste: Reflections at the International Level*, OECD/NEA, Paris.

Country Situations at Policy Level

Chair: Kathryn Shaver

Policy Perspective on R&R in the Finnish Context

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Geological disposal and spent fuel

Spent nuclear fuel from NPP is stored at the power plant sites until it will be disposed of. Initially, the fuel is cooled for one or two years in reactor pools and then transferred to an on-site interim storage. Before disposal, spent fuel will be stored in waste pools for 40 years on average and thereafter transferred to the encapsulation and disposal facilities.

Nuclear waste is defined in the Nuclear Energy Act as "radioactive waste in the form of spent fuel or in some other form, generated in connection with or as a result of the use of nuclear energy". Nuclear waste means also materials, objects and structures which, having become radioactive in connection with or as a result of the use of nuclear energy and having been removed from use require special measures because of the danger arising from their radioactivity.

Spent fuel from the operation of nuclear reactors is defined in nuclear legislation as nuclear waste, destined for disposal in a permanent manner. Due to its high activity and heat generation, spent fuel is regarded as high-level waste.

The spent fuel programme is as follows: disposal site selection in 2000, start of construction of an underground rock characterisation facility in 2004, preparedness for the application of the construction licence in 2012, readiness for operation of the disposal facility in 2020.

Nuclear Energy Act and Decree

The present nuclear-related legislation came into effect in 1988. It consists of, among other things, principles related to nuclear waste management and procedures for decision making. A remarkable alteration from the nuclear waste management perspective was made in 1994. As a consequence, the management of nuclear waste generated in Finland should be carried out in a permanent manner. It also prohibits the export and import of nuclear waste. It states: "Nuclear waste generated in connection with or as a result of use of nuclear energy in Finland shall be handled, stored and permanently disposed of in Finland."

Government decisions in Finland

In 1983 the government made a decision on the objectives for research and planning of nuclear waste management. It also provided a rough schedule for implementation of geological disposal including site selection, construction of the facilities and start for the operation. The decision covers spent fuel, low- and intermediate-level waste as well as decommissioning waste.

In 2000 the government made a decision concerning the construction of a final disposal facility for spent nuclear fuel produced during operation of the existing Finnish nuclear power plants. The decision specifies the construction furthermore: "…in such a form described in the application with regard to the main operating principles of the facility and the structures aimed at ensuring its safety, at Olkiluoto in the municipality of Eurajoki, is in the overall interest of society." In 2001 and in 2010 the government made decisions on extending the construction plans to accept additional spent fuel.

Retrievability

The government of Finland stated in 2000 that "(b)efore any construction licence is granted (for the final disposal facility), the party responsible for the project shall provide specified, sufficiently detailed reports on as well as plans for the re-opening of the repository and factors affecting it, as well as the opening technology and the safety of opening. An up-to-date estimate of the costs of opening shall also be submitted. The plans shall also take account of the fact that the long-term safety must not be impaired as a result of the re-opening and retrievability." The requirement can be regarded as generic and its scope is limited to technology and safety.

Retrievability is related in Finland to the potential availability of alternative technology in nuclear waste management and, especially, options in geological disposal. Retrievability has been used as a criterion when different methods of implementation were assessed and compared with direct geological disposal in the late 1990s. The options were hydraulic cage and deep holes. The comparison of benefits and disadvantages of alternatives is based on environmental impact assessment.

Reversibility

The concept of reversibility is not used in Finland. However, it is a part of the licensing process which takes place stepwise. The licences related to nuclear waste facilities are granted stepwise by the government. The licence to construct a repository for spent nuclear fuel will be applied by the end of 2012. The operation of a repository requires an operating licence issued by the government. In order to receive a licence, it must be ensured that the protection of workers, safety and environmental protection have been taken into account as appropriate. A hearing process involving municipalities, authorities and citizens will be established during the application processes.

Reversibility and Retrievability – Switzerland

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Country situation

Since 1969, Switzerland has used nuclear energy to produce electricity. Five nuclear power plants (NPP) are currently in operation and the construction of two to three new NPP are under discussion. After the five NPP have been in operation for 50 years, the radioactive waste will amount to approximately 100 000 m^3. The aim of the power suppliers to build new NPP is part of the third of the four pillars of Switzerland's energy strategy (2007): *i)* energy efficiency; *ii)* renewable energy; *iii)* large-scale facilities; *iv)* foreign energy policy. With the choice of a particular type of energy – in this case nuclear – a decision has been made for a process that is non-reversible to the extent that it inevitably produces waste that must be managed. Consequently, the term "reversibility" has broader implications than retrievability, because it is also a policy concept. As a complex social concept reversibility cannot be reduced to a technical meaning. However, both concepts may be viewed as useful tools for the implementation of a repository.

Four decades of debate on radioactive waste management have not yet led to a selection of a site for the final disposal of radioactive waste. But Switzerland has learned from past experiences, especially from the rejection of the Wellenberg project in 1995 and 2002. Policy adjustments were implemented since then, based on the observation that safety ought to have priority, but that it is not sufficient on its own. The broad consultation and the early and continued involvement of society are also necessary. Although a participatory approach does not guarantee the success of a project, it can improve the quality of the project and promote its acceptance.

Since 2003, Swiss legislation requires that both high-level waste (HLW) and low- and intermediate-level waste (L/ILW) have to be disposed of in deep geological repositories within Switzerland. In 2008, a stepwise and transparent process with the participation of all involved stakeholders was initiated to find the relevant sites.

According to the Nuclear Energy Ordinance of 10 December 2004,[1] the site selection process for radioactive waste repositories is defined in a "sectoral plan" within the legislative framework of the existing spatial planning and environmental legislation. The Swiss Federal Office of Energy (SFOE) is in charge of the site selection procedure. Site selection is primarily based on technical criteria, with the main emphasis on safety for man and the environment, but it also addresses socio-economic and ecological aspects.

Retrievability is part of the Swiss waste disposal concept

During the 1970s, 1980s and 1990s, a controversial debate on nuclear waste disposal took place in Switzerland. Several working groups and projects were created in order to present a

1. Nuclear Energy Ordinance of 10 December 2004. On line at: *www.admin.ch/ch/e/rs/7/732.11.en.pdf*.

solution for waste management. A first concept was presented in February 1978 by the National Co-operative for the Disposal of Radioactive Waste (Nagra).[2] It was based on deep geological disposal and assumed that radioactive waste would be disposed of in suitable geological formations. Top priority was assigned to long-term safety following the final closure of the repository.

In 1999, the Federal Department of the Environment, Transport, Energy and Communications (DETEC) formed the "Expert Group for Disposal Concepts for Radioactive Waste" (EKRA), which consisted of experts from a broad variety of fields. Its mandate was to formulate basic principles for a variety of waste management options, and its final report (DETEC), published in 2000, formed the basis for Switzerland's concept. The concept called "monitored long-term geological storage" combines the isolation of radioactive waste in deep geological layers with technical and natural barriers, and the option of retrievability at society's request (being one feature of a reversible process).

The principle of "monitored long-term geological storage" was implemented in the *Nuclear Energy Act* of 21 March 2003.[3] The Nuclear Energy Act provides that the obligation to manage and dispose of radioactive waste is met if the radioactive waste has been transferred to a deep geological repository and the funds required for the monitoring period and its closure have been secured. Retrievability during the monitoring period has to be possible without undue effort. During the process of site closure, retrieval is still an option. Even after the closure, it is understood to be technically possible to retrieve the waste, but retrieval would be tied to a higher expenditure and an additional technical effort.

The safety of radioactive waste disposal has to be ensured with appropriate measures before the facility is definitively closed and sealed. Control is comprised of both social and technical components and has to be exercised by a reliable, long-term, independent and democratically legitimate controlling instance.

Reversibility as an overall concept for radioactive waste management

In the Swiss programme, the principle of reversibility has to be taken into consideration in planning a disposal facility, i.e. later generations should have the possibility to make use of new knowledge regarding disposal. Hence, the implementation of the disposal concept including the site selection procedure is a step-by-step process that allows reconsideration of decisions by future generations. Such reversibility is built into the site selection process. The conceptual part of the "Sectoral Plan for Deep Geological Repositories" defines a three-stage site selection process, site selection criteria and the respective roles and responsibilities of the parties involved. It was prepared by the federal authorities under the lead of SFOE. Following a broad consultation process, it was approved by the federal government on 2 April 2008.

According to the Sectoral Plan, the population and interested organisations receive comprehensive information about the progress of the site selection procedure. Intensive co-operation is required with the communes and the population of the six site regions proposed by Nagra in October 2008. Accordingly, regional participation bodies currently are being established in these regions.

At the end of each stage, a public hearing is conducted and the stage is completed by the approval of the federal council. At the end of the site selection process, the parliament has to approve the general license of the site. Subsequently, the Swiss electorate has the option to call for a referendum against the decision of the parliament.

At present, the statements from the public hearing on stage one, which took place from 1 September to 30 November 2010, are being evaluated. The first stage will be wrapped up by the

2. Founded in 1972 and mandated to prepare and implement solutions for waste management in Switzerland. On line at: *www.nagra.ch*.
3. Nuclear Energy Act of 21 March 2003. On line at: *www.admin.ch/ch/e/rs/7/732.1.en.pdf*.

decision of the Federal Council in autumn 2011. The aim of stage two is to identify at least two sites for each waste category (L/ILW and HLW). This process will take four years.

Snakes and ladders

Experiences in many countries show that the disposal of radioactive waste is not a one-way road. Successes have been followed by drawbacks, which might have been the start of new efforts and further steps forward. Like in the game snakes and ladders, there is a starting point and a final goal for radioactive waste management. The starting point is the existence of radioactive waste and the goal is to find a solution to ensure the long-term safety of man and the environment. The implementation of the solution is a step-by-step process with the possibility of taking short cuts (ladders) but also with the risk of falling down in the process (snakes).

For society's decision-making process, it is clear that reversals are part of the "game" and must be addressed knowing that a reversal is not the "end of the game" but a step towards a final solution.

Reference

Federal Department of the Environment, Transport, Energy and Communications (DETEC) (2000), *Disposal Concept for Radioactive Waste*, final report of the Expert Group for Disposal Concepts for Radioactive Waste (EKRA), 31 January 2000. Online at: *www.bfe.admin.ch/radioaktiveabfaelle/01274/01281/index.html?lang=en&dossier_id=01333*.

Safety Requirements for Disposal of Heat-generating Radioactive Waste – Germany*

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Background

In 2010, the German Parliament (*Bundestag*) voted to amend the existing Atomic Energy Act. In so doing, the lifetime of the 17 currently operating NPP was extended by (an average of) 12 years. With plant lifetime extension, however, comes the inevitable increase in waste.

The subject of where to store that waste has been ongoing. One recurrent possibility has been the Gorleben site, which has been under study for many years. Its suitability as a repository for the disposal of heat-generating, high-level waste (HLW) remains to be proven.

In this context, the governing authorities decided in 2010 to demonstrate the retrievability of the waste in the former Asse II salt mine, originally an experimental storage facility for low- and intermediate-level waste.

Inventory of spent fuel

The current German inventory of spent fuel is as listed in Table 1; Figure 1 displays a photograph of the Zwischenlager Nord storage facility.

Disposal of spent fuel and high-level waste

The investigation and exploration of the Gorleben site restarted on 1 October 2010 after a ten-year moratorium. This new undertaking is expected to last approximately ten years. A preliminary safety case will be prepared by the end of 2012, followed by an international peer review. An aerial view of the Gorleben site can be seen in Figure 2.

Table 1: Inventory of spent fuel

Annual unloading per reactor	~15 to 30 Mg HM/a
Total annual production in Germany	~370 Mg HM/a
Produced by end 2009	~13 030 Mg HM
Expected quantity produced by the year 2004	~17 200 Mg HM + ~4 400 Mg HM

*	This text was adapted by the NEA from the author's PowerPoint presentation at the R&R Conference.

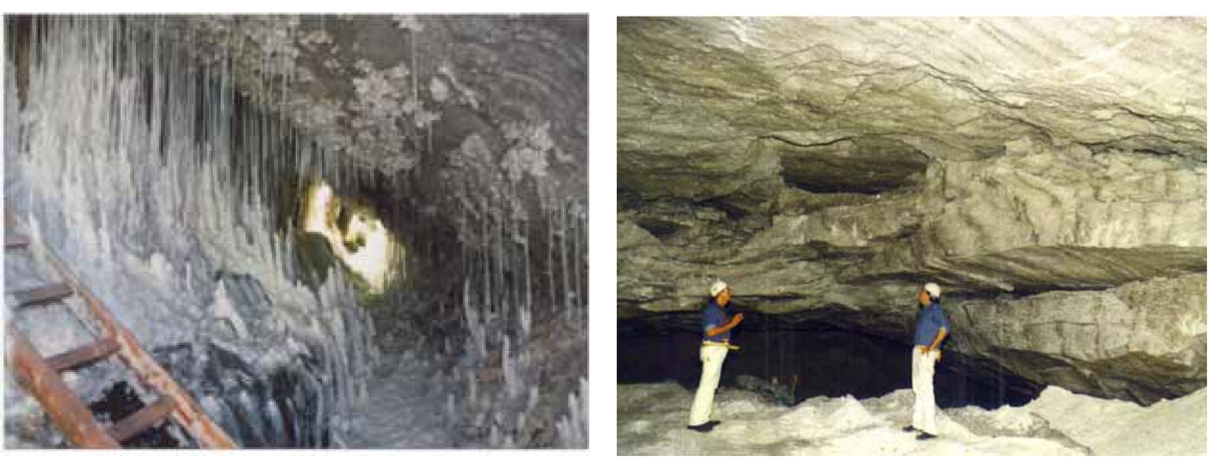
Figure 1: Zwischenlager Nord storage facility for radioactive waste and spent fuel

Figure 2: Disposal project Gorleben

Asse II mine situation

Since 1988 an inflow of saline solution from the overburden has been evident (currently approximately 12 m^3/day). Reduced stability of the mine is observed as cavities had not been backfilled for a long period. Discharge of radionuclides from the emplacement rooms takes place through dissolution processes and gas release into the mine air. Views of the Asse II mine can be seen in Figure 3.

Figure 3: Interior view of the Asse II mine



Procedure for implementation of Safety Requirements

It was determined that certain Safety Requirements needed to be put into place. A timeline of the process can be found in Table 2.

Table 2: Timeline for publication of German Safety Requirements

2008	August	Publication of first draft Safety Requirements (SR)
	October	Public presentation of first draft SR
2009	January	Review of the first draft by waste management commission
	July	Draft publication of Safety Requirements
2010	September	Final discussion with state authorities (*Länder*)
	October	Publication of Safety Requirements

The main stakeholders with regard to the implementation process of the Safety Requirements are the different government ministries (chancellery, environment, economics, research), the states (*Bundesländer*, particularly Lower Saxony), the advisory bodies of the Ministry for the Environment and public experts.

Aspects of the SR which have received the most attention include the possibility to improve a repository or correct mistakes, the establishment of a time horizon for the long-term safety assessment and the imperative for rigorous documentation of a repository once it is closed.

As they now stand, the SR have several distinctive features, which include a fundamental requirement of optimisation (even for the long term), periodic safety reviews during the operational phase, retrievability of the waste during the operational phase, and a demonstration of technical feasibility to recover the waste up to 500 years after closure of the repository.

Safety is one of the major motivations for the establishment of the SR. The operational phase of the repository is projected to last for several decades, and all of the relevant constructions of the repository (sealing of shafts, drifts or caverns) would be built during or at the end of the operational phase. A further guiding principle is that correction of technical or scientific errors must be possible.

Challenges

Many challenges remain to be addressed with regard to retrievability. Up to now no technical concept for retrieving heat-producing waste exist. In order to develop such a concept, the duration of the operational phase must be specified. Furthermore, for as long as retrievability is desired, an area and a licence for the storage of the retrieved waste must be available.

United States Perspective on Reversibility and Retrievability for Geological Disposal

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Reversibility in the United States

In the present context, "reversibility" means the ability to modify, change or reverse a decision and proceed along a different course of action.

Reversibility (prior to waste emplacement) has been formally taken into consideration in the United States programme at two stages. The first of these was during selection of sites for characterisation (1986-87), and the second at the time of site recommendation (2002).

Retrievability in the United States

"Retrievability" means the ability to remove high-level waste after it has been emplaced in a geologic repository; this typically implies permanent removal.

As specified under United States statute, retrievability must be maintained for both economic and safety purposes. Nuclear Regulatory Commission (NRC) regulations further stipulate the time during which retrieval capability must be maintained for safety.

The Nuclear Waste Policy Act of 1982

Under the Nuclear Waste Policy Act of 1982, retrieval is maintained for safety, environmental or economic reasons. The Department of Energy (DOE) specifies the period of retrieval, subject to NRC approval. The NRC further requires retrievability throughout waste emplacement and performance confirmation programmes.

Safety context of retrievability

Repository development is expected to last many decades. A performance confirmation programme is instrumental in the phased approval process, to test and evaluate data used to demonstrate compliance. Performance confirmation activities will be ongoing, conducted after construction is approved and until closure. The principle of retrievability ensures that safety issues are addressed or waste retrieved.

The retrieval requirement prior to permanent closure preserves the ability to act on new information for a specified time period, allowing to be taken into account information that might have been gathered from the performance confirmation programme. The retrieval option must therefore be preserved, commensurately with the time scale of repository construction and waste emplacement.

Potential benefits of retrievability

There are both safety and economic benefits with maintaining a capability to retrieve waste. Retrievability provides the option to retrieve waste from a portion of the repository that no longer is considered to be safe or to enhance an engineered barrier to improve safety. In addition, retrievability provides an opportunity to reverse a decision to consider spent nuclear fuel as waste; whereas, what may be considered as "waste" today could become a resource in the future.

Retrievability issues

The issues with regard to retrievability are also related to safety and economy. Removing ageing fuel to the surface creates new safety and security concerns which must be addressed. Additional monitoring and security measures would be required, and the problem of handling possibly damaged waste packages must also be dealt with. Retrieval could thus be both costly and difficult to perform.

Disposal in the United States

Disposal is considered permanent. It is qualified as passively safe, and there is no expectation of or need to retrieve waste. The DOE is the agency required to perform post-closure monitoring.

Maintaining retrievability after closure is not currently required in NRC regulations, though it is understood that the capability to retrieve could remain for some time beyond closure.

Summary

Reversibility after waste has been emplaced is dependent on the ability to retrieve the emplaced waste. NRC's requirements for retrievability are focused on safety.

If waste is retrieved at some point in the future, a resolution of what to do with the retrieved waste will be necessary.

The concepts of reversibility, retrievability and performance confirmation are linked and have the potential to play a significant role in public acceptance of geological disposal.

Belgian Policies Regarding Radioactive Waste Disposal as well as Retrievability

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Introduction

ONDRAF is the Belgian public body in charge of the management of radioactive waste; its activities encompass the whole spectrum of the management system, i.e. from waste inventory, transportation, treatment and conditioning, storage and final disposal.

The present paper aims at providing a summary of current policies regarding final disposal of the various waste types in Belgium with particular emphasis on the one hand on the meaning of "disposal", "waste", "retrievability" and, on the other hand, on the key drivers in policy approaches.

It should be noted from the start that due to the lack of clear-cut definitions at the Belgian policy or regulatory level, the following distinctions are used throughout this paper; the nature of these distinctions are primarily temporal:

- "reversibility" relates to the operational period of the repository when no backfill or sealing has yet been emplaced around the waste;
- "retrievability" relates to the operational phase after emplacement of backfill material and seals/plugs (while access shaft and galleries are still accessible) and to the post-closure phase (i.e. when access shaft and access galleries are sealed and closed).

Such definitions are actively being worked out today by the Belgian nuclear safety authority (Blommaert, 2010).

Policies pertaining to waste disposal in Belgium

As what long-term management policy concerns, the situation is quite contrasting between short-lived radioactive waste (low- and intermediate-level) and high-level and/or long-lived radioactive waste:

- For low- and intermediate-level/short-lived radioactive waste (so-called "Category A" waste), the federal government decided on 16 January 1998 to opt for a definitive solution, as opposed to long-term storage. The council of ministers of 23 June 2006 decided that this waste should be disposed of in a surface installation on the territory of the municipality of Dessel (NE Belgium). This project is now in full development by ONDRAF/NIRAS in close co-operation with the local stakeholders; the facility should be operational by 2016.
- For high-level and/or long-lived waste there is, as of today, no official long-term management policy. ONDRAF/NIRAS is preparing a "Waste Plan" [accompanied by a Strategic Environmental Assessment (SEA)] that will be submitted to the government in

the first semester of 2011. With these reports, the government will have all the necessary information to take a "decision-in-principle" regarding the policy for the long-term management of high-level waste (including spent fuel) and long-lived waste in Belgium.

The establishment of a programme for the long-term management of waste (or Waste Plan) is one of the legal missions of ONDRAF/NIRAS. There is a legal requirement for ONDRAF/NIRAS to prepare a Strategic Environmental Assessment report together with its Waste Plan and to submit these documents for public consultation. This requirement results from the translation in the Belgian legislative system (law dated 13 February 2006) of two European Directives; the first pertains to the assessment of the effects of certain plans and programmes on the environment (2001/42/EC), while the second provides for public participation with respect to the drawing-up of certain plans and programmes relating to the environment (2003/35/EC).

The reference solution for HLW (including spent fuel) and long-lived waste that will be put forward by ONDRAF/NIRAS in its Waste Plan is geological disposal on the national territory, in poorly indurated clays (Boom clay or Ypresian clays) and as soon as reasonably possible; the development of such a disposal project must be accompanied by a stepwise, adaptive and participative decision-making process.

Irradiated fuels as resource or waste?

One of the specificities of the Belgian situation is the fact that the status (waste or resource) of the fuel irradiated in commercial power plants has not yet been established. Indeed, a parliamentary decision dated 1993 and confirmed by the government the same year put reprocessing of fuel on hold. The consequences of this decision, which was reiterated in 1998, are manifold, notably:

- As reprocessing was, up to 1993, the official policy, part of the irradiated fuel from commercial power plants has been reprocessed. So about 10% of the 5 000 tHM fuel to be discharged from the 7 commercial power plants over a 40-year lifetime has been reprocessed (by Areva, FR). All high-level vitrified waste from reprocessing has been returned to Belgium for storage; the compacted waste is currently being returned to Belgium while the medium-level vitrified waste is still to be returned.
- For the fuels irradiated in research reactors, reprocessing could be pursued and is currently carried out for e.g. the fuels from the BR2 reactor of SCK•CEN (reprocessed by DSRL, UK).
- In its R&D programme regarding disposal, ONDRAF/NIRAS must study, in a balanced way, direct disposal of irradiated fuels from commercial plants, as well as disposal of waste arising from reprocessing of these fuels.

If we combine this with historical waste from various origins, ONDRAF/NIRAS has to consider a very wide spectrum of waste to be disposed of (vitrified, compacted, concrete-mixed, bituminised waste, R&D spent fuels, commercial spent fuels, MOX spent fuels…); this results in quite a large variety of source terms, Engineering Barrier System designs, phenomenological evolutions of the disposal system, operational solutions… With the exception of the spent fuel, all of these wastes can clearly be classified as "ultimate" waste, i.e. waste that cannot, under prevailing and foreseeable circumstances, be valorised.

More fundamentally, the absence of a clear status for the commercial irradiated fuels may create a major difficulty in the dialogue with stakeholders during the siting process and/or in the preparation of a license application. It is also clear that such a situation does not help in the discussions around the rationale for considering the possibility or not to maintain the retrievability option, especially when some of these rationales are linked with the possibility to reuse irradiated fuels as a fissile and/or fertile materials resource.

Retrievability from a policy point of view

As of today, there exist no legal regulations specifically dedicated to disposal (surface or geological) in Belgium. Such regulations are currently in preparation by the Belgian nuclear safety authorities.

However, in the general Belgian regulations regarding nuclear installations and waste management, disposal is defined as a solution "without the intention to retrieve the emplaced waste", a definition which is fully coherent with the definition of disposal in the Joint Convention. Further to this regulatory definition, the safety authorities clearly stated (Blommaert, 2010) that:

- Provisions for retrievability should not harm the robustness of the disposal system and, hence, the long-term safety.
- The disposal facility should reach its final passive configuration (i.e. closure) as soon as possible.

In the governmental decision for final disposal of short-lived waste, retrievability was set up as a requirement. So even if there is legally no intention to retrieve the waste, there is, at least for short-lived waste, a requirement for putting in place retrievability provisions.

Without prejudging the decision that eventually will be taken by the government on the basis of the Waste Plan, ONDRAF/NIRAS considers today that a certain degree of controllability and that provisions for retrievability during a reasonable period of time should be integrated as additional conditions in the proposal for instituting geological disposal as the long-term policy for high-level (including spent fuel) and/or long-lived waste. Such conditions should be coupled with a requirement for the maintenance of control and retention of memory for as long as possible.

From ONDRAF/NIRAS point of view, it must be clearly stated that the potential addition of provisions that would facilitate retrieval after repository closure, should retrieval be considered as desirable or needed in the future, does not imply:

- a change in the primary functions attributed to the repository system, i.e. to confine and isolate waste from the biosphere and then to retard radionuclide migration (there is thus no intention to retrieve the disposed waste);
- a lack of confidence in the repository safety.

The rationale for adding provisions for retrievability and controllability are multiple:

- A parallelism may be sought between the decision taken for short-lived waste and the potential one for high-level and/or long-lived waste.
- These provisions were explicitly expressed in the recommendations of the citizens' conference on the long-term management of high-level and long-lived radioactive waste in Belgium organised under the auspices of the King Baudouin Foundation; the recommendations of this citizen's conference stated indeed that geological disposal in poorly indurated clays in Belgium is acceptable if the disposal can be reversed so that future generations have the liberty to choose their own solutions, taking account of future progress made in the domains of science and technology; such retrievability must be guaranteed for reasonable period of time, i.e. about 100 years (Rauws, 2010).
- Retrievability has also been at the centre of most of the comments, both from the public at large as from statutory consultative bodies, that ONDRAF/NIRAS has received in the framework of the legal public consultation regarding the Waste Plan and the SEA.
- The imposition of "maintenance of control as long as possible" can be seen as an element of the defence-in-depth approach (e.g. with respect to human intrusion) and may also avoid the perception that the objective of geological disposal is "bury and forget"; such a perception was frequently expressed in the comments received in the framework of the above-mentioned public consultation. Hence, providing for control for as long as possible may play a key role in public's confidence.

It is to be noted that there is no common understanding of what retrievability exactly means in practice in the decision for short-lived waste disposal or in the requirements set up for a potential decision for long-lived waste disposal. For instance in the comments received during the public consultation around the Waste Plan, the notion of "retrievability" encompassed everything between flexibility of the decision-making process, the possibility to reverse disposal operations during the operational period of the repository, the ability to take the waste out of the repository after closure and the obligation of keeping the repository open for an indefinite period of time (i.e. creating an underground storage).

Retrievability in practice

The practical "translation" of the retrievability requirement for surface disposal of short-lived waste has been made in close co-operation with the local partnerships and will be tested against the requirements of the safety authorities. In practice, a close link has been established between retrievability and controllability. Therefore, the disposal design incorporates an inspection gallery as well as an inspection "cellar" under each of the disposal vaults in which the waste (embedded in concrete monolith) will be disposed of. These inspections facilities allow the detection of potential leakage or fissures. Considering that the inspection facilities are of limited accessibility, inspections will be carried out by camera robots.

Considering the fact that there is still no decision regarding geological disposal for high-level and/or long-lived waste, only a series of general points could now be made:

- In order to allow a shared "translation" of any retrievability requirement, the latter must be subjected to a multi-disciplinary analysis that covers the following four dimensions (ONDRAF/NIRAS, 2010):
  - scientific/technological;
  - safety/environmental protection (including safeguard-related matters);
  - ethics and societal;
  - financial and economics.

  where the results of a specific dimension are systematically confronted to the views of the others. Such an analysis should make it possible to determine the aims of a retrievability requirement, as well as its scope, limitations and associated RD&D activities.
- As an example, from a scientific/technical dimension point of view, one cannot limit such analysis to design-related issues or technological implications (IAEA, 2009); indeed, the longer the repository stays open, the more complex the phenomenology (longer hydro-mechanical-chemical transients, enhanced microbial activity…). One has to verify that these "open transient conditions" may not impact waste and Engineered Barrier System behaviours and/or create additional (or more severe) perturbations to the host formation and hence, have a potential detrimental effect on long-term safety. In the Belgian case, where the host formation plays a crucial role in ensuring the limitation of water movement and the retardation of radionuclide migration, this will certainly require additional, dedicated RD&D endeavours.
- Due to its multi-faceted content and due to the fact that there is no "out of the shelf" solution, retrievability, and associated controllability, are perfect topics for engaging a dialogue with all stakeholders.
- "Reversibility" during the operational period is to be considered as "good engineering practices" (i.e. the possibility to reverse the operation of waste emplacement). Such "reversibility" imposes that no backfill or sealing has yet been emplaced around the waste and that access shaft and galleries are still open. As such, "reversibility" is an element of the operational safety and takes part in the overall flexibility of the decision-making process that accompanies repository operations.

- It will always be technically possible to mine out the waste of its remnants at any moment after closure; the question there will be the adequacy of the cost (human and financial) versus the benefit obtained (Minon, 1998).
- "Retrievability" as such cannot impact the primary functions attributed to the repository system, i.e. to confine and isolate waste from the biosphere and then to retard radionuclide migration; as such "retrievability" should not be considered as a predominant driver for design development.
- On the other hand, any improvement in the containment and isolation functions of the repository system may have, as an indirect consequence, a positive effect on the degree and possibility of retrievability. Indeed such improvement will ensure a longer integrity of the waste packages and hence ease potential retrieval operations. In that sense, one can see the importance of the presence of a long-lasting engineered barrier system as a provision for retrievability.
- A link must be clearly established between the monitoring perspectives and limitations and the period over which retrievability should be possible (Minon, 2002).
- Costs for the provisions for retrievability can be evaluated and therefore funded by the current waste producers, while what is to be done with waste after retrieval cannot be evaluated (and therefore funded).
- Safety prevails.

Despite the fact that no requirement for retrievability yet exists in the Belgian programme, provisions for retrievability are already embedded in the current ONDRAF/NIRAS design for the Engineered Barrier Systems (see e.g. ONDRAF/NIRAS, 2010 for a description of the geological disposal concept in Boom clay). It must however be stressed, as mentioned above, that these provisions are not directly linked with retrievability considerations. They are rather the logical consequences of a stepwise reinforcement of the containment and isolation functions of the repository system in general and of the Engineered Barrier System in particular. Indeed:

- Vitrified waste and spent fuels are emplaced in a metallic (carbon steel) overpack and then in a massive concrete "supercontainer"; this package, set up at the surface, provides for radiological shielding during the entire operational period, allows easy reversal operations in case of problem during disposal and guarantees the containment at least during the thermal period of the repository life, i.e. a few thousands of years. Due to the very favourable conditions created by the cementitious environment, the integrity of the carbon steel overpack could even be guaranteed over time frames far beyond the thermal period (i.e. for several tens of thousands of years).
- Medium-level, long-lived waste are emplaced in a massive concrete monolith that also provides for radiological shielding during the entire operational period and allows easy retrieval in case of problem during disposal operations; however, due to the absence of a metallic overpack, these monoliths are not designed to guarantee containment integrity much beyond the operational period.

As we can see, ensuring the containment of the waste by an adequate Engineered Barrier System also helps establish provisions for retrievability.

Concluding remarks

"Retrievability" encompasses a very wide spectrum of concepts or meanings as well as of technical solutions. Both for "internal" communication (i.e. within the waste management community) and for external dialogue (i.e. with all other stakeholder), a clear definition of the concepts at hand is needed.

Retrievability may not impact the primary functions attributed to the repository system, i.e. to confine and isolate waste from the biosphere and then to retard radionuclide migration. As such, it may not be the predominant driver for design and EBS development.

Retrievability cannot be seen in isolation of controllability/monitoring and, more specifically of the limitations of these.

To allow constructive and meaningful dialogue, retrievability, in whatever sense, must always be put in its temporal perspective.

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Reversibility and Retrievability – The Swedish View

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The responsibility is stated within the legal framework

The responsibility for managing spent nuclear fuel and radioactive waste is clearly defined in the Swedish legal framework. In order not to dilute the responsibility of the licence holders for nuclear activities and other businesses producing radioactive waste, the Swedish regulations are designed to define requirements to be achieved, not the detailed means for how to achieve them. Within the framework given by the regulations, the licence holders have to define and develop their own solutions, and demonstrate the safety level achieved to the regulatory bodies.

There is no formal requirement in the Swedish legislation saying that a repository should, or should not, be designed to make retrievability possible. The Swedish Act on Nuclear Activities explicitly stipulates that plans should be made for "safe final disposal". The regulation decided by the Swedish Radiation Safety Authority (SSM) says that measures can be taken to facilitate retrievability of disposed nuclear waste or spent fuel during deposition or after closure of the repository. For safety reasons, these measures must be analysed and reported to the regulatory authority.

Definition of waste

The Swedish definition of *nuclear waste*, stated in the Act on Nuclear Activities is:

- spent nuclear fuel that has been placed in a repository;
- a radioactive substance formed in a nuclear plant and which has not been produced or removed from the plant to be used for education or research, or for medical, agricultural or commercial purposes;
- materials, or other items, that have belonged to a nuclear plant and become contaminated with radioactivity, and are no longer to be used in that plant;
- radioactive parts of a nuclear plant that is being decommissioned.

The term *radioactive waste* includes radioactive waste from nuclear activities, as well as from non-nuclear activities (medical use, use of sealed sources, research institutions, consumer products, etc.).

The legislation clearly defines that all licence holders are responsible for the safe handling and disposal of spent fuel and radioactive waste, as well as for the decommissioning and dismantling of facilities. Within the responsibility lies to fully finance all expenses related to these tasks.

Ethical principles

Principles for the management of spent fuel and radioactive waste have evolved over the years and have been discussed by the Swedish parliament. An important contribution to the discussion on retrieval in Sweden has been the ethical principle: "The present generation, that has reaped the benefits of nuclear energy, must also take care of the waste and not transfer the responsibility to future generations." This principle can be combined with a principle worded by the Swedish National Council for Nuclear Waste: "A repository should be designed and constructed so that monitoring and remedial actions are not necessary in the future. However, future generations, probably with better knowledge and other values, must still have the freedom to make their own decisions; we should therefore not make monitoring and remedial actions unnecessarily difficult."

Retrievability – a marginal issue

The issue of retrievability has so far not occupied a prominent position in the public discussion in Sweden. An explanation for this can be sought in the history of Swedish nuclear waste management. An important milestone in the approach to management of the Swedish nuclear waste was reached in the report of a governmental committee in 1976. The question of retrieval of the spent nuclear fuel was not dealt with there, however; the report was completely focused on the question of a final disposal of the nuclear waste. The political decision following this report was to abandon the road to reprocessing and instead find a solution for safe direct disposal deep in the Swedish bedrock. The KBS method for direct deposition in the bedrock emerged in response to the report, and in 1983 KBS-3 was presented, and subsequently became the premise for all planning up until the present. In this context, the issue of retrievability became marginal.

Retrieval is neither presumed or excluded

The Swedish Nuclear Fuel and Waste Management Company (SKB) has in its tri-annual RD&D report several times claimed that the KBS-3 method neither presumes nor excludes retrieval. SKB has formulated its own requirement that the final repository for spent fuel must be designed in such a manner that it is possible to retrieve deposited canisters before closure. This should not lead to technical designs that compromise the long-term performance of the repository, however. Single canisters may have to be retrieved from a deposition hole if something unforeseen happens during deposition. Retrieval of a large number of canisters in a later phase of operation of the repository must also be possible. If another method for disposing of or making use of the spent nuclear fuel is preferred in the future, technology for retrieving canisters will be needed then as well.

Reversibility and stepwise decision making

Reversibility is closely associated with a decision-making model that has been summarised in the concept of stepwise decision making. This model has been inspired by modern decision theory and was introduced in the context of retrievability by the OECD's Nuclear Energy Agency (NEA) and the Canadian Nuclear Waste Management Organization (NWMO). This decision model has long been accepted practice in the nuclear technology field. The Swedish government has not yet decided on a license for a repository for spent nuclear fuel, so there is not yet an application to decide on. But the process that has evolved during more than 30 years can be said to have been a stepwise process. The municipalities of interest for the site selection have had the possibility to say yes or no to further engagement. The demand for open public consultations related to the development of an environmental impact assessment has given the inhabitants an insight into the work done by the SKB and the ability to say no to further investigations based on knowledge and political and social acceptance.

The work done by the nuclear industry can also be said to be stepwise. Over a period of three decades SKB has been developing a method for safely handling and storing the spent nuclear waste for long periods of time. Research and development has been conducted, and studies and investigations performed.

Reversibility and Retrievability in the Context of the Geological Disposal Programme in Japan: Role in Confidence Building

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Confidence building amongst stakeholders, in particular regarding long-term safety, is a key to developing a geological repository. A stepwise approach has been implemented in the legal framework for the Japanese geological disposal programme and the basic guidelines for safety regulations are under development at the Nuclear Safety Commission (NSC) of Japan. Further to this regulatory activity, the NSC is developing a system for "safety communication" among the stakeholders, which supports stepwise decision making with the aim of increasing stakeholder confidence in geological disposal. An accessible safety case may function as a platform for such a communication system, when coupled with reversibility and retrievability as essential components.

Introduction

Japan is actively promoting research, development and utilisation of civil nuclear energy projects within safety constraints established by the Atomic Energy Basic Law. The policy for the use of nuclear energy specifies that all spent fuel is reprocessed, and the recovered plutonium and uranium are used as effectively as reasonably achievable within the country (JAEC, 2005). In order to establish such sustainable use of nuclear energy, a geological disposal programme has been implemented to manage the high-level radioactive wastes (vitrified wastes) and long-lived low-heat generating radioactive wastes (TRU wastes) generated from the nuclear fuel cycle in accordance with the Specified Radioactive Waste Final Disposal Act. The Act clearly mentions that the implementation of waste disposal should be based on public acceptance.

As one of the key players in the process, the NSC has specified a framework for safety regulation of the geological disposal (NSC, 2000) and promulgated the use of risk-informed approach to ensure that the consequences of potential exposure can be evaluated against criteria depending on likelihood (NSC, 2004). This, however, does not necessarily require the introduction of probabilistic assessment for risk-based regulations; rather focus is on a disaggregated approach, which does not require precise evaluation of probabilities.

In addition, the NSC has been actively involved in the site selection process through the Advisory Committee on Geological Repository Safety (ACGRS) which published two reports: *The Requirements on the Geological Environments Considered for Selection of the Preliminary Investigation Areas* (NSC, 2002) and *Licensing Procedure Relating to the Safety Regulation of Specified Radioactive Waste Disposal and Involvement of Nuclear Safety Commission in These Activities (Interim Report)* (NSC, 2007). The NSC held four open workshops before and after publication of the former report to facilitate communications on safety issues with stakeholders. Additionally the NSC organised the Subcommittee on Safety Communication for Geological Disposal (SSCGD) in 2010 to initiate discussions on the framework for safety communication, which facilitates understanding of disposal safety and supports decision making in stepwise repository development.

This paper discusses reversibility and retrievability (R&R) in this context by addressing the following issues:

- How can the best available techniques or best endeavours for risk-informed regulations and safety communication be recognised?
- How can the communications issue be addressed with regard to information asymmetry and the role of the NSC?
- What will the approach for stepwise decision making need in terms of a code of conduct that assures non-confrontational communications?

R&R in the geological disposal programme in Japan

The term "retrievability" is a source of much confusion in the radioactive waste disposal business. Despite OECD/NEA definitions (NEA, 2001), there is no international agreement on terminology to date and, especially in documents intended for non-experts, no clear explanation of what is involved. Indeed, existing material causes more confusion than clarification. In particular, it is not often made clear that waste is almost always retrievable: the variation between concepts is in the costs, environmental impacts and risks to workers associated with it. The key need is to distinguish what exactly the goal of retrieval is.

Here it is especially important to distinguish between reversibility of emplacement – recovery of waste packages in the event of operational problems – and retrieval after an emplacement module has been filled and sealed. In the context of the geological disposal programme in Japan, the relevant key words are understood to have the following meanings:

- *Radioactive waste* means radioactive material in gaseous, liquid or solid form for which no further use is foreseen (IAEA, 1997). In terms of geological disposal in Japan this includes the vitrified wastes and the TRU wastes. Spent fuel is not planned to be directly disposed of (JAEC, 2005).
- *Disposal* means the emplacement of spent fuel or radioactive waste in an appropriate facility *without the intention of retrieval*, while *storage* means the holding of spent fuel or radioactive waste in a facility that provides for its containment, *with the intention of retrieval*. *Closure* means the completion of all operations at some time after the emplacement of spent fuel or radioactive waste in a disposal facility. This includes the final engineering or other work required to bring the facility to a condition that will be safe in the long term (IAEA, 1997).
- *Reversibility* denotes the possibility of reversing one or a series of steps in repository planning or development at any stage of the programme, while *retrievability* denotes the possibility of reversing the action of waste emplacement (NEA, 2001).

The regulator has established the basic policy that geological disposal should proceed step by step, with decision making at each stage. At the present time, reversibility (reversal of decisions once made after re-evaluation) can be justified only when new evidence emerges which contradicts previous knowledge in terms of ensuring safety. Based on the Specified Radioactive Waste Final Disposal Act, a repository site shall be selected through three stages in a site selection process (stepwise decision-making process). In each stage, the implementer needs to obtain the consent of the local community. If consent is not received, the implementer is not allowed to proceed to the next stage. The NSC and the regulator require retrievability until the time of repository closure when the long-term safety is confirmed by safety assessment taking into account additional information obtained through repository construction and operation (NSC, 2000; NISA, 2006).

Ease and safety of emplacement reversal is essential, as operational problems are inevitable with such large-scale, long-term, first-of-a-kind projects. A common problem is that original repository designs developed in many national programmes during the 1970s and 1980s focused entirely on post-closure safety, without any consideration for operational aspects.

 R&R IN PLANNING FOR GEOLOGICAL DISPOSAL OF RADIOACTIVE WASTE, ISBN 978-92-64-99185-9, © OECD 2012

Retrieval after an emplacement zone has been backfilled is not expected to be required for any operational or safety reasons in a well-designed repository in a suitable setting (which would be well established before a repository was licensed for operation). Nevertheless, designing to facilitate this option may be desired to improve flexibility in some national programmes (for spent fuel, U, Pu) or to increase public acceptance.

At the very least, these issues need to be communicated clearly to all relevant stakeholders, so that they are fully aware of the impact of deciding to ease retrieval – and implement any associated monitoring systems. It may be noted that, in some national regulations, performance monitoring and eased retrieval are allowed under the proviso that they do not degrade repository performance with regard to safety. R&D activities are being carried out to achieve advanced designs and monitoring techniques.

Confidence building and safety communication

Long-term safety of the disposal system

Public concern as regards the safety of a radioactive waste repository often relates to possible degradation and release of radioactivity in the distant future. For the regulator, such concerns are addressed by developing different scenarios for possible evolution and assessing them by a conservative modelling approach (NSC, 2004, 2010a, 2010b). Robust designs based on multiple barriers provide a kind of passive "defence in depth", which is in some way analogous to the approach used to assure reactor safety. This is difficult to convey to concerned members of the public unless there is complete trust and confidence in the regulatory processes.

Linking R&R to confidence building

Reversibility has two aspects relevant to confidence building – reversibility of decisions associated with the implementation process and physical reversibility of disposal processes, in particular waste emplacement. The former is essential to the volunteering process for repository siting and the involvement of local communities in decision making is assured in legislation. The government and the implementer should make efforts to explain this more clearly to all relevant stakeholders. Technical reversibility is, however, more directly related to safety.

As the passive performance of the repository system is the basis of the post-closure safety case, it is essential to ensure that all engineered barriers be constructed to required quality levels and that the construction process does not degrade the natural geological barrier. For such a large-scale and long-term project, it cannot be assumed that everything will proceed perfectly and hence procedures need to be established to monitor quality and reverse emplacement in case of problems. This reversal process must be clearly demonstrated and avoid radiation exposure to personnel to the maximum extent practical. Such demonstration is essential to show credibility of the disposal concept and allows many "what if?" questions of stakeholders to be answered.

In terms of retrieval of successfully emplaced waste at a later time, the intrinsic feature that retrieval of wastes is not technically impossible in geological disposal concept should be made within the safety case and clearly communicated to stakeholders – but need not be demonstrated if evidence is strong enough. Designing to ease retrieval should not be precluded, but this should be clearly justified and should not compromise safety. Indeed, the regulator must assure a balanced approach to safety, for both operational and post-closure phases. The option of introducing measures easing retrieval could be debated with stakeholders, especially local communities, for a range of aspects including safety and socio-political issues. Here it is important to note that emphasis on ease of reversal could have negative effects, indicating uncertainty about safety.

With current disposal concepts, there is no clear technical justification for performance monitoring. If this is introduced as a public relations measure, it should be assured to have no impact on safety levels (so, ideally, done in a separate demonstration facility).

Need for safety communication and the roles of NSC

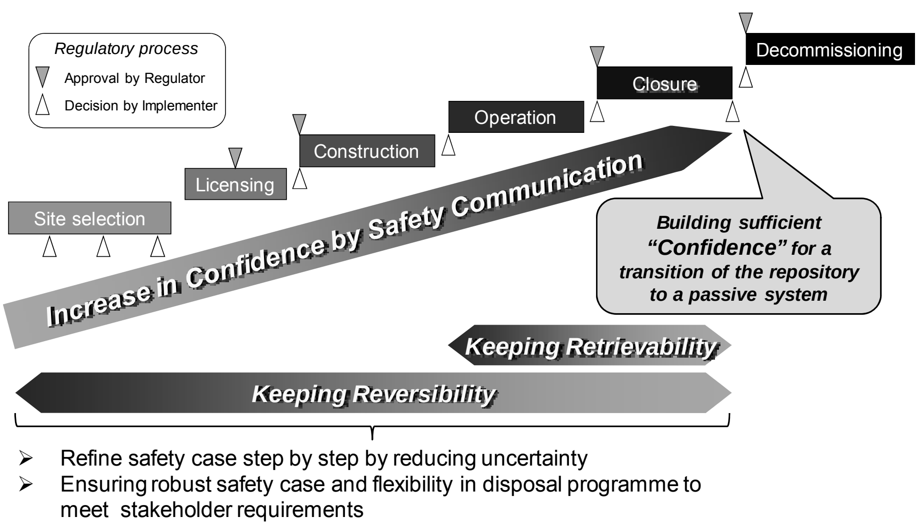
As mentioned, the NSC promulgated the use of a risk-informed approach so that the consequences of potential future exposure scenarios could be evaluated against criteria depending on their likelihood. This, however, does not necessarily imply the introduction of probabilistic assessment for risk-based regulations, but rather the disaggregated approach which does not require precise evaluation of the probabilities. However, Japan is an earthquake-prone country and, being faced with the problem of how to deal with risks due to future catastrophic events, and as a result of lessons learned from past disasters, people are risk-averse. They generally distrust estimated probabilities and focus on pessimistic scenarios; regulators are thus required to consider such pessimism and assure that communication efforts take it into account. Communication is thus incorporated at the highest levels of the NSC thinking, within the ACGRS and the SSCGD.

To address this communication issue, it is also important to recognise that an information asymmetry exists between experts and non-experts. Although the conventional response to an information gap involves supplying as much relevant information as possible to the public, many of the issues involved are highly technical and are further confounded by the explosion of expert knowledge that is anticipated throughout the extremely long-term decision-making process. The proposed solution to this problem is based on two components, a stepwise decision process which allows a smaller number of issues to be addressed at each stage and integration of critical issues within a transparent safety case, which evolves with time as system understanding develops.

Japan's approach to stepwise decision making

The stepwise process for implementation of a Japanese deep geological repository is illustrated in Figure 1. This approach is understood to be flexible enough to be reversible, depending on the outcome of each step and consensus on justification to proceed further. Nevertheless, the previously emphasised desire to divide major decisions into smaller steps, with limited commitment for future steps after each decision has to be balanced with the need to assure programme continuity.

Figure 1: Reversibility and retrievability within safety communication



As far as the emphasis on retrievability indicated in Figure 1 is concerned, the key purpose is to serve as a focus for dialogue with stakeholders. The aim is to reach agreement that confidence in the safety is sufficient to abandon the need for further consideration of retrieval. Here it is important to emphasise that a code of conduct is implemented that assures consensus building with the public (especially local residents) without any form of coercion. Indeed, institutional arrangements such as limited use of the repository site and institutional control prior to repository closure would be implemented as desired by stakeholders, even if entailing significant extra costs and not contributing to improvement of safety performance.

Summary and conclusions

The NSC actively supports safety communication as part of a stepwise repository development process to both enhance the safety of geological disposal and support decision making by stakeholders. A convincing safety case coupled with both programme and technical reversibility provides the basis for the communication approach. Retrieval of waste is always possible and this needs to be communicated to all stakeholders. Enhanced retrievability is not required, but discussion of this topic may be important to allow all stakeholders to reach agreement that confidence in safety is sufficient and there is no need for further consideration of this topic.

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Key Messages from the Angle of Policy Studies and the Social Sciences

Chair: Dan Metlay

Building Bridges between Hard and Soft Knowledge: The Co-production of Andra's Socio-technical Approach on Reversibility

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The legal framing of reversible deep disposal and the shaping of radioactive waste management in France

At the crossroads of political decision making and scientific and technical design, the concept of reversibility appeared in French law with the Waste Act dated 30 December 1991. The study of possibilities for reversible or irreversible disposal within deep geological formations of HLW waste was assigned to the National Radioactive Waste Management Agency (Andra) which, through the same act, became an independent public institution. Fifteen years later, the Planning Act dated 28 June 2006 requests Andra to file a licence application for a reversible disposal facility to be reviewed by 2015, after a public debate. It also states that a new law will have to prescribe the exact reversibility conditions of disposal before a license is granted.

As a result of this legal framing, the design and the implementation of a reversible disposal facility – Andra's CIGEO project – are placed in France within a new innovation regime (Rip and Kemp, 1998). Based upon the progressive elaboration of socio-technical compromises to make radioactive waste governable, Andra's project robustness is measured both in technical and social terms. Matters of concern include, among others, local insertion and land-use planning, techno-economic optimisation, safety analysis and performance assessment, scientific and technical progress, social acceptability… Moreover, the reversible principle implies that Andra must grant future generations the possibility of intervention for at least one hundred years. Defining a reversible deep disposal facility means therefore, for Andra, mobilising much more than technical expertise; it consists also in a kind of mediation work that shapes the project as a public issue (Dewey, 1927; Marres, 2007; Schlierf, 2009). Traditional frontiers between experts, citizens and policy makers are thus blurred in this new regime of innovation. Other than scientific and technical accuracy, Andra's project capacity to hold up multiple perspectives and resisting their respective criticisms will also be assessed.

Knowledge co-production in the elaboration of Andra's reversibility approach

Andra is therefore committed to gathering the different views on the topic of reversibility, technical as well as social and political, and maintaining a continuous dialogue with all interested parties. In order to deal with this complexity, social sciences and humanities research (SSH) was integrated into Andra's scientific programme in 2008. Studies were launched to actively explore the many sides of the notion and elaborate a comprehensive rationale on the topic; the robustness of Andra's proposals is scrutinised in interdisciplinary fora.

A modest and progressive approach has been adopted by Andra since then, aiming at developing an interdisciplinary research community on the topic: PhD grants and complementary research at the base; scientific meetings to exchange knowledge, confront ideas and make emerge new collaborations; specific studies to feed research; publications to gain academic recognition…

This initiative goes well beyond the usual rhetoric of "openness", which frequently hides a rather simplistic approach toward society. In the collaboration between Andra's scientists and engineers and SSH researchers initiated more than two years ago, there is no question at all of "listening" passively to the public and "confirming" how people are blinded by (irrational) fears (Irwin and Wynne, 1996). On the contrary, the underlying assumption is that SSH researchers are researchers like others and share with them a general interest in knowledge production. Co-producing knowledge with other scientists, engineers and stakeholders can be (made) interesting for them if only their specific identities are respected and recognition within their communities is (made) possible (publications, participation to scientific meetings, teaching, etc.). Finally, the definition of a reversible geological disposal facility can be (made) a promising fieldwork for them.

One of the most prominent results of this collaborative effort is the book *Making Nuclear Waste Governable: Deep Underground Disposal and the Challenge of Reversibility* (Andra, 2010), which is devoted to the current French approach on reversibility. Throughout the different chapters, one written by an Andra team and the others by Yannick Barthe, Pierrick Cézanne-Bert and Francis Chateauraynaud, the book discusses the issue of how to implement "definitive securing" of the waste, as stated by the French law, while providing flexibility over time. Its originality is precisely to focus on the specificities of the operational provisions being considered.

The book analyses the trajectories of actors and arguments related to reversibility since the late 1980s, shedding light on the ambivalences of the concept and the stakes coming into sight in the public space: long time scales, organisational issues, media polarisation, actors' strategies, social values, approaches on risk and uncertainty… It also examines the ethical and political qualities of the main solutions proposed and discusses the various decision-making models and safety cultures associated. In this regard, the introduction of the reversibility principle appears to be a radical innovation both in technical and in political terms. Andra's CIGEO project is presented as a socio-technical project in which reversibility is defined recursively.

Andra's recursive definition of reversibility, a technical and political innovation

A reversible deep disposal facility is something of a counter-intuitive notion since, as opposed to the notion of storage (temporary by nature), deep disposal is conceived of as a definitive solution. Therefore, Andra adopts a recursive definition for reversibility, which relates scientific and technical development to the decision-making process. The envisioned repository is thought of on the basis of current knowledge, so as to ultimately be sealed in. How it precisely progresses in time will depend on intermediate decisions, which will be made according to regularly performed assessments and the state of knowledge of the time, within the framework of a stepwise management and a modular repository design.

Supported by strong scientific, R&D and monitoring programmes, Andra's approach on reversibility grants future generations, for at least one hundred years, the possibility of making choices in intermediary operational stages: to proceed with the predetermined scheme, or to procure the means for reassessment, or to bring about changes in the disposal process or else to reverse it, up to the retrieval of emplaced packages.

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Nuclear Waste under Mode 2 – Knowledge Production

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The Swedish National Council for Nuclear Waste, established in 1989, consists of academic scholars from the natural and technical sciences as well as the social and humanistic sciences. The council has attended to the contribution of knowledge and theoretical perspectives from social science and the humanities at several occasions and most recently in a special report from 2007: *Strålande forskningsutsikter? En översikt om kärnavfallsfrågor inom samhällsvetenskaplig forskning* (*Radiating Prospects for Research? An Overview of Nuclear Waste Issues in Social Scientific Research*) (Bergquist). The report concludes that most of the research in Sweden has been made with the support of SKB (Swedish Nuclear Fuel and Waste Management Company), i.e. the company which has the main responsibility of finding a technical solution for a safe deposition of HLW in Sweden. Since 2004 SKB has conducted a special social scientific programme with a focus on local processes of decision making, local social economic factors and attitudes towards nuclear waste (even as international perspectives have also been highlighted in other projects).[1] The programme has contributed to our knowledge about the history of nuclear power and nuclear waste. The significance of this programme notwithstanding, research that analyses the nuclear waste issue in a larger democratic and economic perspective is lacking.

Furthermore, there is need for more theoretical perspectives on nuclear waste from both humanities and social science. What are the more general social and cultural conditions for the activities of the main actors on the national and international scene? One important example is the so-called "Mode 2" theory on science and society. This idea was introduced in book published in 1994 (Gibbons), wherein a number social scientific scholars argue that contemporary research is moving from academic, investigator-initiated and discipline-based knowledge production (Mode 1 knowledge) to a "context-driven" research, i.e. research carried out in a context of application, arising from the very work of problem solving and not governed by the paradigms of traditional disciplines of knowledge (Mode 2 knowledge). This idea was further elaborated by Helga Nowotny, Peter Scott and Michael Gibbons in another book from 2001:

> One important change is the erosion of the collectivist belief-systems that characterise the science system and generate the norms which bind it together. The result is less "segregation" from, and more "integration" with, society. Scientists now share their once exclusive systems for communicating information with these "outsiders". One way of putting it is to say that the rising tide of individualism in society now has reached collectivist scientific communities. (Nowotny, 2001)

The Mode 2 theory has been contested by other scholars, but it may nevertheless highlight certain important problems when it comes to the nuclear waste issue. One concerns the questions of *alternative methods* for handling nuclear waste. Have non-geological methods been unduly

1. Further information is available at *www.skb.se/Templates/Standard____24519.aspx*.

marginalised and certain geological methods received inordinate and scientifically questionable attention? If so, is this due to the integration of science and society resulting in a "community of practice" between scientific, social and political interests? What are the conclusions to be drawn from this (alleged) development?

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Participant Perceptions on the Nature of Stakeholder Dialogue Carried out by the United Kingdom's Nuclear Decommissioning Authority (NDA)

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Introduction

Between October 2005 and September 2010, the Nuclear Decommissioning Authority (NDA)[1] in the UK held bi-annual two-day stakeholder meetings with nuclear site community representatives, trade bodies and industry regulators. The NDA emphasised that the National Stakeholder Group (NSG) process was not a decision-making forum for stakeholders and that accountability for decision making remains with NDA. The focus of the process was "dialogue between participants as an opportunity to explore issues and submit proposals for consideration by the NDA and/or its contractors." The NDA Stakeholder Charter (2005) also states that the NDA will "establish an open and interactive relationship with its stakeholders" and "engage with stakeholders and consult widely to ensure there is ample opportunity to understand, comment on and influence its strategies and plans."

The research carried out by Whitton (2010) concentrated on the dialogue used to engage participants and a concept of fairness, by empowering stakeholders not just to consider whether a meeting or process has been a "success" but also to consider their role in the dialogue process and how they perceive their influence on the decisions made. Influence through deliberation is considered by the author to add to Rowe and Frewer's[2] concept of fairness. By moving away from technocratic decision making towards a deliberative model of engagement, stakeholders can realise a level of influence through fair dialogue. This is discussed in terms of the links between the engagement process and the decisions made. It has also been recognised by the same author, citing Reed (2008), that the structure of the convening institution (in this case the NDA) and its ability to institutionalise stakeholder engagement as a method to influence strategy is also fundamental to successful engagement and understanding the current approach adopted.

The stakeholder-led approach initially adopted by the NDA, the nature and role of "dialogue" and how stakeholders perceived this dialogue to influence the NDA decision-making process

1. The purpose of the Nuclear Decommissioning Authority (NDA) in the United Kingdom is to oversee and manage the safe and cost-effective decommissioning and clean-up of the UK's civil nuclear legacy and where possible to accelerate programmes of work that reduce hazard. The organisation took over the overall responsibility for nuclear licensed sites that were previously owned and operated by British Nuclear Fuels Limited (BNFL) and the United Kingdom Atomic Energy Authority (UKAEA).
2. According to Rowe and Frewer (2000), political theorists and social scientists have traditionally argued that concepts related to public acceptance (e.g. fairness) are of greatest importance regarding participation in policy setting, while those arguing from an economic and scientific perspective have argued that the quality of the decision and process is more important (and often, that lay persons lacking knowledge should have little role to play in technical/scientific policy making). In their opinion, both aspects need to be considered: an exercise that is fair and has good acceptance, but poor process, is unlikely to be implemented by the convenors of a process, while an exercise that has good process but poor acceptance is likely to be met with public/stakeholder scepticism, dispute or boycott.

were important themes of the research. The section below provides a brief summary of the work and compares the findings from Questionnaire 1, issued in November 2006 to those of Questionnaire 2 issued in May 2008, to assess any change in stakeholder perception between NSG-3 and NSG-6.

Stakeholder-led approach

In May 2008 as in November 2006, the majority of participants that responded either "strongly agreed" or "agreed" that the NDA engagement process has been a positive step by NDA and had been driven by stakeholder requirements relevant to NDA strategy.

The findings from Questionnaire 1 demonstrated the frustration felt by several participants regarding the dominance of some voices, particularly in the plenary sessions of the first NSG in October 2005. This situation had been seen to improve by the third NSG in November 2006, predominantly due to a reduction in the length of plenary sessions, the introduction of carousel sessions and the development of a "firm but fair" facilitation style by the convenors of the NSG. At the time of Questionnaire 1, participants were broadly supportive of this type of environment at the meetings although some were concerned regarding the limited time available to discuss some issues of interest.

By NSG-6 in May 2008, some participants had become concerned regarding the perceived lack of influence that they had over the NSG agenda, suggesting that the NSG was now over-controlled, restricting debate and meaningful outcomes for participants. The balance between direct NDA agenda setting, confirmation of the issues that participants would like to discuss and the request from some participants that NDA make clear the areas that stakeholders can and cannot influence remains unresolved.

This issue was demonstrated visibly at NSG-5 in November 2007, when stakeholders were required to "take back control" of the meeting to enable a discussion of the Draft NDA Business Plan to take place. Although some stakeholders clearly felt empowered by this experience, in a stakeholder-led forum such action would not be necessary. This evidence led to the conclusion that by adopting a strict facilitation style and allowing the meetings to be controlled by the pre-set agenda, the opportunity for debate between participants and participants and NDA on issues of interest was being reduced.

The importance to participants of having the opportunity to discuss and air alternative view points, without the threat of overt criticism and to scrutinise NDA plans was highlighted by Questionnaire 1. The agenda-led facilitation style now seen at the NSG was implemented post-NSG-1 to encourage this and to reduce the role of dominant voices in the plenary sessions, an initial concern of some participants. However, the recent feedback from participants suggests that this had gone too far and participants' comments regarding the influence that they had over the agenda and the perception that NDA was increasingly controlling items for discussion is considered here to be a manifestation of this.

Transparent links between the engagement process and NDA strategy

NSG participants remained confused regarding how their views and opinions expressed at the NSG influence NDA strategy. When asked directly, 60% of participants in November 2006 and 62% of participants in May 2008 (Questionnaire 1 and 2, respectively) felt that it was not clear how stakeholder views were taken into account by NDA. From those participants who did feel that it was clear how their views influenced NDA decision making, this view appears to be based on discussions with the NDA on a 1:1 basis.

Participants' role and influence was an issue that they had raised on several occasions during the engagement process and was included in the aims of the Waste Issues Group (WIG), a temporary subgroup of the NSG, derived by group consensus at the first WIG in February 2006. The WIG process was concluded at the end of March 2007 and issued a final report in June 2007.

Section 5, "Progress and Influence", of the WIG final report states:

"The WIGs Terms of Reference indicate a desire to influence and improve the decisions the NDA makes. However, during the early stages of the work the group was concerned that it was not always clear what impact their work had on NDA. Several mechanisms were put in place to improve this, one being a tabular format of recommendations and comments from the group that the NDA then respond to alongside with how these have been taken on board." (Convenor, 2007)

Despite an accurate record of the work activity and discussion points, evidence of action as a result of stakeholder comment was absent from the table. This type of response, without evidence of action from NDA, could explain the confusion regarding the level of stakeholder influence that the majority of those who responded to both questionnaires felt.

The issues surrounding the impact and influence that stakeholders have on NDA decision making have also been discussed by the NDA Independent Assessor for the process. In a recent report for NDA (Shared Practice, 2008), the authors state, "The areas where there was least satisfaction with this [May 2008] NSG meeting were in terms of the design, structure and facilitation of the meeting, and the level of influence of stakeholders on the NDA." These comments are also based on a questionnaire issued by the assessor.

Deliberative dialogue

In Questionnaires 1 and 2, 83% and 95% respectively of participants agreed that the NSG was a "deliberative" process. In Questionnaire 1, many participants stated that it was too early in the process to state this with confidence particularly as the plenary session in the meetings provided limited opportunity for deliberation. In Questionnaire 2, many of the comments provided were also at odds with the initial agreement from participants that the NSG was deliberative. To resolve this apparent confusion, an additional question was provided in Questionnaire 2 to fully comprehend participant's perception of the term "deliberative dialogue".

The question asked stakeholders which one of three descriptions best described the NSG. In summary, when presented with three descriptions of different types of "dialogue" only 37% of participants associate a basic deliberative description of dialogue with the NSG process (i.e. "have a two-way discussion with NDA regarding the issues surrounding the work that the NDA oversee").

There are several possible explanations for the confusion:

- Participants believe that the transparency provided regarding the work of NDA and an opportunity to express and discuss their views with other participants at the NSG constitutes deliberative dialogue rather than consultation.
- Participants misinterpreted the description provided of deliberative dialogue. For example, the description of deliberation provided in Questionnaire 1 and repeated in Questionnaire 2 used the phrase "an open process of dialogue" in part to describe the term deliberative. Further questioning used the more specific phrase of "have a two-way discussion (i.e. debate) with NDA".
- The variation in structure between NSG meetings regarding opportunities for discussion and debate (i.e. variation in the length and occurrence of plenary sessions where open debate was encouraged) has created an inconsistent response from participants and a degree of confusion.

It is likely that all three of the above explanations are relevant in some way to participant perception of the process and the most likely explanation for the inconsistency between the replies (much informal deliberation takes place between participants who attend the NSG). When descriptions of different models of "dialogue" are provided, only 37% of participants agreed that deliberative dialogue was taking place between NDA and participants at the NSG and recognise that other forms of "engagement" were taking place such as "commenting and asking questions on the information provided" (46%) and "receiving information and updates from NDA on work and progress" (17%).

Conclusions

NDA demonstrated a significant commitment to stakeholder dialogue between October 2005 and September 2010, both in terms of time, cost and availability of staff members at both the nuclear site and national level to be available to stakeholders. By not providing a transparent account of how participants formally influenced the outcome of meetings and "NDA thinking", some stakeholders appeared confused regarding their role at the NSG.

Much informal discussion occurred around each stakeholder event; however, this does not translate into a formal demonstration of stakeholder influence. NDA did not produce the evidence for NDA action as a direct result of NSG comments, to match the commitment that they demonstrated to stakeholder engagement in general. This represented a missed opportunity in terms of validating the dialogue in the minds of stakeholders and increasing decision-making resilience for future iterations of NDA strategy.

The ability of participants to: express views; have honest engagement with NDA; understand other stakeholder positions; expect transparency as to what is and what is not open for discussion and how discussions influence NDA decision making were all high-priority issues for the participants who replied to both questionnaires. In addition, these factors are also typical of a deliberative process of dialogue and an important part of this research. Despite some of the components of deliberative dialogue being achieved in part, participants were confused regarding the extent of their influence and role at the NSG.

If consultation rather than deliberative dialogue was the overall aim of the NSG, many of the components discussed above would not have been required; however, this should have been made transparent to participants of the NSG.

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Reversibility and Retrievability: A View and Review from the RWMC "Forum on Stakeholder Confidence" (FSC)

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Introduction

The Forum on Stakeholder Confidence (FSC) is a multinational group of experts created by the OECD/NEA Radioactive Waste Management Committee (RWMC) in 2000 to address the societal dimension of radioactive waste management (RWM). The FSC explores means to ensure effective dialogue among all stakeholders and to strengthen confidence in decision-making processes and socio-technical systems of RWM. Through its varied activities, including participative learning, the FSC has documented a wealth of experience told in many voices. This ongoing record benchmarks practice, and allows progress and change to be assessed. Two-page flyers summarise several major topics. All FSC publications are available online, most for free: *www.oecd-nea.org/fsc*.

In its ten years of existence, the FSC has been interested on a number of occasions by the topics of reversibility and retrievability. The FSC has looked into these topics from the perspective of how measures of societal dialogue and control may contribute to stakeholder confidence and decision making for RWM plans, facilities and operations. In particular, the FSC has kept abreast of developments in the NEA Reversibility and Retrievability (R&R) project of the RWMC and provided comments to subsequent versions of its draft findings report. Pertinent FSC ideas and publications were then presented at the Reims 2010 conference. This paper briefly reviews those FSC inputs in light of discussions heard in Reims, and offers some remarks on the R&R project from the FSC standpoint.

FSC findings on R&R

In this section, three pertinent FSC publications are identified. Their findings relevant to reversibility and retrievability are quoted and reviewed.

Stepwise Approach to Decision Making for Long-term Radioactive Waste Management (2004, and flyer)

The report entitled *Stepwise Approach to Decision Making* has been evaluated as one of the most useful and most frequently recommended FSC publications.[2] The report, released in 2004,

1. Reviewed, amended and accepted by the FSC membership; updated subsequent to conference discussions. With acknowledgements to Anna Vári (Academy of Sciences Hungary), Jo-Ann Facella (Nuclear Waste Management Organization Canada) and Meinert Rahn (Swiss Federal Nuclear Safety Inspectorate), for their particular input.
2. According to the online survey of FSC members, former workshop participants and interested parties, conducted in summer 2010 at the occasion of the 10-year anniversary of the Forum.

is summarised in a flyer, and an article was published in the *Journal of Risk Research* (Pescatore and Vári, 2006). The report describes R&R as supporting or constituent features of stepwise decision making.

i. R&R as supporting or constituent features of stepwise decision making

"The key feature of a stepwise decision-making concept is a plan in which development is by steps or stages that are reversible, within the limits of practicability. In addition to the institutional actors, the public is involved at each step and also in reviewing the consequences of previous decisions. This is designed to provide reassurance that decisions may be reversed if experience shows them to have adverse or unwanted effects. Discrete, easily overviewed steps facilitate the traceability of waste management decisions, allow feedback from regulators and the public, and promote the strengthening of public and political confidence. They also allow time to build trust in the competence of the decision makers as well as the implementers of a waste management project." (pp. 7-8)

"Decisions are already being taken – and progress towards radioactive waste management solutions is already being made – in a stepwise fashion. Governments and the relevant institutions are incorporating provisions that favour flexibility in decision making, such as reversibility of decisions and retrievability of waste." (p. 8)

"Stepwise decision making allows for reversibility of decisions. Reversibility denotes the possibility of reconsideration of one or a series of steps at various stages of a programme. Such a reversal, of course, must be the result of careful evaluation with the appropriate stakeholders. This implies a need for review of earlier decisions, as well as for the necessary means (technical, financial, etc.) to reverse a step. Reversibility also denotes that, when practical, fallback positions may be incorporated both in the long-term waste management policy and in the actual technical programme. In the early stages of a programme for waste disposal, for instance, reversal of a decision regarding site selection or the adoption of a particular design option may be considered. At later stages during construction and operation, or following emplacement of the waste, reversal may involve the modification of one or more components of the facility or even the retrieval of waste packages for some period of time, from parts of the facility. Thus, reversibility in the implementation phase requires the application of a retrievable waste management technology.

Not all steps or decisions need be or, indeed, can be fully reversible, e.g. once implemented, the decision to excavate a shaft cannot be reversed and the shaft 'un-dug'. On the other hand, these decisions can be identified in the process and used as a natural hold point for programme review and confirmation. Reversibility is thus also a way to close down options in a considered manner. In the same vein, if the need to reverse course is carefully evaluated with appropriate stakeholders at each stage of development of a facility, a high level of confidence should be achieved, by the time a closure decision is to be taken, that there are no technical or social reasons for waste retrieval." (pp. 8-9)

"Competing requirements of technical safety and societal control are to be reconciled in long-term waste management. Due to the extremely long-lasting potential danger of radioactive waste, the primary feature that waste management facilities should demonstrate is long-term safety. At the same time, several stakeholders demand future controllability and retrievability of waste when these are placed in underground repositories. Only a step-by-step approach to technical implementation can assure that a balance between safety and controllability considerations, appropriate to a particular national or programme context, may be met simultaneously and that robust systems for waste management may be established. Such robust systems include monitoring during characterisation, operation and (in the case of final disposal) the post-operational phase. In response to the tensions between considerations of technical safety and societal control, many implementing organisations are focusing their efforts on developing a final repository from which the waste is retrievable. In some cases, retrievability for some period of time is also a legal requirement." (p. 9)

The quotations above indicate that the concepts of "reversibility" and of "stepwise decision making" (SDM) are closely related. The flexibility provided by potentially reversible steps is an important and appreciated feature for improving stakeholder confidence in waste management plans.

Indeed, it is striking that when certain national programmes have been obliged to "start again" they most often choose to design and carry out a stepwise process with clear phases of planning and reflection (including extensive and intensive public consultation), decision and implementation. Examples include the United Kingdom and Canada. We observe that in such cases, a forced and substantial reversal has demonstrated the importance of flexibility and adaptability, which can be provided by a stepwise approach.

ii. Ideal features of stepwise decision making and implications for R&R

The FSC publications explain why SDM is useful for building stakeholder confidence, offer practical advice and point to applications of SDM in various countries. Some ideal features of a stepwise decision making approach, described by the FSC,[3] contain *implications* for reversibility:

- In stepwise decision making, a plan lays out policy development and implementation by steps or stages. If necessary these may be revisited and adjusted, within the limits of feasibility.

Thus, the decision to reverse – "revisit and adjust" – implies a judgment of "feasibility", supported by an assessment of the benefits and disadvantages of reversing a decision.

- Main stakeholders are involved at each step and also in review of the results of decisions taken in previous steps.

Thus, societal stakeholders ideally participate in assessing the need for, desirability and feasibility of reversing a decision.

iii. Advantages of a stepwise approach and links with R&R

The FSC also identifies advantages of a stepwise approach in view of building stakeholders' confidence in waste management systems. These advantages too may be read with reversibility in mind:

- Research, policy making and stakeholder input are linked in a cycle of shared learning. This allows involved actors to build more familiarity with and control of the issue at hand.

Familiarity and control have been shown to be important components in stakeholder confidence.[4] *In particular, accepting technical options or volunteering as a candidate host community are shown to be easier when communities can move through stages that allow them to become well informed and progressively more committed, instead of being obliged to accept "all or nothing". Reversibility is a tool among several that can improve control, as explained in the next item.*

- Making choices by stages facilitates adaptation to inevitable changes in legal, economic, social, technical or political conditions. This is useful in a lengthy project.

A stepwise process does not "run away" from decision makers, but instead remains within control and can be adjusted to its context – as the context evolves or as it becomes better understood. The ability to reverse certain decisions, when they are revealed to no longer be adapted, is an advantage.

- The stepwise plan provides clarity to all stakeholders about the stages of the programme, the roles of those involved, and their opportunities to influence the outcomes.

Such clarity is important in the case that a decision comes under review for possible reversal.

3. The bullet items related to SDM (parts ii and iii) are all quoted from the FSC flyer on this subject, and *annotated* in the present contribution to the R&R conference.
4. See e.g. (NEA, 2010a), pp. 19-20.

The FSC observes that the way SDM is handled varies from country to country in line with the legal and democratic frameworks specific to each one. Moreover, the actual reversibility of certain steps (e.g. the retrievability over time of emplaced waste) will also depend on the technical disposal concept retained and developed, and on the geology of the site.[5] In sum, there is no "one-size-fits-all" solution for planning or implementing reversibility and retrievability. Furthermore, even when staged programmes are designed they may not be acceptable to all stakeholders, or partial failures to move forward may occur. However, stepwise decision making has led to decisions that are viewed as legitimate and can be more easily sustained. In this way, the stepwise approach – which implies and relies on theoretical reversibility, of which retrievability is a practical element – may in practice *diminish* the future need to reverse some decisions.

More Than Just Concrete Realities: The Symbolic Dimension of Radioactive Waste Management (2010, and flyer)

This report (NEA, 2010a) details what the FSC has learned about the "symbolic dimension" underlying actions, gestures and decisions in the area of RWM:

> "The Forum on Stakeholder Confidence … has found that key concepts of radioactive waste management (RWM) (e.g. safety, risk, reversibility, retrievability) carry different meanings for the technical community and for non-technical stakeholders. It has also learn that some highly value-laden socio-economic concepts (e.g. benefit packages, community, landscape) are interpreted differently by different societal groups, and that opinions and attitudes are not simply a faithful reflection of decision making, actual events and communicated messages. Perceptions and interpretations of events and objects also play a role. Deep-seated values and norms, knowledge and beliefs, group identification, cultural tradition and self-interest are some examples of factors that shape perceptions and interpretations." (p. 3)

i. Utility of accessing the symbolic dimension through dialogue

Different persons and groups may assign significantly different meanings to events and to words. The FSC *Symbolic Dimension* report (NEA, 2010a) suggests that developing sensitivity to and explicit awareness of such differences – sometimes unspoken – can help to formulate decisions that are better grounded and more sustainable. What is the implication for reversibility? When it becomes apparent that a decision may need to be reversed, then a good understanding of different perceptions, priorities and values may facilitate the process of assessing the decision and of judging whether it is feasible to reverse it.

It was found in the FSC report that dialogue is necessary to reveal divergent understandings and values, and to build-up and check shared ones. In the same manner, the FSC sent the following advice to the RWMC in March 2010 (RWMC, 2010):

> "FSC meetings, and particularly the workshops held in a national setting, typically aim at the joint creation of knowledge about RWM themes. The interaction among stakeholders is organised in the goal too of enhancing mutual understanding and building mutual trust. The FSC, over ten years of operation, with analysis of case study experience and live encounters in the workshops, has come to believe that the process of creating and exchanging meanings is as important as the actual topical outcomes of this process. Moreover, it must be considered that in society, certain central RWM concepts and principles (for instance: safety; reversibility …) cannot be successfully defined in a top-down manner; instead, their multiple meanings should be clarified through dialogue. Importantly, this dialogue must be renewed at various decision points over the multi-year cycle of RWM, because even when decisions have been "banked", over intervening periods the societal views on e.g. ethical values, priorities, or other features of definition may very well shift and should be checked in order to tune actual implementations."

5. For example: due to deformation properties, salt and clay environments appear less suitable for long-term retrievability, while crystalline rocks show less deformation in the long run and provide good boundary conditions for retrieval.

That advice clearly engages notions of reversibility, and the need for built-in dialogue processes for reviewing and assessing decisions to respond to changes in societal views. To grasp societal views, sensitivity to the symbolic dimension is required.

ii. Symbolic dimension of R&R

From the FSC reflection on the symbolic dimension of RWM, we can also conclude that the symbolic valence and weight of RWM choices should be anticipated by institutional actors. In this light, building *reversibility* into a stepwise RWM programme may directly symbolise desired values. Recognising the potential need to reverse a decision is equivalent to recognising that we are not infallible. It shows that we provide ourselves and future decision makers with tools to improve a decision should new events, or better understanding, suggest the need to do so. In sum, the feature of reversibility communicates modesty, foresight and openness:

- In the technical realm, reversibility indicates the willingness to identify, study and correct inadequate concepts or actions.
- In the societal realm, reversibility indicates the willingness to adapt to changing societal preferences.

Reversibility does not guarantee that decisions will systematically be overturned, but it does communicate that if a decision is later found to be faulty then it may be adjusted. This is a sign of realism and maturity.

Does *retrievability* too have a symbolic dimension? The answer is doubtless "yes"; interestingly, several varying, sometimes contrasting, symbolisms are found. Some RWM policy makers have judged e.g. that offering the possibility to retrieve emplaced waste may send a signal that there is low confidence in the future performance of a repository. In contrast, other programmes have provided measures for retrievability because being able to "get in again and fix something" without needless obstacles is simply considered good engineering practice, and aligns symbolically with the realism and foresight discussed above.

Discussion at the Reims conference suggested that either or both of these two alternate symbolisms – lack of confidence and reassurance – may be present in societal stakeholders' minds when they consider R&R.

Further conference discussions about the desirability of R&R as part of any national RWM programme used colloquial or metaphoric language that points to a symbolic dimension. The view was expressed that while R&R are meant to offer an "off-ramp" from an unwanted situation, they should not be presented to societal stakeholders as "idiot-proofing" against ill-taken or immature decisions (for the objective should always be to take excellent decisions). Nor should R&R be offered as "cookies" to sweeten a choice that societal stakeholders might otherwise find bitter.

Such discussions highlighted the need for high consistency in RWM across behaviours, plans and discourse, which should all support chosen fundamental values such as safety and transparency.[6] R&R are not "magic wands" and they must not be used as "decoys". Instead, like other programme features, R&R must stand up to stakeholders' examination and show that they are appropriate (or not) to help address RWM issues as these are framed in each context.

R&R have both a technical and a social meaning. One could argue that reversibility is an engineering concept, part of the ongoing adaption to the state-of-the-art; however, at the same time R&R are taken up into the legal framework of any given country in order to serve shared values. In this transition, institutions are forced to publicly debate their technical and social decisions and open them to criticism, sometimes going so far as to revise them.

The FSC report (2010a) shows that these value-clarifying activities rely on dialogue and on the ability to recognise the symbolic dimension.

6. Organisational adaptation to such demands is studied in NEA (2007). See also the FSC Glossary Handbook (forthcoming).

Radioactive Waste Repositories and Host Regions: Envisioning the Future Together (2010)

In April 2009, the FSC met for its annual National Workshop and Community Visit in Bar-le-Duc, France. Among the participants were representatives of institutional authorities, local and district councils, civil society organisations, universities, waste management agencies and some 20 FSC delegates from 13 countries and the European Commission. Delegates visited the area in Eastern France where a 15-year stepwise technical and social process had culminated in designating the site where a deep geological repository may be constructed for the disposal of high-level and long-lived radioactive waste. An important feature of the French laws framing this process is the parliamentary requirement on the implementer to deliver to the regulator a grounded plan for reversibility. Subsequently, a decision is to be made by Parliament on the conditions or criteria for reversibility.

The FSC workshop included a session during which a panorama of involved French actors [the National Waste Management Agency (Andra), the National Review Board and the local monitoring committee CLIS] expressed their views on, mostly, retrievability. After these plenary presentations, the delegates broke out into six small mixed discussion groups, and considered four questions:

- What are the different actors' objectives for retrievability?
- How can different actors' expectations be accommodated?
- What are the limits/implications of reversibility/retrievability?
- Is there recognition that the retrievability objectives and expectations may evolve with time?

The workshop proceedings (NEA, 2010b) provide a detailed record of those discussions and the points made. Overall, they confirm earlier FSC findings: namely, that various stakeholders demand future controllability and retrievability of waste for several reasons. Socio-technical implementation should thus assure that a balance between safety and controllability considerations, appropriate to a particular national or programme context, is reached, and that robust systems for waste management are established. Such robust systems include monitoring during characterisation, operation and (in the case of final disposal) also the post-operational phase. Furthermore, the point was made that R&R discussions and decisions ought to be considered from the start of the project. To achieve this, flexibility should be highlighted as an informing principle in repository implementation.

FSC internal discussions and input to the R&R report

The FSC was kept abreast of R&R group progress, and given the possibility to input to the draft report as it was developing.

FSC topical session on R&R

In the context of this ongoing information exchange, a topical session on R&R was held in September 2009 during the 10th Regular Meeting of the Forum, under the FSC theme "Research, Development and Demonstration and Stakeholder Confidence". FSC members prepared for this discussion by submitting a short status report on their own country's position or work regarding R&R, from the point of view of stakeholder confidence and engagement. Five NEA member states were represented in this way.

The topical session included feedback from discussion of R&R at conferences organised on a national or international basis by Andra to contribute to "developing a technical and societal concept of reversibility in France". The FSC also learned about the "retrievability scale" or an explanatory brochure meant to support dialogue that benefitted from review by local stakeholder groups in France and in Scotland. This "R-scale" includes graphics that help to consider how R&R fit into stepwise processes, and to visualise how retrievability becomes less accessible across the long term. As noted in the summary record of the meeting, "the FSC colleagues were impressed with the process of development of the R-scale (…). The integration of technical and societal input appears to be highly successful, and the process of integration would merit analysis in and for itself. The scale-related work is interesting also for helping develop regulatory guidance."

Discussion of the topical presentations brought up issues such as: the meaning of "closure"; the role of regulators; the continuity between R&R and monitoring.

FSC observations on the R&R draft findings report of September 2010

At the 11th Regular Meeting of the FSC in September 2010, time was allotted to a discussion of the most recent draft of the R&R report, which had been circulated to all FSC members prior to the meeting. FSC members (who over time had followed the progression of the draft and project thinking) felt that the document provided a good foundation for discussion at the Reims conference. Responses and comments included the following:[7]

> *"The report shows convincingly that reversibility and retrievability are not technical matters alone –* definitions and decisions related to these concepts should not be delegated solely to technical experts. Processes and plans developed will need to meet societal requirements as well as technical requirements. From a stakeholder confidence perspective, reversibility and retrievability may be a means toward another end, rather than ends in themselves. The definition that society gives to this end may evolve over time."
>
> *"The discussion in the report is consistent with the principles and best practices discussed by, and emerging out of, the FSC*[8]. Such principles include: the need to involve stakeholders in decisions about plans and processes in order to build confidence in them; and the need to start involvement early and continue throughout the implementation of these plans in order to ensure that both technical and social requirements are being addressed, even as these may evolve over time. These principles represent key issues for the success of waste management programmes. Respecting these principles is part of seeking the "social licence" that may (or may not) be granted to RWM plans. One must think through the implications of these principles for the implementation of what once was seen as a matter to be left to technical experts. Waste managers should make certain that the approach to R&R can be seen by citizens as exemplifying these principles."
>
> *"The report attempts to integrate social and technical considerations* in understanding what is involved in making decisions in a certain area and why. The early drafts of the paper had started with a relatively simple understanding that the key decision to be made is between safety and retrievability, putting technical experts and uninformed citizenry at two opposing ends of a scale. Such thinking could reduce the issue at hand to, *"How do we communicate to people why they should not want reversibility and retrievability?"* However, the paper has evolved to a more nuanced discussion about the broad range of inherent "dilemmas" which need to be considered in making decisions about reversibility and retrievability. Stated in other words, the paper acknowledges the multiplicity of trade-offs that need to be made in any decision. The paper makes a very strong case that there is no single best, universally applicable answer to the questions raised or the trade-offs implied by a given reversibility decision."
>
> "Are all the dilemmas and trade-offs inherent in the issue characterised well in the paper? Not necessarily. However, this is an area for discussion and debate. This is a case where the *process* of discussion, engaging people across nations, and importantly within nations, is building confidence – irrespective of the outcome or social consensus emerging from that debate."

7. From notes provided by J-A. Facella of NWMO, Canada.
8. Several persons are members of both the FSC and the R&R working parties, but this alone does not suffice to explain the good overlap in understanding.

Discussion in light of presentations at the Reims Conference and Dialogue

The FSC has investigated reversibility and retrievability from the perspective of stakeholder confidence in systems – both technical and institutional – for the management of radioactive waste. Reversibility is an important tool for flexibility. Because it provides the possibility to review a decision before going on to a next step, to correct the decision if appropriate, and if necessary to change course, reversibility is in line with the values and good practices promoted by the FSC. Reversibility corresponds to the stepwise decision-making approach [set out in (NEA, 2004)].

When a programme builds in reversibility, it sends a strong symbolic message that societal stakeholders are not expected to accept and adjust to a *fait accompli* without opportunity to input their views or priorities. Reversibility signifies that a stepwise programme of decision making is in place, which helps to provide a guarantee that local stakeholders, in particular, are not obliged to make an "all or nothing" decision. Reversibility creates the opportunity to involve a broad panel of stakeholders in assessing decisions and as such, contributes to ensuring that a "social licensing" process takes place.

The perspective of retrievability, as an instance of reversibility, implies that systems must be in place to understand, monitor and assess the performance of the disposal system. Retrievability provides reassurance that in case of error or of other necessity, humanity has some means of control over the emplaced wastes.

R&R are not panaceas, however. This paper has largely reviewed the socially desirable aspect of building in the ability to reverse, within appropriate limits, a decision. It has highlighted the good practice aspects – from a societal and an engineering point of view – of conserving retrievability. At the Reims conference, in contrast, differing views were sometimes expressed. While little fundamental criticism of reversibility was voiced, still some countries have not made reversibility a structural priority. Some national programmes do not place any emphasis on conserving retrievability, nor do they exclude it.

Conference dialogue suggested that reversibility (and particularly retrievability) becomes more difficult and costly as time passes. Retrievability is time-consuming and thus may cause higher doses to those working to achieve it. If retrievability is exercised, there furthermore must be an alternative storage or disposal solution to handle the retrieved waste. In light of such facts, several speakers emphasised that R&R should not be used as programme features to divert the attention of civil society from the range of safety issues, nor to falsely reassure potential hosts that their own hosting decisions are of little lasting consequence. Instead, R&R if present in a national programme should be viewed as instruments affording opportunities to identify and discuss trade-offs, and to allow public discussion of the programme's overall quality management. Beyond the intrinsic safety benefits R&R may offer, they may also enhance the ability to fine-tune the RWM process so that it may become more robust and worthy of societal confidence.

Remarks on the approach exemplified by the R&R project

Findings, best practice and values presented in the FSC body of literature (of which just a few publications were quoted here) are compatible with the findings and approach taken by the R&R group. Both working parties reflect a veritable trend in RWM, in which there is a rational commitment to the good governance of a long-term endeavour that is both technical and societal. In both the FSC and the R&R project group, reversibility is explored as one potentially valuable feature of this good governance, and the pragmatic aspects of its implementation are considered under a social as well as a technical lens.

The Reims Conference and Dialogue applied the round-table discussion format successfully used at FSC workshops. It was expected that dialogue across lines of nationality and role may result in possible future improvements to planning and implementation in the programmes where R&R are retained as part of the RWM approach.

The R&R group attempted to involve a diverse range of stakeholders in its three years of work. The success of this endeavour was clear at Reims, where participants recognised the exemplary openness of the conference and the opportunity given to civil society to speak in both round-table groups and plenary. It was commented that this scenario would have seemed impossible some years ago. Furthermore, civil society's various inputs and resulting dialogues at the conference were explicitly acknowledged to be valuable by technical specialists in attendance and by policy-maker participants. Outside the conference, development of the retrievability scale has involved technical and non-technical specialists; the R&R group's report has been developed through a progressively more inclusive approach. These conducts are a sign of openness to the unexpected and to change, which is a corollary of reversibility.

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9. Note that most OECD/NEA reports and flyers referenced are available also in French. Find these publications online via *www.oecd-nea.org/fsc*.

The Economic Analysis of Reversibility in the Radioactive Waste Disposal and the Real Options Theory

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Decision makers in the nuclear field have the difficult task of balancing the objectives of environmental protection and human safety with those of cost minimisation for the storage infrastructure. Both objectives interact in the optimisation issue of choosing the appropriate disposal stage according to a complex set of variables influencing the decision.

Consequently the ability to adjust the disposal facilities according to the arrival of information over time is essential.

In France, a 2006 Act institutes the reversible deep geological disposal as a norm, with different possible levels of retrievability of the radioactive waste packages. The reversibility in the gradual process of construction of a storage deposit is considered in order: *i)* to preserve some ability to take into account technological progress by considering the arrival of new information; *ii)* to allow future generations to make their own decisions about the storage of the waste. Moreover the exceptional dimension of temporality is important and must be taken into account in the decision process when defining the concept of reversibility.

From the perspective of the economic evaluation of a reversible storage project, the multiplicity of uncertainties surrounding this issue renders the traditional method of calculating the net present value of the project irrelevant. Indeed, it tends to undervalue decisions, discounting the expected benefits and costs using exclusively the information available at the time at which the decision is taken, namely at the original date. The Real Options Theory provides a more complete framework for project valuation and decision making when uncertainty and flexibility are central to the decision issue. It makes the arrival of new information in the future possible and it permits to consider some decisions that are irrelevant or impossible to take at the initial date but that may be essential in the future. So there is a need to valuate these options available to the current decision maker or future generations: this can be a new evaluation of the disposal process (for example a new technology, much safer or more space saving, could emerge), the retrieval of radioactive waste if new information justifies it (a new use of waste could be discovered in the future) or continuation on the same path.

Also for the economist, reversibility is a complex concept and its analysis cannot be separated from the opposite concept, namely irreversibility. In a first approach, an irreversible decision is a decision that irrevocably condemns the exploitation of new information and thus any adjustment in time. Conversely, a decision is reversible or less irreversible if the decision maker can integrate newly acquired information and thus revise different choices (Arrow and Fisher, 1974; Henry, 1974).

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A second possibility to study reversibility in economics refers to the different types of costs involved in the project. Thus the construction of a geological repository of radioactive waste is a specific investment which cannot be assigned to another use. In this situation the initial expenditure, typically called "sunk cost", is irreversible. The degree of reversibility of costs is strongly linked with a complementary notion, flexibility. Indeed, if the alternative to "recover" the original cost when unfavourable conditions exist, the opportunities created by different sources of flexibility give no additional value to the project.

Since the 80s, the Real Options Theory is a modern approach used to better analyse issues of strategic decisions in domains with a high degree of uncertainty and an important dimension of temporality: natural resource exploration, energy industry, biodiversity, etc. At least two reasons explain the success of Real Option Theory. On the one hand, as mentioned above, it permits to take into account the dynamic feature of innovation, and more generally, the accumulation of information over time (scientific, geopolitical, ...). The discount rate and distribution of future earnings are no longer the only central points of the evaluation. On the other hand, this theory comes within the scope of the theories of decision and basically helps to answer the following question: What is the price to be paid today in order to preserve a wider flexibility for a future decision? This price can involve the technical costs or constraints, but also the social constraint (it is possible to consider a "willingness to pay" for current generations).

In the case of radioactive waste, if the decision maker decides to close definitively the repository of radioactive waste, he gives up the opportunity to open it later and recover the radioactive materials contained in the ultimate waste if new techniques of treatment and recycling are available. By doing so, he abandons an option: Its value must be evaluated in order to assess its opportunity cost in the decision process.

From these particular characteristics of the French project of radioactive waste disposal, our research in economics aims to offer some theoretical insights to analyse the relationship between reversibility, and more particularly retrievability, and the significant costs characterising the project. The objective is to show how the real options theory can be used to analyse the issue and evaluate different possible storage processes.

The sequentiality of decisions and the existence of various options for a single decision point make economic computation more complex than in a decision framework with simple options. Actually, the reversible storage project involves multiple interacting options that can create future opportunities. The value of an option at a given date may be different depending on the options available at later dates and thus its value must be computed together with other options. This is what we call compound options: They create important interactions in the evaluation of the project.

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The EKRA Studies and the Formulation of the Swiss “Long-term Monitored Geological Disposal” Concept

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Introduction

The Swiss “Law on Nuclear Energy” (LENu, 2003) prescribes the elimination of radioactive wastes according to the following principles:

- The waste producer must eliminate waste in a safe and permanent manner, either in a “deep geological repository” in Switzerland, or (as an exception) in a safe facility in a foreign country (art. 30, 31, 34).
- After an appropriate procedure of investigation and safety analysis, the final authorisation for the exploitation of the repository is conditioned by the favourable conditions of the site as demonstrated during the construction phase, and the demonstration that waste can be retrieved with a “reasonable effort” until the final closure of the repository (art. 37).
- The owner of the repository has to establish during the “observation phase” (meaning: until final closure of the repository) a monitoring of the repository and its environment. The federal government may order further monitoring after closure of the repository (art. 39).

The topic of this conference talk is the presentation of the basic concept of the “deep geological repository” as formulated by the law (the so-called “EKRA concept of monitored long-term geological disposal”) and of its option of reversibility, and to give a short overview of the process on the long way to go as described in the official planning (“Sectoral Plan for Deep Geological Repositories”) (FOE, n.d.).

Switzerland has currently five commercial nuclear reactors, producing approximately 40% of the electric power of the country. Nuclear wastes from these plants, as well as from industry, research and medicine, are planned to be eliminated in two different repositories, depending on waste activity and duration of radiotoxicity:

- A repository for about 77 000 m^3 of low- and intermediate-level waste (L/ILW).
- A repository for about 7 500 m^3 of high-level waste (HLW), composed of vitrified waste and conditioned spent fuel. The attribution of about 2 600 m^3 of alpha-toxic waste to one of these facilities remains open.

The national co-operative society NAGRA has the task of planning and realising the repository as a mandate from the waste producers, under the control of the federal authorities.

The EKRA concept

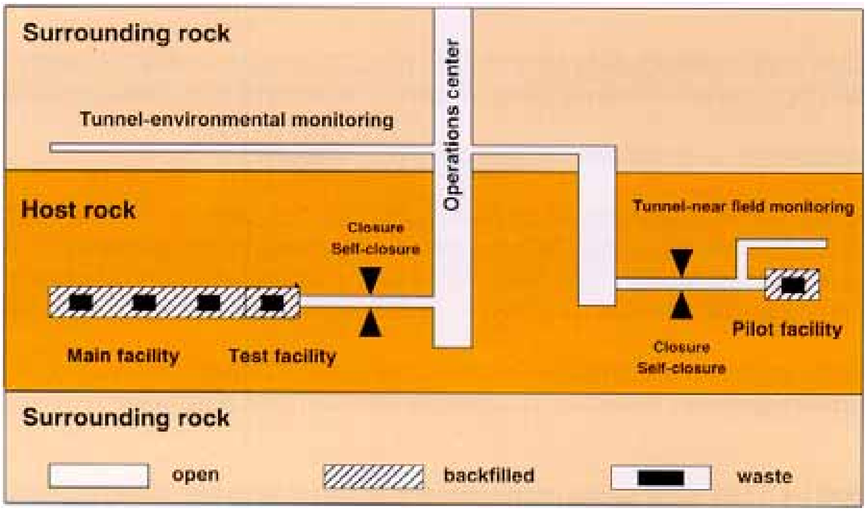
The concept established by the working group EKRA (Wildi, 2000), is based on three basic findings:

- Safe disposal of radioactive waste is a responsibility of the generation that takes profit from the electricity production of the nuclear power plants.
- The only currently internationally recognised method for safe long-term disposal of radioactive waste is disposal in deep geological repositories in appropriate host rocks in a stable geological context.
- Monitoring of the repository and the possibility to retrieve waste in case of necessity are a demand of a large part of society.

The ethical requirements of EKRA for a sustainable and safe repository have therefore been formulated as follows:

- guarantee for the permanent protection of humans and the environment;
- no undue burden on future generations;
- no undue restrictions of options for future generations;
- possibility for corrective actions;
- adequate societal decision-making process for repository implementation.

Figure 1: Schematic concept and system elements of the monitored long-term geological disposal facility (Wildi, 2000; Hufschmied, 2002)



From the technical point of view, EKRA put forward a concept based on a deep geological repository combining three different facilities (Figure 1):

- *Test facility:* This facility serves as a rock laboratory for the site-specific studies that are necessary for the safety demonstration required for the operation of the repository. The facility is constructed once the site has been selected and may remain in use during the operation of the main facility.
- *Main facility*: Most of the waste is disposed of in this facility. The architecture of the facility (access, cavern system for the disposal and its geometry), the installation and the backfilling have to be conceived and realised in a way that retrieval remains a technical option. Once the waste has been emplaced in the caverns, these are backfilled and sealed. However, access and service tunnels will remain open, and waste can be retrieved

without any excessive effort and at relatively low cost, e.g. using remote-controlled tunnelling equipment. The time of closure and sealing of the facility will be decided by the government.

- *Pilot facility*: This is a key facility of the technical part of the concept of monitoring and reversibility. Representative volumes of the different wastes and waste forms will be deposed of in this separate pilot facility, with the aim of validation of long-term predictions as well as identifying possible early indications of safety barrier failures. The main functions of the facility are the following:
  - monitoring the long-term evolution of the engineered barriers and the near-field;
  - verifying the predictive models to demonstrate long-term safety;
  - serve as a demonstration facility, which allows long-term control beyond the closure of the test facility and the main facility.

In relation with the pilot facility the following activities are planned:

- monitoring of the engineered and near field natural barriers (host rock), development of monitoring instrumentation and their replacement due to ageing and technical progress;
- development of repairs and improvements to the engineered barriers;
- tests on clean-up measures in the case of unexpected release of radionuclides into the near-field and the geosphere;
- development of retrieval techniques of waste.

Sealing and closure of the facility (or the retrieval of waste from the pilot facility) will be decided later as a function of experience and monitoring results.

In addition to this technical part, EKRA also recommended in its first (Wildi, 2000) and second reports (Wildi, 2002), institutional and organisational measures, and measures with respect to the schedule of radioactive waste disposal. Among these recommendations, one may mention [for a complete listing see (Wildi, 2000, 2002)]: The need for a permanent public debate to resolve the problem; the need to adapt the legislation to the requirements of the programme for waste elimination, including monitoring and the option of reversibility; the need for a clear schedule and follow-up for the programme; the need for independence from waste producers of the programme and the agency in charge of the elimination programme (Nagra); the need for independent research, in order to guarantee the scientific follow-up of the programme, as well as the maintenance of know-how.

Key messages

- Reversibility of radioactive waste disposal was a demand of large parts of Swiss society in the 1990s.
- A concept was developed by an interdisciplinary expert group, and introduced into the Swiss Law on Nuclear Energy in 2003, combining the safety requirements of final disposal, and the possibility of reversibility over the long term.
- Key elements of reversibility are an appropriate layout of the repository and long-term monitoring of both the repository and the environment in a way that the decision of either sealing of the main repository or retrieval of waste is open to a future generation.
- To be implemented, this concept needs a permanent public dialog on nuclear waste disposal and appropriate mechanisms of public involvement. Conservation of know-how has to be guaranteed by an open research and education programme.

Implementation of the concept

The concept of monitored long-term geological disposal has been widely accepted by public opinion. Some parts of the concept have been implemented, others have not yet been considered.

Implemented elements of the EKRA concept include:

- The technical aspects of the EKRA concept have been included in general terms, and partly in detail, in the frame of the Law (LENu, 2003) and Ordinance (OENu, 2004) on Nuclear Energy.
- The establishment of a detailed technical programme for elimination has also been included in the law.
- The implementation programme, including a detailed schedule for site selection and mechanisms of public involvement, has been fixed by the federal government in the Sectoral Plan for Deep Geological Repositories (FOE, n.d.) and is currently under way.

Elements of the EKRA concept that have not been considered and open questions:

- Switzerland still has very little independent research on long-term disposal questions, as well in the field of social sciences, as in natural and engineering sciences. Most research is funded by and depends on the waste producers. No education programme (e.g. doctoral school) on the university level is oriented towards key aspects of long-term storage.
- The agency in charge of the elimination programme (Nagra) still depends exclusively on the waste producers. This may be perceived negatively by public opinion.
- Questions concerning technical and institutional aspects of long-term monitoring and reversibility, as outlined by EKRA, have not been further developed in adequate depth and still need to be embodied.
- Co-ordination of the technical plan for the elimination of radioactive waste, in particular concerning questions related to waste quality (gas-producing elements) and other technical aspects, and of the Sectoral Plan for Deep Geological Repositories remains difficult. Also, within the Sectoral Plan, the question of what action, or what geological investigation has to be performed in which phase of the project is still open for debate.

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A Citizen's Perspective on Reversibility: Observations from the Citizens' Conference on the Long-term Management of High-level and Long-lived Radioactive Waste in Belgium

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Context

The Belgian Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS), the public body responsible for managing radioactive waste, has drawn up a draft plan for the long-term management of processed high-level radioactive waste in Belgium.

ONDRAF/NIRAS' aim in producing that waste management plan is to prompt the government to take a policy decision on:

- a standard solution for the long-term management (i.e. disposal) of B and C waste;
- the decision-making process and the schedule for implementing the chosen solution;
- how public approval can be secured and maintained.

Belgium has a long (30 years plus) tradition of R&D dedicated to the long-term management of long-lived and high-level waste. In particular, the geological disposal of these types of waste in argillaceous formations has been studied in an underground research laboratory. However, an official policy regarding the long-term solution for these wastes is still lacking.

The Belgian Law of 13 February 2006 (based on the EC directives 2001/42 and 2003/35) sets out the framework for the imposition of the plan and the consultation procedure to be organised. In parallel with that statutory procedure, ONDRAF/NIRAS has also taken further initiatives designed to already initiate a social dialogue when the waste management plan comes into being. In a country like Belgium, which has a limited tradition of public participation, it was remarkable for ONDRAF/NIRAS to show such a degree of initiative.

In spring 2009, ONDRAF/NIRAS organised its own public consultation process to identify the concerns of stakeholders and citizens alike. It then asked an independent organisation, the King Baudouin Foundation (FRB/KBS), to arrange a participative consultation process on the decision-making procedure and scope of a decision. To this end, the Foundation opted to use the "citizens' conference" method.

The citizens' conference

Methodology

A public forum like a citizens' conference is a classic method used in participative science and technology assessment. It was developed in 1987 by the Danish Board of Technology (*Teknologirådet*), a body established by the Danish parliament and has already been applied in many countries (including Australia, Canada, the Netherlands and Switzerland).

A group of between 12 and 50 citizens is selected at random. Ensuring the diversity of the group's members in terms of their gender, age, level of education and rural or urban background, among other things, guarantees an ensuing diversity of opinions within the group. However, the resulting group is not statistically representative of the population as a whole.

Over three weekends, these participating citizens explore the designated topic and discuss it among themselves and with experts and policymakers. Finally, they draw up recommendations. The citizens' conference procedure is geared towards reaching a consensus, though it also allows room for minority views.

The format of a citizens' conference is strictly determined, but in terms of its actual content it is a very open process, with the citizens themselves choosing priority topics for discussion, the profiles of the experts they wish to meet and the questions they want to put to the experts as well as writing their own recommendations.

To fulfil its brief, the King Baudouin Foundation brought 32 citizens together over three weekends between November 2009 and February 2010 and asked them this question: "Which values, standards, arguments and considerations do you feel to be important when taking a policy decision on the long-term management of high-level, long-lived radioactive waste?" The citizens involved fixed the profiles of the experts they wished to meet (nuclear physicists, geologists, engineers, environmental activists, ethicists, political scientists, members of parliament and so on).

This initiative was characterised by:

- A complete independence vis-à-vis NIRAS/ONDRAF; the Foundation was fully entrusted by NIRAS/ONDRAF to organise the citizens' conference (the fact that NIRAS/ONDRAF was funding the initiative was, however, clearly acknowledged).
- A multi-disciplinary steering committee (sociologist, nuclear engineer, regulator, philosopher, hydrogeologist, legal expert, …) that advised the King Baudouin Foundation.
- External researchers from the universities of Liège and Louvain-la-Neuve evaluated the citizens' conference using four key criteria:
  - fairness (internal and/or external);
  - transparency;
  - competence;
  - efficiency.
- NIRAS/ONDRAF's commitment to hand over the final report of the citizens' conference to the federal government together with the definitive version of the Waste Plan.

At the end of the citizens' conference, the citizens submitted a report with recommendations to ONDRAF/NIRAS, which was widely disseminated by the King Baudouin Foundation.

Recommendations made by the citizens' panel

The citizens' panel drew up 30 recommendations. Here are some of the more striking ones:

- The citizens' panel finds the deep disposal in clay a valid option. After hearing what the experts had to say, the citizens are confident that layers of clay afford good protection against radioactive radiation. According to them, though, there is one important proviso: the federal government must decide that the disposal can be reversed so that future generations have the liberty to choose their own solutions, taking account of future progress made in the domains of science and technology. This reversibility must be guaranteed for a period of 100 years. Such a 100-year period was considered by the citizens as a reasonable one for reversibility.

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- The citizens insisted that the federal parliament adapt the Law on Nuclear Energy to ensure that the funds for managing radioactive waste end up in the possession of a public institution.
- Europe must provide a uniform definition, classification and inventory of radioactive waste. However, Belgium should not wait for this to happen before continuing to seek a solution for its existing waste. While awaiting a European agreement, the decision-making centres for existing waste must remain national and public.

"Reversibility" in the waste management plan

During the consultation procedure organised by ONDRAF/NIRAS

During the consultation procedure organised by ONDRAF/NIRAS in spring 2009, the following five waste management options were put to the participants:

- the so-called "zero option" (not deciding anything);
- continued storage pending the development of advanced nuclear cycles;
- everlasting storage;
- deep geological disposal;
- a multinational option.

ONDRAF/NIRAS has stated its preference for deep geological disposal. Hardly any of the documents submitted to the participants by ONDRAF/NIRAS at the time spoke of reversibility or retrievability.

At the citizens' conference

Rather than taking the aforementioned five management options as their starting point, the participants in the citizens' conference opted instead for an open framework. The issues of reversibility and retrievability were raised in an information brochure that was given to the participants at the start of the citizens' conference.

During the first weekend the participants decided which aspects of long-term management of high-level, long-lived radioactive waste they deemed to be most important.

Immediately, the issue of "reversibility" was raised, though it did not dominate the discussions. Among the participants serious question marks remained concerning the desirability of a reversible management option. The topic was discussed from an ethical (inter-generational justice) rather than a technological perspective.

During the second weekend the participants continued to identify priority issues and formulated the questions to put to their experts in the course of the third weekend of their deliberations. Reversibility figured in the discussion about how and when to reach a decision, but the participants were no closer to a clear opinion regarding its desirability. At the time, the debate about reversibility was inherently linked to the discussion about the potential of an advanced technology (e.g. partitioning and transmutation). The reasoning behind their thinking seems to have been that if the prospects are good for the emergence of an advanced technology capable of reducing the waste problem, then now was not the right time to decide on a long-term management policy.

During the third and final weekend reversibility gradually became a central issue in the citizens' recommendations. After their discussions with the experts, the citizens concluded that:

- New technologies would probably not provide a solution for all waste, and especially not for existing high-level, long-lived radioactive waste.

- Belgium had no clear alternative to deep geological disposal in clay and the taking of a policy decision seemed legitimate.
- No viable European or international solution appeared to be imminent.

Based on these lines of thinking, "reversibility" became a central issue in the minds of the vast majority of participating citizens, who duly worded their recommendation as follows:

> "As citizens, we find that the solution proposed by ONDRAF/NIRAS (deep disposal in clay) is valid, provided that the federal government guarantees reversibility for a reasonable period of 'at least' 100 years, as from the date of disposal.
>
> By reversibility we understand the possibility of subsequently opting for a technologically and financially different waste management solution.
>
> […]
>
> We can support the solution proposed by ONDRAF/NIRAS for the following reasons:
>
> - After hearing what the experts had to say we feel confident that clay strata offer good protection against radioactive radiation.
> - Geological disposal would make the waste less easily accessible to badly-intentioned people.
> - If future generations decide not to retrieve the disposed-of waste, there will be no cause to move it again.
>
> The reasons why we are insisting on a guarantee of reversibility for the duration of a reasonable period are as follows:
>
> - To leave future generations free to decide in favour of whatever solutions they may choose, given that technology is constantly evolving.
> - Because a reversible solution is likely to be a robust, safe solution, whereas society will have to continue monitoring and working on the problem. This also calls for more flexibility and a higher degree of operational safety.
> - Because if we do not already insist on reversibility today, the financial resources to fund a reversible solution will not subsequently be available when needed.
> - Because if future research demonstrates this is not the right solution, we will still be able to opt for an alternative." (KBF, 2010)

Only one panel member did not sign this recommendation. The member in question thought that reversibility was not desirable.

In short, we can say that whilst reversibility was just a vague concept at the beginning of the citizens' conference, in the course of their deliberations it became a key concept on which a virtual consensus could be reached with respect to the long-term management of high-level, long-lived radioactive waste. Primarily ethical, but also technological and financial arguments were put forward in favour of this approach. At the same time, the citizens linked reversibility with the need to pass on knowledge and "social memory" from generation to generation.

In the draft waste management plan

In the draft waste management plan published in June 2010, ONDRAF/NIRAS wrote: "The social consultation procedure set up by ONDRAF/NIRAS clearly highlighted the importance attached by the citizens to the reversibility or even retrievability of the waste." (p. 149)

ONDRAF/NIRAS intends to oblige by ensuring that there is a "flexible, gradual decision-making process, in which the linked elements of reversibility and retrievability figure as prerequisites when designing disposal facilities and planning subsequent disposal". (p. 150) Nonetheless, ONDRAF/NIRAS pointed out that "reversibility and retrievability cannot be viewed as unlimited restrictions (in terms of time, the costs of types of waste, safety and security, among others)". ONDRAF/NIRAS wants there to be "clarity regarding the potential conditions of reversibility and retrievability that people wish to see incorporated into the disposal programme, among other reasons because of the financial implications." (p. 152)

After the statutory public consultation process

The topic of reversibility also cropped up in various observations made during the organised statutory consultation process (from the public at large as well as from statutory consultative bodies).

Based on those observations, ONDRAF/NIRAS considers today that complementary demands to geological disposal should be integrated in the policy proposal:

- a certain degree of controllability and reversibility;
- the maintenance of control and retention in memory for as long as possible.

These demands must be subjected to both a scientific and technological analysis and an analysis focusing on safety and funding. At the same time, a social consultation process is required. All this should make it possible to determine the aims of these demands, as well as their scope and limitations and integrate them into the plans for deep geological disposal (among other things through appropriate R&D activities).

Conclusion

A citizens' conference in Belgium on the deep disposal of high-level, long-living radioactive waste achieved tangible results. The randomly selected participants seemed perfectly able to take on board the most important ethical, technological, environmental and economic aspects and form sound, non-ideologically-driven opinions. ONDRAF/NIRAS duly took account of a fair degree of the citizens' opinion, especially with regard to reversibility and the importance of passing on control and "social memory" to future generations.

The deep geological disposal of high-level, long-living radioactive waste remains a socially sensitive issue in Belgium, as elsewhere. The "reversibility" of the retained management solution (in this case deep geological disposal in clay) seems to be a precondition for which substantial public support can be mustered. However, the concept raises a whole series of technological and financial questions for which answers have yet to be found.

Social consultation and dialogue will remain essential throughout both the ongoing preparatory phase and the implementation of the management option.

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Round-table Discussions on Key Messages from the Angle of Policy Studies and the Social Sciences

A round-table discussion session was held in the afternoon of 15 December 2010 at the Reims "R&R" Conference and International Dialogue, following the social sciences presentations of the previous session. All attendees were brought together in six parallel groups. The conference organisers were responsible for dividing up the attendance to ensure a mixed composition of stakeholder roles in each small group. The secretariat also assigned a facilitator and rapporteur for each group. (Some groups rotated or re-assigned these roles when reconvening for a session on the following day.)

The breakout round-tables were encouraged to discuss the following three topics:

1) *Which key message(s) from policy studies and the social sciences are worth remembering? Why?*
2) *The various countries show specificities and commonalities on aspects such as the symbolic dimension of R&R, policy-building approaches, local stakeholder involvement, etc. Which are valuable lessons to retain?*
3) *Governance of RW has been made possible by the distinction of roles and the independence of actors taking part in the decision-making process: evaluators, regulators, representatives of the interested parties and the public, operators... Is there any specific role to be played in this process by the social sciences and humanities, by economic research?*

The rapporteur from each breakout group gave a brief summary of the discussions at the beginning of the following day's session. These reports were then agreed upon with the facilitator of the session, and are provided in the following pages.

Group A – Discussion on Key Messages, Policy Studies and the Social Sciences

Enrique Biurrun, Anne Bergmans

The group started with an introduction of the members to the others. Group A was a very mixed group, with participants from waste management agencies, regulatory bodies and governmental administrations, as well as people from local communities near potential sites and social scientists.

The main topic dealt with by the group was: Which key messages are worth remembering, and why?

One very important point is that any provisions made to ease retrievability may not compromise safety, either during repository operation or in the long-term. Furthermore, these two terms are quite different: while reversibility is related to decision making in the process of repository development, retrievability concerns actual measures taken to render possible withdrawal of waste from its disposal position in the repository.

Two local stakeholders of the Bure region were present in Group A, and made important contributions to the discussion, presenting laypersons' concerns with the disposal issue.

One of them expressed her conviction that reversibility is heavily challenged once the HLW is vitrified. She had been told that the vitrification process is irreversible. Therefore, once the glass logs have been produced it is not possible to recover the radionuclides dissolved in the glass form. It was explained to her that re-extraction by technical means is difficult but possible, but that such a process cannot occur naturally in the repository. Moreover, reversibility is rather concerned with undoing the disposal process and withdrawing the waste from the repository, and not so much with undoing the waste conditioning process.

Further discussion unveiled that their criticism is more fundamental, and not eased or mitigated by a repository project that is reversible or by a repository that contains provisions for retrievability. Her concern was expressed by saying that man cannot guarantee safety for periods of 100 000 years and more, which are completely beyond our scale of experience. Therefore, it was in her opinion more reasonable to leave the waste on the surface for a lengthy period.

It was then argued that it is the responsibility of the present generation to take care of the waste we produce in the best possible way. There is no guarantee that society will remain stable for longer periods, so that at a later time a "better" solution can be implemented. Therefore, decisions on repository construction should not be unduly postponed.

Such arguments, in turn, bring the focus of attention to the issue of how to deal with the unavoidable uncertainties that exist with regard to future repository development, and how to prevent wrong judgment. The Asse case was quoted as an example of wrong judgment. In the ensuing discussion it was clarified that Asse was the first deep geological repository in the world, so that no experience was available on site selection. In spite of its shortcomings, Asse was at its time, in the late 1960s and early 1970s of the previous century, a much more careful practice than the then-usual sea dumping practiced by many countries. And there is consensus that the site can be appropriately secured.

In any case, an intensive dialogue with the affected population near the site is very important, as the decision makers can learn a lot from the concerns expressed by local stakeholders. Moreover, the decisions shall be only made when there is a high degree of certainty about the future repository safety. There is no urgency in decision making that would justify premature decisions.

One participant expressed then her personal position that a precondition to repository development should be the stop of the production of more waste, i.e. a phase-out of nuclear power use. Subsequently the participants were asked to express their opinion in this regard. In general, it was said that while in some countries the waste issue is seen as independent from the further use of nuclear power, e.g. in Sweden, in others it is not. Particularly in Germany, the opposition to nuclear power use has always focused on opposing repository projects; the line of argument there is that nuclear power must be stopped since there is no solution (i.e. a repository) for the HLW.

The discussion then turned to consider what could/should be the role of social sciences in regard to repository project, particularly in regard to achieving public acceptance. One participant expressed that not only should the role of social sciences and social scientists be appropriately defined, but so should the roles and interactions of all participants. The public should perceive that nobody is left alone with his concerns. Trust and confidence are of paramount importance, difficult to achieve and easy to lose. In any case, confidence requires transparency.

But the issues related to repository safety have a high degree of complexity, in many cases beyond the possibilities of understanding of laymen. This brings about a great difficulty in the communication between scientists and the general public. Social sciences and social scientists can be helpful in this regard by reflection and by bridging between scientists, repository developers and society at large, thus creating the necessary transparency.

Conclusions (as presented on 16 December 2010)

In answer to the question "What specific role can social sciences play?" the group came to the conclusion that there are first and foremost many types, disciplines and schools within the social sciences and that all of these have different things to contribute.

Among these contributions, the following were listed explicitly (but not exclusively):

- offer different frameworks and knowledge basis: support "out-of-the-box thinking";
- question how society works, how the process of science and expertise works, how these two interact;
- address issues such as ethics, values, …;
- identify methods to facilitate dialogue and offer "translation" between different interests, views and concerns.

From the group discussions we also concluded that the biggest challenges for long-term HLW management, and in particularly geological disposal come with the remaining technical and social uncertainties, linked to the long time scales involved. A combination of a belief in progress and innovation on the one hand, and historical experience with bad examples of technology went wrong on the other hand, raises concerns and makes people, and in particular local stakeholders sceptical about how we can be sure today of what is the best solution. The group agreed that the only way to overcome this is to talk and come together to a conclusion on what the best option is, given the available technology today. But dialogue takes time, and there needs to be room for re-evaluation and renegotiation, and everyone needs to be prepared to keep an open mind. As was understood from the local stakeholders, the question of nuclear new build puts some pressure on this dialogue process, as it risks blocking a serene debate on waste management. Otherwise, it was also remarked that if you wait to deal with the waste until there is no more nuclear power generation, then you risk losing the technical knowledge.

Discussions on 16 December 2010

The group discussion during the second day first analysed the attitudes in different countries with regard to nuclear power use in general and to retrievability in a deep repository. While for instance in Canada opponents to nuclear power favour retrievability, pro-nuclear citizens are rather sceptical with regard to it. In Sweden it is the opposite, i.e. people with a positive attitude toward nuclear power use favour retrievability, whereas nuclear opponents are against it. Germany has been an exception to this, with both pro-nuclear and opponents alike considering that a repository should not contain any provision for easy retrievability. This has recently changed, with a retrievability requirement being introduced into the Safety Criteria for Underground Repositories following a political requirement of the state of Lower Saxony.

As on the previous day, a stakeholder with a negative attitude towards nuclear power use pointed out her feeling that it is "immoral" to use nuclear power since it produces radioactive waste, a process she considers an irreversible potential danger. She elaborated further that retrievability is a surrogate to "sell" the repository as a solution for the waste. Therefore, the real question is not retrievability, but whether we should have a repository or not.

Other participants with a more positive attitude toward nuclear power pointed out that the use of fossil fuel is also an irreversible process, and that they lead to discharging greenhouse gases into the atmosphere, which has a negative impact on the planet's climate. On the other hand, significant amounts of waste currently exist, and irrespective of the future use of nuclear power a solution must be provided for this waste. Moreover, the impact of a bigger or smaller repository is approximately the same.

The discussions then turned to the fact that there have been failures of first repository programmes in several countries, notably in Canada, Sweden, Belgium and the United Kingdom. Later efforts have been successful in Sweden and progress is also evident in Canada and Belgium. In all of these countries the role of the regulator is important and the regulators are trusted. Trust is essential, and must be earned; it does not develop by itself. A key element to achieve trust is the perception that the regulator is a truly independent institution, with no conflict of interests that focus only on protecting the citizens. The repository operation and the operation supervision especially must be entrusted to institutions clearly and visibly separated. In some countries, most notably in Germany, there is no independent regulator but a mixture of partially contradictory roles assigned to actors with clear interdependencies. In such cases, trust in all actors is especially difficult to achieve.

A local stakeholder then pointed out that the French participation institution CLIS is an association of politicians and not of citizens. The discussion turned to consider the differences between countries as to how the democratic structures work might heavily condition how local stakeholders can interact. The amount of people involved is also an issue that plays an important role in the ways and means for implementing local involvement. While in Nordic countries a relatively small amount of people live near any potential repository site, this is not the case in densely populated central Europe.

The Retrievability Scale developed during the last few years is deemed helpful to visualise the involved problems and to communicate not only to the general public but also to a technically educated audience what reversibility and retrievability is all about. While discussing R&R it is also important to keep in mind and to communicate that there are conflicting fields, as e.g. safeguards. In this context it was pointed out that physical and administrative repository closure may well be up to many years apart.

Also in case of some particular repository host rocks, notably rock salt formations, the best long-term safety can be achieved by backfilling and closure of disposal areas as quickly after disposal as possible. Maintaining drifts and galleries open for easing retrievability is therefore in conflict with optimisation of long-term safety. In any case, the group considered that R&R is an issue that needs to be considered, and that if not properly addressed and resolved, it would hinder rather than favour stakeholder involvement.

Finally, the group briefly considered that, if a decision to retrieve waste from a repository is ever made, it must comply with the justification principle of radiation protection. This is to say that it must be carried out to prevent a real and not a just perceived danger. The radiation exposure received by workers and the public during waste retrieval, its interim storage and later re-disposal must be lower than the doses avoided through the retrieval operation. Moreover, retrievability will not be credible if the fate of the retrieved waste, its necessary storage and later re-disposal is not a part of the considerations.

Group B – Discussion on Key Messages, Policy Studies and the Social Sciences

Gloria Kwong, Claire Mays

Our group used a different approach to initiate our discussion. Rather than starting with the four guiding questions, we went around the room to gather our views/feedback on the presentations given to us earlier.

Overall, our group agreed that many nuclear waste management implementers have used the retrievability concept as well as monitoring the performance of the repository as tools to build confidence so as to gain public acceptance.

However, implementers may not realise that such a tactic may be interpreted by some as a sign of inadequate confidence. That is, if the implementers are confident with the safety performance of the repository system, why do we need a "Plan B"?

Our group then identified that positive and negative impacts often arise due to differences in perceptions and/or expectations which in many cases are influenced by our experiences. The situation is somewhat similar to finding differences between technical and psychological meanings and values in managing and retrieving used fuel.

At this point, our group realised that while retrieval of spent fuel or waste appears to be technically feasible, perhaps a more important question to ask is: "How can we determine why retrieval is required"?

The post-closure phase was identified in our discussion as a rather critical phase. Some individuals may consider that monitoring the performance of the repository stimulates doubts. How the monitoring system should be designed as well as how monitoring data are to be interpreted may not be easily agreed upon. It may be that different demands are made on monitoring: for professionals, monitoring may communicate doubts about the safe performance of the repository. In contrast, for local citizens, monitoring simply helps to reply to the question "Are we safe?" In this context, monitoring information provides ongoing, valuable assurance. (This is currently the case in e.g. central France in the area of uranium mill tailings storage. There, environmental monitoring is welcomed and citizens contribute to follow up.) Monitoring is not very expensive and it may provide significant added value in terms of confidence.

Similarly, the retrieval operation of spent fuel or waste, particularly in the far future post-closure phase, may actually be more complicated than we assume today. Benefits may be outweighed by radiological and financial risks. Implementers shall be careful not to give misleading information to the public.

Our discussion then moved towards the topic of effective communication with the public. One member specifically noted that the communities must not be treated as one entity. Assuming that there are "general" behaviours of the involved communities is not a wise approach because we are all different. A wide range of perceptions, attitudes and behaviours shall therefore be considered.

Continuing on the public communication topic, one member in the group suggested he prefers that R&R be marketed as something not so dissimilar from best practice in other engineering fields: "design for disassembly". The example used by this member is the auto industry, which plans the recycling pathway of the used car components. R&R provide a means to recover useful resources from used nuclear fuel with the objective to avoid/reduce hazards to be imposed in future generations. Rather than shaping communication strictly in terms of how the "required" legal criteria are met in implementing a nuclear waste management programme, such an approach carries a positive, environmentally responsible image and shows the public the advanced thinking on how to eliminate future problems.

The remark of legal requirements then led our discussion to what role the regulators should play in repository development. Views of our group members on this topic varied. While one member felt strongly that regulators must not participate in/promote any nuclear waste management activities, others feel that regulators taking an active, "stakeholder" role carries positive weight as long as their neutrality is maintained. In Sweden and other countries, the safety authorities play an active role as the "peoples' expert" and this does not damage their ability to regulate.

Our discussion then moved forward to discuss the economic aspects of R&R. Overall, we feel that this is one area that deserves more work. Waste generators definitely should play a more active role in conducting research work to improve our current understanding of the economics of R&R.

Studies conducted thus far have not clearly identified the elements for quantifying the polluter pays principle. While the issue may seem trivial to consumers, for whom the individual contribution is a very small proportion of the energy bill, for operators this represents very significant sums and decisions about provisioning.

Group C – Discussion on Key Messages, Policy Studies and the Social Sciences

Beate Kallenbach-Herbert, Irena Mele

In response to the question: "Which key messages from policy studies and the social sciences are worth remembering? Why?" Group C responded that it is important to note that there are different interpretations of R&R. For instance, there is no clear and commonly agreed definition, e.g. regarding time frames, complexity, the technical efforts required for retrieval and the costs. There are different definitions of safety in social science and technical science.

However, social sciences can facilitate the process of mutual learning by different stakeholders on needs, objectives and implementation of R&R. Here, the aspect of "mutual learning" is important; this is in contrast to an approach of "educating stakeholders". Each participant should be open to changing their point of view with the objective of improving decision making.

Among other messages worth retaining are these:

- The Belgium approach of a "citizens' conference" was a good start to a discussion on R&R which can be used as a means for a national approach.
- Retrievability is a response to public discussions, not a result of technical/natural scientific research.

The group considered the issue that emerged from the presentations: Is reversibility an argument to increase acceptability of RW disposal? On the one hand, disposal might be more acceptable for politicians and the public if an option for intervention is given. On the other hand, there is no one shared opinion of stakeholders regarding retrievability. For instance, the opinion on retrievability seems not to be correlated to the opinion on the use of nuclear energy as different correlations can be found in different countries and within countries. Therefore the response to providing retrievability cannot be predicted to be greater or lesser acceptance.

Going on to discuss the second question, "Which are valuable lessons to retain from countries' specificities and commonalities on R&R aspects?", Group C found that R&R is more than a "symbolic dimension" in many programmes, as it may have relevant influence on the disposal concept. Similarly, legal requirements on retrievability have important impact on the implementer's work (examples were given from France and Germany). Some participants were of the opinion that legal requirements on retrievability are politically motivated. But these have in any case a high influence on the disposal concept and thus on the implementer's work.

In contrast, the absence of restrictive requirements on retrievability gives more freedom to concepts. In this light, Group C found that requirements on retrievability should not be too strict in order to avoid undue pressure on the implementer's responsibility for developing a safe disposal concept.

The opinion was expressed in Group C that retrievability cannot contribute to the safety of the repository in the longer term. Further discussion highlighted that retrievability after the end of operations may be a burden (e.g. in terms of hindering the closure of a mine, or making financing difficult to plan). However, in other cases, retrievability may represent a good opportunity for future generations (for e.g. recycling of resources, implementing enhanced technologies of waste management). Indeed, examples exist where retrieval (or at least retrievability) of waste after some decades is considered as a safety enhancement process:

- For a near-surface LILW repository in Hungary retrieval was discussed as a safety enhancement option.
- At the Stocamine disposal facility for non-nuclear waste, retrieval is discussed as a solution for safety problems.
- In the Asse mine for LILW in Germany assessments regarding feasibility of retrieval are under way.

Finally, in regard to the third question: "Is there any specific role to be played in the process of RW governance by the social sciences and humanities, by economic research?" Group C pointed out that the social sciences can:

- deliver the tools for a process of mutual learning and an iterative process;
- support the communication of safety concepts;
- provide a bridge to support a common understanding of safety in the very long term;
- facilitate discussions on societal values, e.g. regarding burdens for future generations.

Regarding procedural aspects, social science can contribute to prospects of future societies by learning from the past. Examples were cited of social science contributions regarding various professional questions.

Group C further pointed out that there is a strong relationship between the stability of societies and safety. Such stability may also be fostered by good social science knowledge.

Finally, on the economic side, retrievability concepts have to consider financial implications of retrieval for future generations. No concept at this date is seen to fully address the handling of financing of future measures for waste retrieval in case it should be necessary. Questions that have to be treated are:

- Should financial contributions be made available for future generations' retrieval measures?
- If so, what amounts of money are necessary, for which time scales, under what conditions may these be used, etc.?

Group D – Discussion on Key Messages, Policy Studies and the Social Sciences

Holmfridur Bjarnadottir, Christina Necheva, Philippe Lalieux

The group consisted of participants from different countries that presented different interests in relation to nuclear waste: interest organisations, industry, regulatory authorities, independent advisors, researchers and the European Commission. Rather than following the discussion questions given by the organisers, the discussion facilitators opted for encouraging an open discussion about the topics of reversibility and retrievability. The discussion illustrated the variety of interests represented by the participants that was reflected in the broad scope of views. Hence, it cannot be claimed that the group came to an agreement regarding the questions that were set out to discuss and no definitive answers were provided. However, different views were presented and debated. The main discussion points are summarised below.

Does the inclusion of reversibility and retrievability in legislation, regulations (and Council Directives) mean that R&R is required?

The discussion started with information about the European Commission proposal for a Council Directive on the management of spent fuel and radioactive waste. Although retrievability and reversibility are not addressed in the proposed directive, it was discussed whether the lack of intention for retrieving the disposed radioactive waste or spent nuclear fuel excludes possibilities for reversibility or retrievability. This led to a broader discussion of similar inclusion in national legislations and regulations, where a majority argued that the inclusion of the terms implies that retrievability is technically possible but not required.

Key messages from the social sciences?

The participants generally agreed that the attention given to results from the social sciences is increasing. This led to a discussion centred on the following questions:

- Does that represent that the natural sciences have failed?
- Are the social sciences acting as a "last resort", i.e. taking care of issues that nobody else wants to address?
- Have social aspects become more important than the technical ones in the debate of nuclear waste? Even as a means to achieve acceptance for the project as a whole?
- Or, have the social sciences lagged behind and the focus on social sciences is a sign of the development occurring within the field?

It was generally agreed that it is inappropriate (and even wrong) to diminish social sciences as an add-on to the process. They need to be an integral part of the process and cannot be separated from the technical ones.

Reversibility as a mean to reach acceptance?

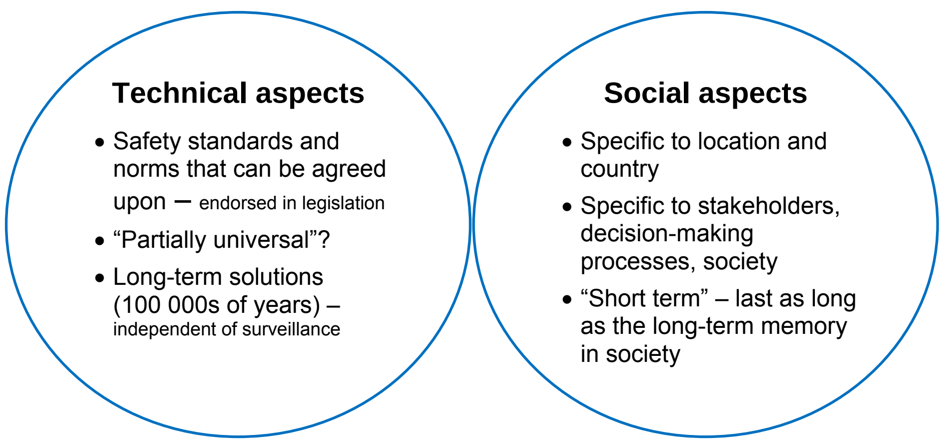
The group discussed a viewpoint presented by a speaker earlier in the day where it was claimed that reversibility could be used a means to reach acceptance. This led to a discussion on the concept of acceptance in the field of nuclear waste disposal. Some viewpoints are presented below:

- Does the focus on *acceptance* mean that we are striving to "sell" a finished product, i.e. that the outcome is already predetermined (needing acceptance)?
- Why focus on *acceptance* rather than involvement, understanding and dialogue?

Reflections on the technical and institutional/social aspects of reversibility

The group participants identified a certain division in the R&R debate between the technical aspects of reversibility on one hand and the institutional/social aspects on the other. In a somewhat simplified way the different aspects could be grouped together as shown in Figure 1.

Figure 1: Technical and institutional/social aspects of reversibility



The *technical aspects* were argued to be partially universal and the solutions can be exported between countries, i.e. those can present safety standards and norms that can be agreed upon and can be endorsed in legislation. The solutions are long term (100 000s of years) and are often independent of surveillance.

The *social aspects* (often related to reversibility) can be claimed to be more linked to specific location and country (including relevant stakeholders, legislation, societal and cultural factors and decision-making processes), are more "short term" than the technical solutions in that they are linked to institutional arrangement and societal aspects and only last as long as the institutional long-term memory. However, the notion of reversibility as presented at the conference seems to be based upon a rational/stepwise decision-making process that can be traced back and reversed. This presents a simplified and positivistic view of how complex decisions are made in society.

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Group E – Discussion on Key Messages, Policy Studies and the Social Sciences

Shawn Smith, George Hunter

Within Group E, we discussed a variety of aspects related to the social sciences. Five key messages of the discussion may be highlighted.

First is that citizens' workshops are a good practice and should be organised by independent, highly respected, non-nuclear-related organisations. There was some discussion on whether the citizen group should be random or mainly comprised of local citizens. It was noted that everyone is a stakeholder. Groups of randomly selected citizens tend to discuss/focus on big principle items, where local stakeholders tend to focus on specific issues. The general consensus was that the workshops were opportunities to build trust. Although the King Baudouin Foundation workshops were funded by the implementer, this was not an issue.

The next key message is that a long-term road map for establishing and maintaining trust is needed. The EKRA framework is a good foundation in evaluating the process. However, public trust in government plays a key role. Clear roles and responsibilities within government are a key factor in building public trust.

It was noted that although the level of trust in government and nuclear posture may differ between countries, methodology, general principles and generic ethical issues are valuable lessons to retain. Where certain outcomes may be specific, others may be universal.

Another key message was that for an informed discussion, definitions need to be clearly stated. The current definitions of R&R are still not yet universally understood. It was noted that the current definitions appear to be tailored to national programme plans. For example "reversibility" is generally viewed as a way to open a dialogue; the opponents, however, view reversibility as a way to buy the decision. It was also noted that it is important to discuss the terms "reversibility" and "retrievability" separately, as they relate respectively to the stepwise decision-making process versus the actual physical manipulation of waste. Another area discussed under the definitions of R&R was that R&R and their subsequent consequences have a symbolic dimension. When communicated, we must distinguish between R&R in the pre- and post-closure phase; these issues are easier to address in the early pre-phase, and much harder in the post-phase.

There was agreement within the discussion that there is a role for social sciences in the process. Dialogue solely based on the technical aspects tends to result in no solution or path forward, whereas including social factors helps work towards a technical approach. The concept of "humility" as one example can be considered under the light of a human emotion or of a set of technical provisions. Many felt that it was important to distinguish between the social system and the natural system as human behaviour cannot be modelled and there are some uncertainties, both social and technical. Nonetheless, social sciences need to have a role as they are part of the entire system.

There was a discussion on the meaning of safety and whether it was an attitude based on technical or humility aspects or a combination of both. The issues with communicating safety over the long time frames associated with geologic disposal were particularly noted, as was the fact that intergenerational aspects are very difficult to quantify. The three categories of a "risk management society" were discussed as they relate to the long time scales, however, there was no general consensus into which category(ies) – complex, uncertainty, or ambiguity – reversibility or retrievability fell into.

Group F – Discussion on Key Messages, Policy Studies and the Social Sciences

Jantine Schröder, Claudio Pescatore

Group F recognised that a clear discussion first requires clear definitions! They settled that reversibility is the *possibility in principle* to change decisions, and retrievability is the *possibility in principle* to remove containers from a repository. The time perspective is also crucial. R&R is about gradual processes, not a black-and-white set of options (retrievability/no retrievability). In this respect there is a need for a scale. Finally, Group F noted that one should be clear that we are talking about permanent, passive disposal: retrieval is not the end goal, only part of the voyage.

The question was then posed as to whether retrievability is always a good idea or a desired option. First of all, the "meaning" to be given to retrievability through the term's definition is country-specific, e.g. it may depend on the relevant host formation. On that basis, the following ideas were expressed in Group F:

- Regulator and implementer need to obtain a deliberative agreement that must include civil society.
- Anything can be retrieved, all it comes down to is cost (including worker safety).
- Industry demands that we behave economically: "If something needs to be retrievable, just put it somewhere where it can be reached!"
- Before a discussion on R&R begins, the meanings of "disposal", "waste" and "closure" must be established and agreed upon. If wanting to permanently dispose of something that is "ultimate waste" cannot be settled on, the complexity of R&R cannot be tackled.

The group then turned to issues of dialogue with the public. Various social science speakers in the previous session had remarked that "R&R is a good opportunity to enter into dialogue with the public." Group F wondered if these are really new and crucial topics for stakeholders, or just one item among other issues, maybe not even at the core of the debate for the public, but easy to focus on for the nuclear community.

The principle followed in RWM used to be "bury and hide"; now we know it is more complicated. The engineer is no longer alone and that is a good thing. A group member from France noted: "R&R forced us to think and communicate better about the pre-closure period and not to put all the focus on the long term, post-closure. Overall, this broadened our thinking."

A paradox was seen when attempting to combine permanent passive disposal and R&R. Should this not be called "storage"? Could this combination be a confusing compromise between politicians and technical people? The national programme should make explicit what is wanted, why and when.

Finally Group F considered the driving forces behind R&R. These are of different natures:

- political (creating public trust for nuclear or for decision making?);
- ethical (intra- and intergenerational justice: do not foreclose options);

- economic (reuse);
- safety (in case of unwanted findings, especially during the phase of direct oversight).

This last driver, safety, highlights the question of the connection made between R&R and monitoring.

 R&R IN PLANNING FOR GEOLOGICAL DISPOSAL OF RADIOACTIVE WASTE, ISBN 978-92-64-99185-9, © OECD 2012

Perspectives on R&R from Institutional Players

Chair: Bernd Grambow

Waste Retrieval/Removal Requirements for the Waste Isolation Pilot Plant

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The Waste Isolation Pilot Plant (WIPP) is a deep geologic repository sited in salt beds in Southeast New Mexico for the permanent disposal of defence-related transuranic (TRU) waste, and is operated by the United States Department of Energy (DOE). Work to site the facility started in the early 1970s and has progressed past site characterisation, design, permitting, construction and first waste disposal to a point where more than 70 000 cubic meters of waste have been disposed. Conceptual designs, governing rules and statutes for the WIPP have historically included requirements for waste retrieval or waste removal. This paper discusses the rationale for waste retrieval and removal requirements and how the concept of waste retrieval and removal has evolved as the mission of WIPP progressed from a pilot project to an operational disposal facility and eventually to the post-closure phase.

Prior to the early 1940s, most radioactive materials were generated in small quantities for research. Later defence activities generated by-product radioactive materials that were stored in underground tanks, disposed in trenches, pits, boreholes or other near-surface disposal methods. The priority to create weapons materials in the name of national defence was greater than the priority to ensure long-term isolation of radioactive waste materials. It was not until the 1950s that the agency responsible for weapons production started to look into radioactive waste disposal techniques. In 1955, the National Academy of Science was tasked with investigating practical radioactive waste disposal options. The resulting report issued in 1957 identified geologic disposal (in salt) as the most promising disposal option (NAS, 1957). Although the Atomic Energy Commission (AEC) was investigating disposal options, it was not until 1970 that it decided that certain wastes with long half-lives should be segregated and retrievably stored until a geologic repository was available for permanent disposal. This waste was termed "transuranic" and is the waste that would eventually be disposed in WIPP. Investigations by Oak Ridge National Laboratory (ORNL) in the late 1960s termed "Project Salt Vault" finally led to a proposed site in Lyons, Kansas. Political and technical reasons eventually led the AEC to abandon the site. Other work by ORNL and the United States Geological Society (USGS) identified a salt formation in south-eastern New Mexico as a potential site in the early 1970s. Further investigations identified a location in the Delaware Basin that showed promise. The AEC[1] proposed a waste disposal "pilot project" at this location for disposal of first transuranic and later high-level waste. The pilot project would test the suitability of this location during which time all waste experiments would be retrievable (Weart, 1975). If the experiments and site investigations met disposal performance criteria, the site would progress into a permanent waste disposal facility. At that time, it was thought that locating a site for a pilot project with retrievable waste would be more publicly acceptable.

At the time of these siting activities, the AEC was self-regulated. All radioactive waste management and disposal requirements were developed and enforced by the AEC. The reorganisation act of 1970 formed the Environmental Protection Agency (EPA) which was later tasked in 1976 to write generic standards for disposal of radioactive waste. In 1985, the EPA

1. The AEC is the predecessor agency to the DOE.

promulgated a standard with radioactive waste containment, assurance and individual protection requirements (EPA, 1985). One of the assurance requirements stated that the disposal system should be selected so that removal of the waste would not be precluded for a reasonable period of time after disposal.

As time marched on so did the requirements for WIPP. Congressional action and the state of New Mexico added additional requirements for the WIPP, some of which relate to retrieval and removal. The DOE understood that the state of New Mexico had to be involved in the WIPP project. The state and DOE entered into a formal agreement starting in 1981 that required the DOE to perform specific activities, provide funds for independent oversight and inform the state of experimental results and involve them in decision making. The agreement also included requirements for formal retrieval demonstration plans for waste that would be used during the test phase and to report results of mock-retrieval demonstrations to the state.

In preparation for the test phase, Congress required the WIPP to annually demonstrate that waste could be retrieved from the disposal rooms, should a roof fall or collapse occur (Weart, 1975). This demonstration was done in 1992 using remote-controlled robotic equipment. It was proven that experimental waste containers could be identified, uncovered and retrieved from a disposal room that was mostly obstructed by slabs of salt rock and debris placed to simulate a roof fall. A documentary video was developed to show this robotic demonstration. Shortly after the demonstration, Congress passed the WIPP Land Withdrawal Act (LWA) in late 1992, which removed land from the Secretary of the Interior for use by the DOE (US Congress). The act authorised the DOE to use the land for waste disposal and directed the EPA to write site-specific certification criteria (to demonstrate compliance with their generic disposal standard 40 CFR 191). The LWA also directed DOE to write retrieval plans for test-phase waste and annually demonstrate retrievability. These requirements mirrored those of the state of New Mexico. The test phase was to include high-level waste (HLW) experiments that could include spent nuclear fuel. The state of New Mexico and stakeholders were not convinced that the DOE would retrieve the test waste after it was emplaced in the WIPP underground. Additional political concerns about HLW led Congress to later amend the WIPP LWA (US Congress, 1996) to remove the requirement to conduct underground waste experiments (i.e. the "test phase") and prohibit HLW from being emplaced at WIPP, thereby eliminating the requirement for experimental waste retrieval.

Before the WIPP could begin actual waste disposal operations, the DOE was required to demonstrate compliance with the EPA's Long-term Disposal Standards of 40 CFR Part 191. Contained in these disposal standards is a provision for "waste removal". Waste removal differs from waste retrieval in that "removal" occurs after disposal, and retrieval occurs during "storage". This distinction is important here because the term "disposal" carries with it the assumption of permanence. For example, at the WIPP there has been no engineering consideration given to systems that might facilitate waste removal in the future. The DOE's demonstration of compliance contained a report which concluded that *removal* of waste from the disposal system is feasible for a reasonable period of time after disposal (DOE, 1996). The EPA standard also had a condition for waste retrieval. If the EPA revokes the certification, the DOE must retrieve, as soon as practical and to the extent practicable, any waste emplaced in the disposal system. The EPA did not require the DOE to demonstrate this capability or include a retrieval plan. EPA stated that these requirements were intended to call into question any other disposal concept that might not be so reversible because they believe that future generations should have the option to correct any mistake that this generation might unintentionally make (EPA, 1985).

The DOE demonstrated compliance with all aspects of the EPA's disposal standards in 1998 through a formal EPA certification decision (EPA, 1998). The first radioactive waste was emplaced in WIPP in March of 1999. It was not until 2007 (and again in 2008) that actual retrieval events occurred. Two separate waste drums were emplaced that were later identified as not fully meeting the WIPP's acceptance criteria. Because the specific deviations from the waste acceptance criteria were not of the type that would impact worker and public health and safety, the drums were retrieved from the underground and returned to the waste generators. Although retrieval significantly impacted WIPP operations on these occasions, this activity demonstrated waste retrieval was possible during the operational phase of WIPP.

Waste retrieval/removal considerations have been a part of the WIPP project from its inception. Waste retrieval/removal formal requirements have changed as the WIPP project evolved from conceptual design to actual waste emplacement. Early disposal concepts included retrieval to foster public acceptance of a potential site. Later state and federal requirements were more demanding and required that waste retrieval plans and demonstrations were necessary prior to allowing test-phase waste to be emplaced in WIPP. As the project matured, the retrieval/removal requirements became less burdensome in that retrieval plans and removal feasibility studies were required rather than formal retrieval demonstrations. The concept of retrieval/removal of waste has played a key role in WIPP's history. Retrieval demonstrations have occurred for mock and actual transuranic waste containers. The project has demonstrated to the regulator that waste removal after closure is feasible for a reasonable period of time after closure and as a result, WIPP is well on its way to fulfilling its mission to safely dispose of radioactive waste.

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Retrievability and Reversibility – Outcome of the ESDRED Project*

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How can waste package retrievability be dealt with, from a technical point of view, in two different national repository concepts, the French disposal concept in clay (Andra) and the German disposal concept in salt (DBE Technology)?

This issue was assessed by NRG within the framework of the ESDRED Project.

After a brief description of the ESDRED Project (its content and scope), a general presentation of the two mechanical emplacement systems respectively developed by Andra (pushing robot for horizontal disposal cells) and DBE Technolgoy (industrial demonstrator for vertical boreholes) within the frame of ESDRED is made.

The specificity of each disposal concept is also enhanced, as far as the Andra's design incorporates from scratch some specific reversibility features, while DBE Technology's main objective is to attain an encapsulation of the waste by the host formation as quickly as possible.

Reflecting on these findings, NRG has developed an expert opinion and delivered comments and recommendations to the two national implementers for improving reversibility in their disposal design. The main items related to this assessment work are presented.

Finally, the two national implementers express their point of view *vis-à-vis* NRG's recommendations and discuss their current positions concerning retrievability issues and how this is likely to affect the overall repository design evolution.

* The full paper being unavailable at the time of publication, only a short summary is included.

Swedish Retrievability Scenarios

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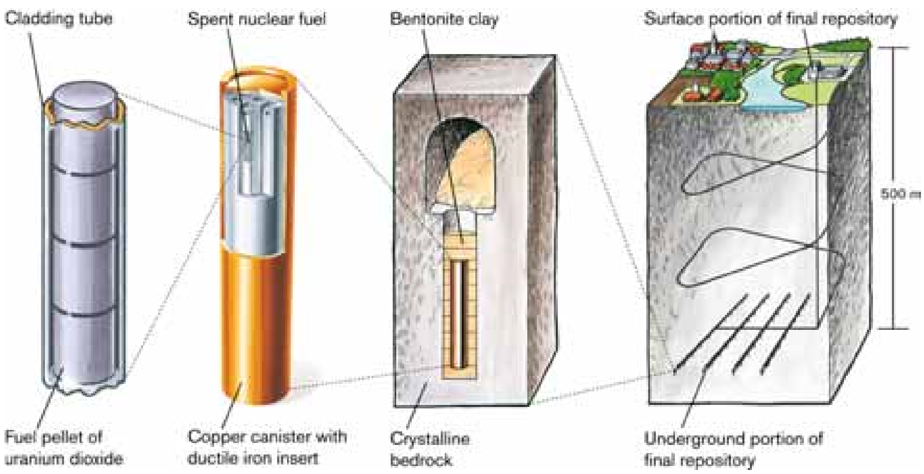
The retrievability concept

SKB prefers to employ the concept of "retrievability" in most discussions of relevance to the Reims "R&R" conference. Subtle differences between retrievability and concepts such as "reversibility" (and "recoverability") are difficult to communicate to a wider audience. The use of obscure terms creates a risk of blurring the discussion. SKB finds moreover that it is vital to uphold a clear distinction between retrievability before closure and retrievability after closure.

Figure 1: SKB's final repository KBS-3



Starting points

SKB's task is to plan, construct, build and operate a *final repository* for spent nuclear fuel (*not* a facility for long-term storage). There is currently no legislation or other provision in Sweden prescribing that it should be possible to retrieve spent nuclear fuel. However, SKB cannot exclude situations whereby the issue of retrieving material from a repository may have to be addressed. Therefore, retrieval of canisters from a KBS-3 repository (Figure 1) will be possible, both before and after closure, though it will be a more complicated process after closure than before.

In Figure 2, we have mapped SKB's plans for a KBS-3 repository onto the NEA "R&R" group's "retrievability scale". We show the steps and activities in a "Swedish retrievability scale". In the following pages we consider scenarios for retrievability before and after repository closure. (Figure 3 presents an image of the planned final repository at Forsmark.)

Figure 2: The NEA "retrievability scale" adjusted to SKB's plans for a KBS-3 repository – a Swedish retrievability scale

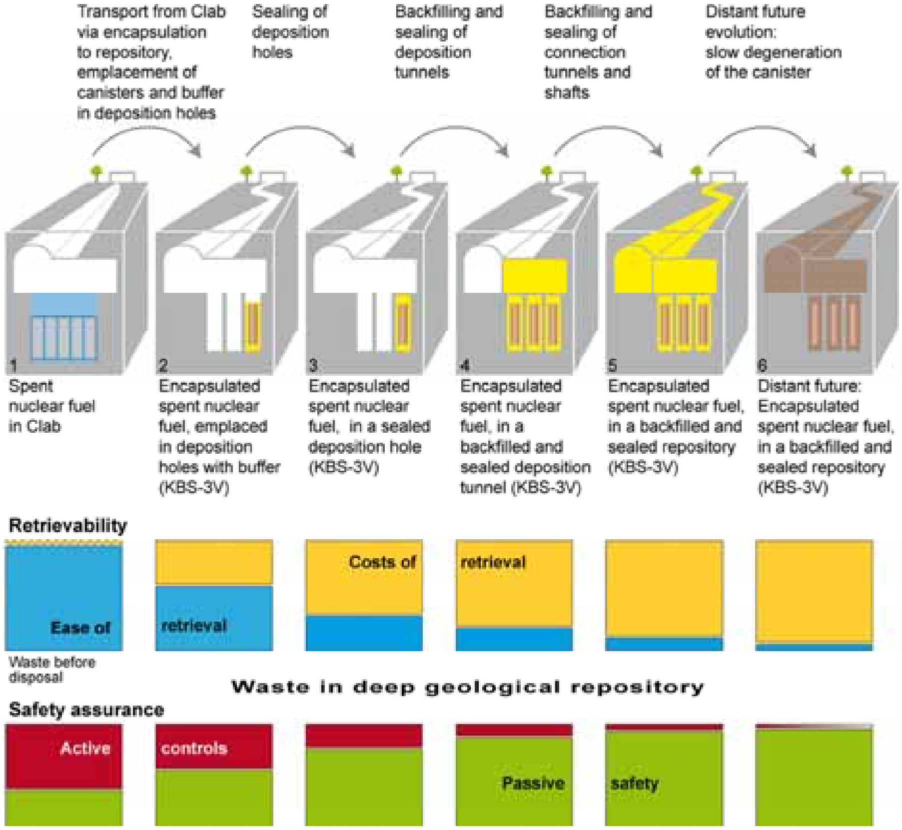
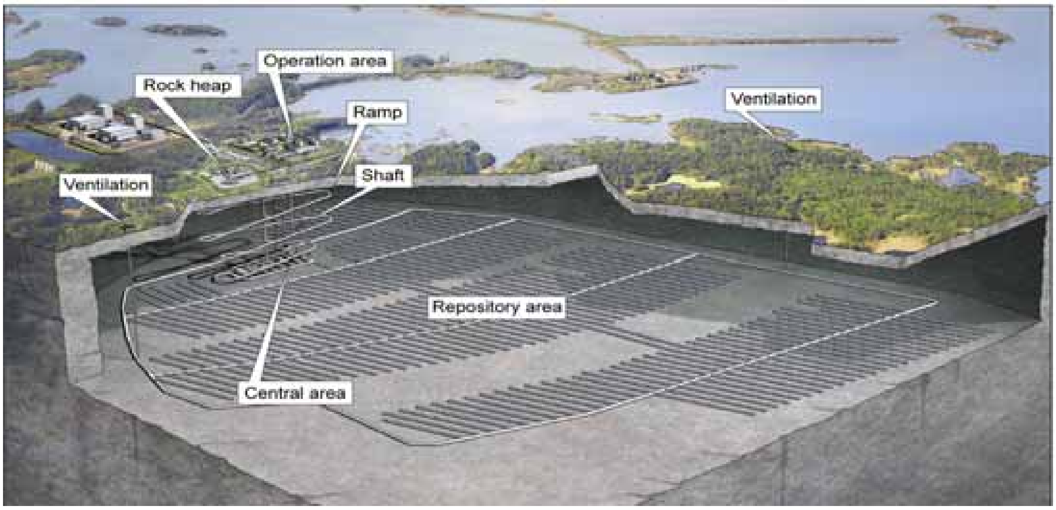


Figure 3: Planned final repository for spent nuclear fuel at Forsmark



Retrievability before closure

Scenario 1: Shortcomings/mistakes during deposition operations may have to be corrected by retrieving single canisters for inspection or other measures

It is realistic to assume that shortcomings and mistakes will occur during deposition operations. We must therefore be prepared to handle a situation that may call for a retrieval of single canister(s) to a place where inspection or other measures can be safely carried out. This situation is considered in research at the Äspö Hard Rock Laboratory, where it has been shown how to remove a canister from a deposition hole with a bentonite buffer. This scenario will be more fully addressed in the safety case included in SKB's applications in March 2011.

Scenario 2: During the operation time of the repository the acquisition of new knowledge results in the long-term safety case being questioned

According to current plans, the repository is expected to operate until the 2070s. Though the possibility of the long-term safety case being called into question seems to us to be highly improbable, it is, however, worth reflecting upon.

The necessary response measures depend on the detailed implications of such new knowledge and when the scenario occurs. Measures could range from what can be achieved within the framework of a "revised" KBS-3 repository, to a retrieval of some or all deposited canisters in order to plan for an alternative site or method for final disposal of the spent fuel.

Scenario 3: During the operation time of the repository it is decided that new nuclear power should be installed in Sweden

Assuming once again an operation time up to the 2070s, a decision to install new nuclear power in this scenario would be based on the notion that new reactor types could make use of the remaining energy content in today's spent fuel.

SKB does not speculate on the probability of such a development. It does not seem probable that such a scenario would result in retrieval of already deposited canisters.

A more likely development could be the cancellation of further deposition operations in the repository, which could then be closed and sealed with deposited canisters remaining there. Alternatively, the spent fuel that remains in the Central Interim Storage for Spent Nuclear Fuel (Clab), located near Oskarshamn nuclear power plant, could be used.

Retrievability after closure

Scenario 4: Sometime after deposition of the last canister the acquisition of new knowledge results in the long-term safety case being questioned

A decision on closure of the repository cannot be expected unless responsible actors (operators, regulators and policy makers) are strongly convinced of the long-term safety case. In theory it cannot, however, be excluded that the acquisition of new knowledge results in the long-term safety case being questioned. Which measures must be taken under such a scenario?

This is not a question for which we can produce a proper response – only generations living at the time will be able to address this type of situation. The current generation, though, has a responsibility to contribute to the knowledge base so that future generations will be equipped to respond appropriately.

Scenario 5: Sometime after closure of the repository, the repository is regarded as an asset containing valuable material and not "waste"

It is assumed that such a scenario would take place later than about 2080. As with Scenario 4, we have to assume that a decision on closure of the repository cannot be expected unless those who will be responsible (operators, regulators and policy makers) are strongly convinced that the contents of the repository are "waste" and not assets. Theoretically however it cannot be excluded that an opposite assessment will be made in the future.

Once again, it will be up to those living at the time to address the issue. They will be the ones to judge if resources needed to make use of this "asset" are in due proportion to what can be achieved through a retrieval operation.

Legal issues under discussion

Currently identified legal issues are listed below. Some of these issues are being discussed within SKB and a Swedish government committee, while others are not regarded as priorities at this time:

- responsibility for a sealed final repository for spent nuclear fuel;
- ownership of spent nuclear fuel in a final repository;
- application of national and international provisions about safeguards and physical protection on a sealed final repository for spent nuclear fuel.

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United Kingdom Perspective on Retrievability

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Introduction

In 2001, the United Kingdom government and devolved administrations[1] initiated a Managing Radioactive Waste Safely programme with the aim of finding a practicable solution for the UK's higher-activity waste. Following recommendations by the independent Committee on Radioactive Waste Management (CoRWM) in 2006 and a programme of consultation, the government published the Managing Radioactive Waste Safely (MRWS) White Paper (Defra, 2008).

The White Paper also states that the siting of a geological disposal facility will be based on a voluntarism and partnership approach. It also identified the Nuclear Decommissioning Authority (NDA) as the organisation responsible for implementing geological disposal and the NDA has established the Radioactive Waste Management Directorate (RWMD) to manage the delivery of geological disposal. Our recently published report, *Geological Disposal – Steps towards Implementation* (NDA, 2010) describes the preparatory work undertaken so far, the planning of the future work programme and the management arrangements to deliver it.

The programme for delivery of geological disposal for the UK is in the very early stages and it will be some time before a site is selected. In the meantime any considerations of designs of disposal facilities cannot be either site or geology specific. A range of generic geological disposal concepts is available that can provide safe and secure geological disposal of higher activity wastes for any suitable UK geological environment. At this early stage, before potential sites have been identified illustrative designs have been developed based upon specific assumptions derived from the typical characteristics of the geological environments that occur in the UK. These illustrative designs have been developed drawing on work done both in the UK and in international programmes in a number of different geological environments. We have considered three broad (generic) host rock types which are higher strength, lower strength sedimentary and evaporite rock.

This paper provides a brief background to policy and regulatory requirements related to retrievability; it considers definitions for the various terms used; discusses retrievability in design and reflects on some previous and current work on retrievability.

Policy and regulatory requirements

Government policy regarding retrieval of radioactive waste from a geological disposal facility is reflected in the 2008 MRWS White Paper (Section 4.22), which states:

1. The Scottish Executive was not a sponsor of the 2007 MRWS consultation on the framework for geological disposal of higher-activity radioactive waste. It continues to support long-term interim storage and an ongoing programme of research and development.

"Government's view is that the decision about whether or not to keep a geological disposal facility (or vaults within it) open once facility waste operations cease can be made at a later date in discussion with the independent regulators and local communities. In the meantime the planning, design and construction can be carried out in such a way that the option of retrievability is not excluded." (CoRWM, 2006)

In its review of options for the long-term management of radioactive waste, CoRWM considered both geological disposal, incorporating an "intent to backfill and seal as soon as waste is emplaced", and phased geological disposal, in which a disposal facility could remain open for several hundred years, pending future decision making. Whilst noting that a phased approach imparts greater flexibility to future decision making, CoRWM stated that "leaving a facility open, for centuries after waste has been emplaced, increases the risks disproportionately to any gains." (CoRWM, 2006)

In the White Paper (Section 4.20) (Defra, 2008), the government acknowledges that there is a divergence of views on the issue of retrievability, but on balance, considers that CoRWM's conclusion was correct. The White Paper notes that closure at the earliest opportunity once facility waste operations cease provides greater safety, greater security from terrorist attack, and minimises the burdens of cost, effort and worker radiation dose transferred to future generations.

The White Paper also highlights CoRWM's observation that it is likely to be at least a century from publication of their final recommendations until final closure of an entire facility is possible, and that in practice, it could be longer. The government notes that this time scale provides sufficient flexibility for further research to be undertaken and supports CoRWM comments that this time delay may provide sufficient reassurance for those people who wish to retain the possibility of doing something else with the waste.

In the context of a voluntarism/partnership approach to decide the siting of a geological disposal facility, the White Paper notes that local government should be responsible for major local decisions within the siting process, including, for example, whether potential retrievability of wastes has been adequately considered. It is suggested that one of the objectives of a community siting partnership should be to seek to develop partner and local community confidence that the question of potential retrievability has been adequately considered, taking account of regulatory constraints.

An important issue in the context of retrievability is the distinction between storage and disposal. Historically, Nirex referred to the Phased Geological Repository Concept as providing an extended period of underground storage, during which the disposal facility and its contents would be monitored, and the waste would be retrievable if desired (Nirex, 2001). However, it should be noted that both government and the environment agencies regard emplacement of waste in a geological disposal facility as disposal, and distinguish between storage and disposal, based on whether there is an "intention to retrieve the waste at a later date" (Defra, 2008; EA/NIEA, 2009). This distinction has important implications, first for allocating regulatory responsibilities to the relevant body, and also for requirements on the operator to demonstrate management arrangements for retrieval.

The GRA considers:

"…placing waste in a disposal facility as 'disposal', even though later actions, such as backfilling tunnels or sealing access shafts, may be needed to establish the environmental safety case fully. After it has been emplaced, the waste can still be retrieved, but this tends to become more difficult as time goes by, as further actions are taken and as closure approaches. Even after the facility has been closed, it is still possible in principle to retrieve the waste. However, this guidance does not require the waste to be retrievable after the act of disposal, i.e. emplacement of the waste." (EA/NIEA, 2009)

Hence, the environment agencies do not require that retrievability be factored into geological disposal, and note that after "disposal", it may be possible to retrieve the waste, but with increasing difficulty over time. The environment agencies *do* require that the incorporation of retrievability into geological disposal should not undermine the long-term safety of a geological disposal facility (which would be demonstrated in the environmental safety case for the facility). The GRA notes the particular implications that this would have in terms of demonstrating package longevity:

> "If a developer/operator makes provisions for retrievability, these should not unacceptably affect the environmental safety case. For example, a developer/operator might propose to keep a facility open that would otherwise be ready for closure, solely to maintain the option to retrieve waste emplaced in the facility. In such circumstances, the environmental safety case would need to demonstrate that processes such as degradation of waste packages would not unacceptably affect the safety of people or the environment. Such a demonstration would need to consider the effect of remaining open on the environmental safety case both for the period before the delayed closure and for the post-closure period." (EA/NIEA, 2009)

Definitions

The term "retrievability" is used to refer to a number of different approaches to remove radioactive waste from a repository after it has been emplaced. RWMD uses the following terms, as described by CoRWM (2006), to distinguish between different types of retrieval activities:

- *Reversibility*: In the international context, the term "reversibility" is often used to denote the ability to reverse decisions, most commonly, as part of a phased decision-making process.

  In contrast, this term has been used in the UK to describe retrieval where the waste can be removed from a geological disposal facility by reversing the original emplacement process. Reversibility in this context is only possible before any form of backfilling or sealing has taken place, and is dependent on the continued integrity of the waste packages, disposal vaults and emplacement equipment.

- *Retrievability*: Where it is possible to withdraw the waste from a geological disposal facility by building in a methodology that would allow access to the waste even after disposal cells or vaults had been backfilled.

  This could be achieved, for example, by keeping access tunnels open for a period after emplacement and backfilling, and by ensuring that any buffer/backfill materials could be readily removed.

- *Recoverability*: A term developed by CoRWM where waste is recovered from a closed geological disposal facility by mining or similar intrusive methods.

  Once access tunnels have been backfilled, and/or a geological disposal facility has been sealed, intrusive re-excavation operations would be required to recover the waste. These would be likely to pose greater technical challenges and be more expensive than other forms of retrievability.

Addressing retrievability in design

Taking account of the direction in the White Paper and the environment agencies' guidance, we, NDA, as implementer will ensure that consideration of retrievability is an integral component of design development.

Once communities have taken the decision to participate, we would engage with them to gain a better understanding of their views related to retrievability. This will help us to clarify key community drivers for retrievability, e.g.:

- Is the main driver to retain the option for retrieval allowing time to gain greater confidence in the integrity of the design and safety case?
- Is there a view that there may be future benefits through re-use of the waste?
- Are there other reasons?

In preparing designs it is important for us to:

- understand the views of local communities with respect to retrievability;
- consider how these might be addressed in specific geological environments;
- assess the impacts on safety, security, environment, cost and other implications for future generations;
- discuss with communities and regulators how these might be best addressed.

There are several factors which influence the relative ease with which waste can be retrieved:

- The geological environments in which the facility is sited. The range of generic geological environments considered will have different levels of retrievability, which would need to be factored into the approach to providing retrievability within the design.
- Different waste types would rely on different disposal solutions and the engineered barrier requirements (e.g. bentonite), and would need to take account of the appropriate timing for placing the engineered barriers.
- The rock support design and factors influencing support, such as depth and physical properties of the rock.
- The durability of waste packaging and the effects of vault environment (corrosion/loss of integrity).

Previous and current work on retrievability

Retrievability has been considered in several international programmes and has been the subject of wide discussion within waste management organisations and also with other stakeholders. The major focus for retrievability has been the retention of retrieval as an option. There is wide agreement that while the intent is disposal, retaining the option of retrieval within a stepwise process has lead to wider acceptance that such a long-term project can progress with effective review and control. All agree, however, that the option to retrieve should not be an argument for compromising on the ultimate requirement for long-term safety, isolation of the hazard and placing a burden on future generations.

RWMD is currently involved in international initiatives looking at the drivers behind stakeholder preferences for retrievability, building on studies over the last decade, and investigating how stakeholder opinions have evolved. These include participation in workshops on retrievability organised by the Nuclear Energy Agency (NEA). The NEA has produced *The NEA Retrievability Scale* (2009) as a communication tool to help explain how retrievability, passive safety and the need for active control are related.

Practical considerations have been given to retrievability by several international waste management organisations and this has included several full scale demonstrations of retrieval. Examples of these are: the use of remote water-jet cutting to retrieve a backfilled waste package in the UK (NNC, 1997); retrieval of a dummy canister emplaced in a vertical deposition hole and surrounded by bentonite buffer in Sweden (SKB, 2008). The EC ESDRED Integrated Project (with 14 partners from 11 European countries) included several practical demonstrations of retrieval of different disposal containers both underground and in surface mock-ups (EC, n.d.).

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NUMO Study on Retrievability

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Introduction

Retrievability is one of the measures designed to ensure flexibility of the geological disposal project which extends over approximately 100 years. Preparatory discussions are currently under way toward establishing the basic guidelines for licensing the geological disposal project in Japan. In 2010, the Nuclear Safety Commission of Japan (NSC) set up a committee to discuss how the safety of geological disposal should be communicated to the general public. In this context, the NSC placed particular focus on the roles of retrievability in such communication activities.

NUMO is currently working on producing a milestone report entitled *Safety of the Geological Disposal Project 2010* (NUMO, 2010). In this report, NUMO intends to introduce its policy on how the safety of geological disposal will be assured, and will address the technical developments since its establishment in 2000. NUMO's position on retrievability and the technical achievements in this respect are also presented in the 2010 Technical Report.

This paper introduces the legal requirements relating to retrievability as the background to NUMO's position on this topic and the technical advances that have been made. It should, however, be noted that NUMO's position is based on current conditions and that future developments pertaining to legal requirements will have to be accommodated.

Current regulatory policy on retrievability

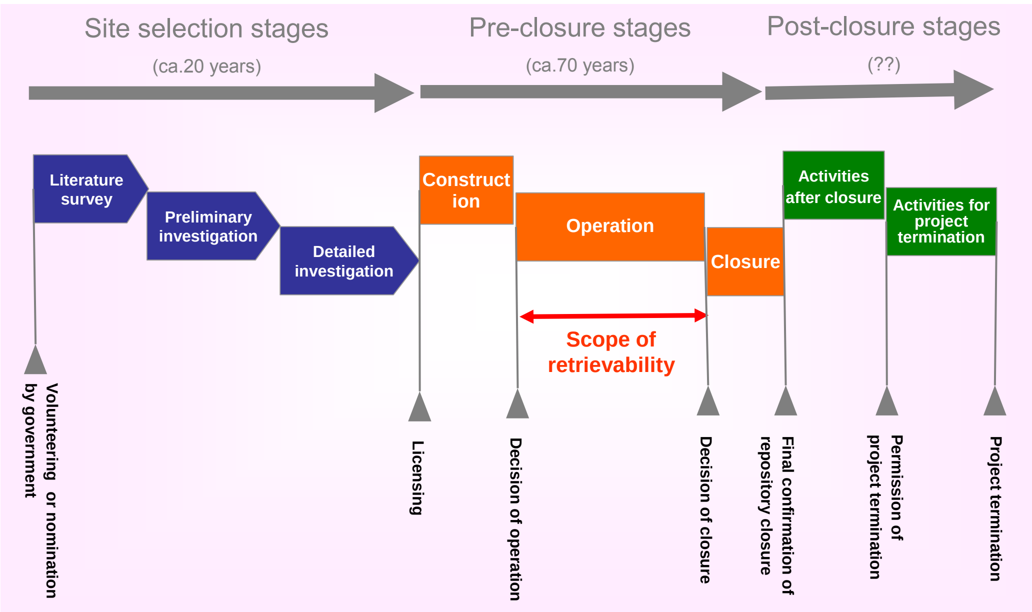
At present, there are two major reports that define the role and requirements relating to retrievability in the Japanese geological disposal programme. One is the report entitled *Basic Policy on the Safety Regulations Concerning HLW Disposal* issued by the Nuclear Safety Commission in November 2000. This report states that, "Data must be accumulated during the construction and operational phases with a view to repository closure for the purpose of confirming the reliability of the safety assessment. It is important to retain the possibility of retrieval until such confirmation is completed." (NSC, 2000)

The other is the report *Safety Regulation System for Geological Disposal of Radioactive Waste* issued by the Radioactive Waste Safety Subcommittee of the Nuclear and Industrial Safety Agency (NISA) in September 2006. This states that "For retrievability up to the time of closure of the repository, as a requirement for ensuring safety, it is necessary to adopt a design that takes retrievability into consideration and to secure concrete retrieval measures in the stages prior to the decision on closure." (NISA, 2006)

NUMO's position on retrievability and reversibility

Considering the current requirements set out in the regulatory policy reports, NUMO intends to maintain retrievability during the period between the beginning of waste emplacement in the disposal tunnels and the time of the decision to close the repository (see Figure 1). At that time, all of the safety arguments are complete and it will no longer be necessary to maintain the possibility of retrieval.

Figure 1: NUMO's plans to maintaining retrievability during the pre-closure period of the repository



NUMO intends to apply the following design factors – of which retrievability is one – for repository concept development and facility design:

- long-term safety;
- operational safety;
- engineering feasibility/quality assurance;
- engineering reliability/robustness;
- site characterisation and monitoring;
- retrievability;
- environmental impact;
- socio-economic aspects.

When making a strategic decision on how to incorporate retrievability into the repository design, a wide range of factors need to be taken into account. These include legal, regulatory and social requirements, technical assessment of feasibility and overall programme evaluation (e.g. cost, time and safety). Considering such factors, NUMO believes there are two fundamental strategies to be followed. These include: *i)* developing methodologies and equipment for retrievability without modifying the repository design; *ii)* modifying the repository design to ensure ease of retrievability. Considering the high level of uncertainty in the factors to be considered, NUMO is keeping open the possibility of both strategies and is developing a wide range of technologies that allow both options to be pursued in the future.

With respect to reversibility, it is ensured during the three stages of site selection process and NUMO is not intending to on to the following steps if legal requirements are not fulfilled or if consent from the local stakeholders is not obtained. However, still under discussion is how reversibility should be defined after a license is given by the authority.

Technical achievements regarding retrievability

NUMO has conducted a generic feasibility study in order to identify the technically critical issues in retrieving waste from the disposal tunnels. The results show that most of the engineering work could be carried out using existing technologies, e.g. construction and mining technologies. However, using remote handling techniques for saturated buffer material was identified as a critical work component. NUMO has therefore carried out a study on how emplaced buffer materials can be removed to allow the waste packages to be retrieved. Based on the preliminary study, three possible approaches have been identified:

- overcoring technique;
- softening bentonite buffer technique;
- special container to isolate the overpack from the buffer.

Figures 2, 3 and 4 show the concept for the activities to be performed for each technique. The overcoring and softening bentonite buffer techniques are along the lines of Strategy *i)* above, and the use of a special container to isolate the overpack from the buffer follows Strategy *ii)*.

Figure 2: Overcoring technique

Method to release constraint (mechanical method: overcoring machine)

1 – Overcoring machine is used to obtain test sample of stone and concrete.

2 – The corer is rotated and the drill bit will cut through the buffer material around the overpack.

3 – In order to avoid excessive cutting heat from friction, water or compressed air is used to remove heat and cutting mad.

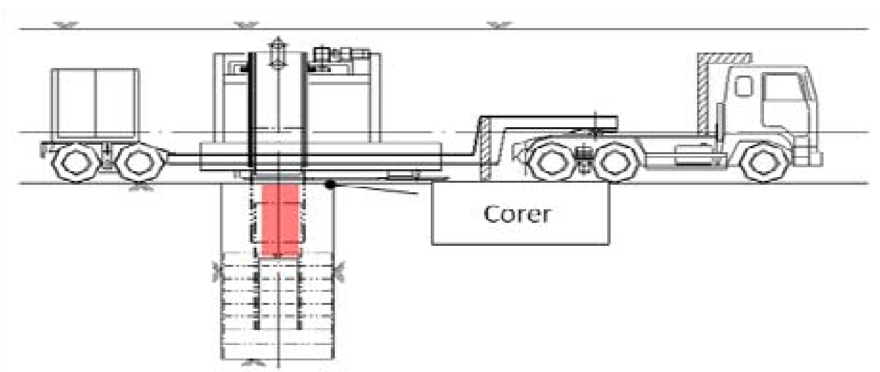
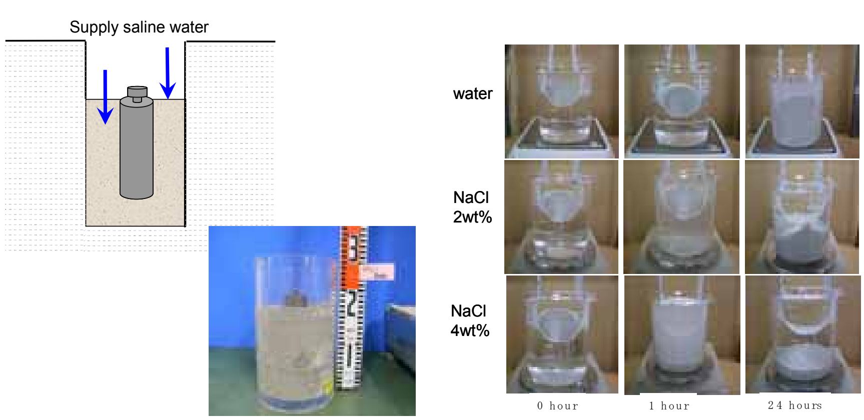


Figure 3: Softening bentonite buffer technique

In order to soften the bentonite buffer, saline water is applied inside it

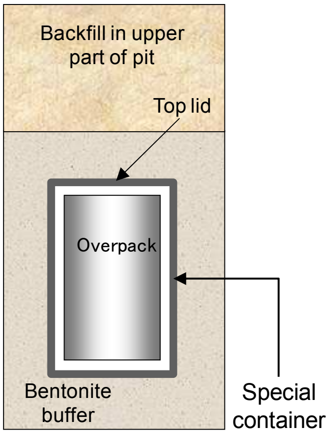
A Japanese R&D organisation (RWMC) is currently working on collecting fundamental data by small-scale tests



1/14 size test

Bentonite behavior test in different solution

Figure 4: Special container to isolate the overpack from the buffer



Issues to be resolved:

(1) Special container must withstand the *swelling pressure* from buffer.

(2) *Top lid* of the special container must be designed to be set and removed by *remote handling* system

⇩

Further study is needed to evaluate the feasibility of this design

Conclusions

In this paper, NUMO's position on retrievability and the related technical achievements are summarised. Under the current scheme reversibility is assured during the site selection phase and further discussion is required on how it should be defined in the overall geological disposal project term. Considering possible developments in the legal framework over the next few years, NUMO will be required to take these into account and to make the necessary modifications regarding how retrievability is defined in the geological disposal programme in Japan.

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Perspectives on R&R from Institutional Players

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In France reversibility is required by law, and reflects social and political demand. The law, however, does not provide conditions for implementing reversibility. Instead, it calls upon scientists to issue specific proposals before a new law is promulgated as a preliminary to obtaining authorisation to build a waste repository. A dialogue between various players, scientists and stakeholders is required to prepare these proposals. It gives designers of the repository the opportunity to assess social expectations and integrate them. It is also an opportunity to examine together possible technologies, as well as scientific and technical limits. Andra is involved in various forms of dialogue with social players, including local interactions through the local information and oversight committee for the Meuse/Haute-Marne Centre. To help understand this dialogue, Andra has recourse to human and social sciences.

The principal expectations that Andra has been able to detect to date are:

- retaining the option of retrieving waste if future technical progress makes it reusable, although French law restricts disposal to final waste;
- retaining the option of switching to another mode of waste management, also with the assumption of technical evolution;
- retaining the option of intervention when the repository does not evolve as planned – this expectation concerns disposal safety;
- desire to control evolution of the process;
- local residents' fear of being left alone with the repository, which they believe will be abandoned after its closure.

As for this last point, the concept of closure requires clarification. It is a technical action, which consists of backfilling the access shafts, and is not a decision to abandon the site or to forget it. There is no reason that monitoring of a site need cease after closure. Monitoring can continue from above ground, at the surface. Retrievability of waste also does not cease with closure, as shown in the OECD Nuclear Energy Agency's retrievability scale.

To answer these different expectations, Andra is studying two kinds of proposals.

The first type of proposal is technological in nature. It involves all technical measures that can be taken in the design of the repository to favour retrievability of waste packages and reversibility in general. To be as effective as possible, integration must be part of the preliminary draft design, and must continue later during basic design.

The second type of proposal involves governance of the waste repository. It concerns providing the resources for continuous, reversible step-by-step control of the disposal process, in an extension of the French laws of 1991 and 2006 pertaining to long-term waste management. Proposals involving governance are based on combining an organisational framework and taking appropriate technical decisions. They involve the period between emplacement of the first waste package and closure of the access shafts, which can be considered the reversibility period, without prejudice to maintaining subsequent waste retrievability.

Technological proposals

From a technological perspective, Andra proposes that intermediate-level long-lived waste be placed in robust concrete containers. Such containers retain their integrity for at least a hundred years in underground repository chambers ("cells"). The repository chambers formed from clay and their access tunnels can be lined with concrete as with highway or railroad tunnels, while adopting dimensions that can limit structural deformations for at least a century. Repository chambers for waste packages are continuously ventilated as long as they have not been closed, thus assuring hygrometric conditions conducive to preserving concrete. Waste packages can be stacked in an accurate, regular manner in the repository chambers with handling space to facilitate retrieval.

For high-level waste, Andra is studying thick steel containers that can last several centuries. Such containers are not placed directly in the clay, but in tubes that are also made of steel and designed to support rock stresses and prevent handling gap around waste packages from filling up. The entrance to each repository cell is designed so that air in access tunnels cannot enter the cells. This in turn prevents steel from being corroded by oxygen in the air as long as the repository remains accessible and ventilated.

Another technology involving reversibility concerns the use of instruments that monitor changes in the repository. They measure variations in temperature, pressure, deformations, etc. in the structures over time. Some of the sensors planned for this purpose have already been proven over several decades in large civil engineering works. Andra is also studying the option of supplementing these sensors with more innovative devices. Andra has initiated research and development efforts and oversees the European research programme on Monitoring Developments for Safe Repository Operation and Staged Closure (MoDeRn).

The architecture of underground structures is designed for retrieval of waste packages using today's proven technologies that would be installed at the bottom of each repository cell up to the surface. To retrieve intermediate-level long-lived waste packages, a trolley on rails running the entire length of the repository chamber could collect packages and transport them to the chamber entrance, where they could be handled by other equipment capable of raising them to the surface through a network of tunnels. For high-level waste, a robot has been tested in various situations to verify its ability to retrieve packages and transport them to access tunnels.

Andra's research is also concerned with technical resources for managing packages once they have been retrieved from the repository. It has thus been verified that it would be possible to transport retrieved packages to other sites. In addition, in the framework of research on interim storage provided by the law, Andra is studying technical concepts for facilities that can accept retrieved waste disposal packages. This will lead to technical solutions that are more advanced than current industrial storage facilities, and provide greater versatility in handling waste packages.

No compromise between reversibility and safety is considered in the studies. A repository is designed from the outset for closure. In contrast with extending the storage period, use of a repository avoids leaving the responsibility for waste to future generations while protecting people and the environment over very long periods. None of the technical measures taken for reversibility should degrade the safety level of the repository, before or after its closure. Despite having the option of retrieving packages, safety of the repository before and after closure must be demonstrated even before obtaining authorisation to build the repository. In particular, it must have been demonstrated that it is possible to close the repository safely even under extreme accident assumptions in which it is no longer possible to retrieve some packages.

R&R IN PLANNING FOR GEOLOGICAL DISPOSAL OF RADIOACTIVE WASTE, ISBN 978-92-64-99185-9, © OECD 2012

Proposals concerning governance

Once the decision has been taken, construction of underground structures of the repository will be proceeding gradually as waste arrives over a period as long as a century. Given the time span, construction and operation of the repository must be undertaken in successive phases. The start of each phase of work could then be subject to scientific and technical review and a decision-making process integrating operating experience feedback and technological developments. This implies the notion of a modular, adaptable project that does not limit later generations to technical decisions made today.

The law stipulates that only Parliament can authorise final closure of the repository. Prior to final closure, partial closing actions will include sealing each repository cell and backfilling tunnels that provide access to these cells. They will constitute as many successive steps. One particular aspect of Andra's propositions for technical design of the repository is the possibility of delaying each step of closure, especially the second step on the NEA retrievability scale, which occurs prior to closure of repository cells. This delay allows time for decision making at each step.

The successive steps in construction of the repository and its closure could constitute interim, programmed milestones so that the various players can monitor the disposal process: construction of new disposal modules, clearing the steps for partial closure and extending the time for observation of the repository. A repository designed to be reversible offers the option to choose between several management options.

Each milestone must correspond to a decision-making process. Examination for each decision will be based on data of various types, including operating feedback and measurements made in the repository, general scientific and technical progress, advances in research on other management methods and possible changes in social expectations. Technical examination must include safety reviews of the repository and costs; the method for waste management may be questioned. This step-by-step process will result in periodic re-evaluation of conditions and length of reversibility, as is done with periodic safety reviews for authorising extension of operating licenses for nuclear facilities.

Reflections on Flexibility, Reversibility, Retrievability and Recoverability by the Belgian Nuclear Safety Authority

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Introduction

Disposal is the last step in the management of radioactive waste. It aims at ensuring an optimal protection of workers, members of the public and the environment during the different phases and time frames of the disposal system, by containing the wastes and isolating them (keeping the radioactive substances away) from man and the environment for as long as necessary, taking account of the hazards represented by their radioactive content. From the radiological protection point of view, special attention is given to the long-term safety. For surface disposal, operational safety is comparable with current practices, for which sufficient practical experience is available. For deep disposal, however, the combination of nuclear safety and mining/tunnelling safety will create new challenges for operational safety.

The prime objective of disposal is to safely dispose of the waste without the intention of ever taking it back. This is easily acceptable for the so-called ultimate wastes and short-lived wastes, but poses some questions concerning the potentially reprocessable and economically valuable spent nuclear fuel. Do we otherwise have to take into account hypothetical technical developments in future, allowing a reduction of the hazards of the wastes? How far should the principle of freedom of choice of future generations be guaranteed knowing that retrievability may be limited by safety and safeguard considerations?

A requirement for retrieval of the waste from a repository might be understood differently:

- Society might see this obligation as a reflection of the lack of confidence of the regulatory authority in the long term-safety of the repository.
- On the other hand one may consider that such provisions would allow future generations to retrieve the waste in a “safe” manner if they decide to do so.

In this document the Federal Agency for Nuclear Control (FANC) seeks to explain its expectations with regard to flexibility, reversibility, retrievability and recoverability in the development of a repository.

Terminology

Differences in understanding and in application of terminology such as reversibility, flexibility, retrievability, removal, recoverability, adaptability, physical closure versus regulatory closure/release, … may lead to confusion between technical and non-technical communities.

In the framework of national disposal programmes, terms like flexibility, reversibility and retrievability are used frequently. They may be referred to as “concepts”. However there is only poor consensus worldwide about their content and about their applicability and enforceability in national disposal programmes. Indeed, legislative, societal and economical circumstances are different between countries and therefore the applicability and enforceability may be interpreted and applied differently.

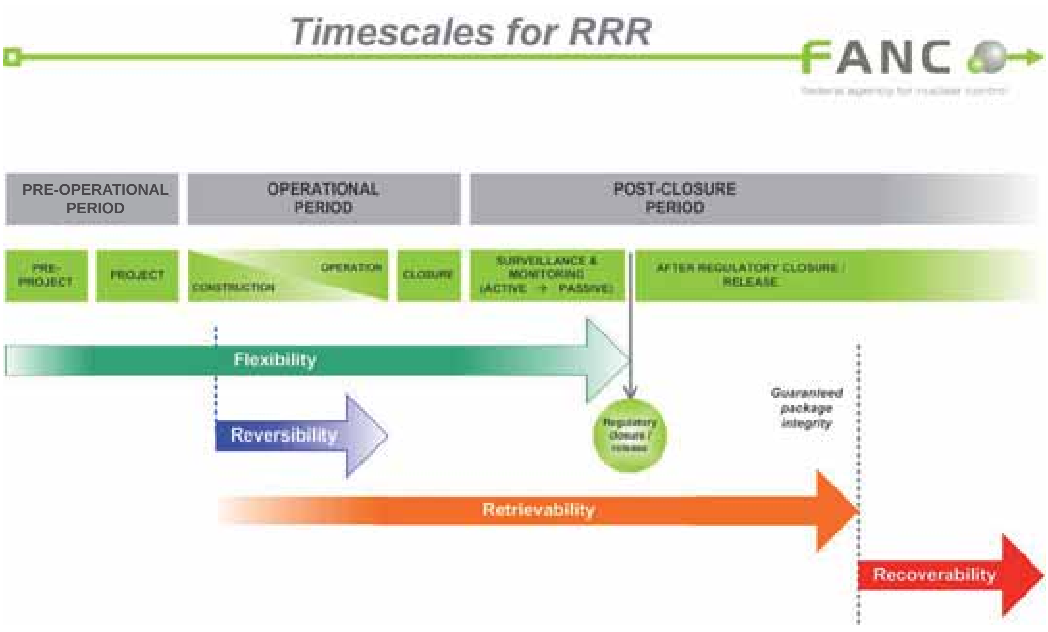
In order to avoid any misinterpretation in the wording and in view of a clear and transparent communication with the national waste management organisation (ONDRAF/NIRAS) and stakeholders (including the general public), the Federal Agency for Nuclear Control (FANC) proposed a definition of these concepts that is slightly different from existing ones (IAEA, NEA).

Belgian context

At present there are no generic legal requirements for reversibility or retrievability of waste disposed of in any type of repository. No decision has yet been taken on the long-term management of long-lived medium- and high-level waste. The relevant national waste plan was developed by ONDRAF/NIRAS and made available for public consultation in 2010. The final waste plan will be submitted to the government in the course of the first semester 2011, awaiting a decision in principle on the long-term management of these substances. No decision has been taken as yet to declare commercial spent nuclear fuel as waste.

In the past years, the FANC elaborated a strategic note on disposal of radioactive waste, describing the different periods and phases of a repository (see Figure 1) and explaining its views and expectations on the development of a disposal system. This strategic note covers all types of repositories and clearly marks the major steps and hold points along the process timeline, requiring a license or at least a permit from the safety authority.

Figure 1: Flexibility, reversibility, retrievability and recoverability (RRR) in perspective of the different stages of a repository



The purpose of this document was also to describe the point of view of the FANC on the application of the previously mentioned "concepts". Although a description/interpretation of "flexibility", "reversibility" and "retrievability" is given in the document, the way in which future developers of disposal systems/sites should take these concepts into account was not developed. Whereas flexibility is purely related to the process as such, reversibility and retrievability are associated with the waste emplacement and waste retrieval/recovery operations and hence are to be considered as technical implementations of flexibility.

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The strategic note clearly states that provisions for reversibility and retrievability should not harm the robustness of the system and hence the long-term safety. Moreover it mentions that the disposal facility should reach its final passive configuration as soon as possible (closure).

"Closure" of a repository consists of removing all direct access to the waste and its receiving structures (e.g. galleries, modules). This means that the repository, upon closure, reaches its final passive configuration. In the specific case of geological disposal, waste contained in a backfilled and sealed section of a disposal gallery is considered to be in its "sealed final configuration", which may be interpreted as closure of part of the disposal facility.

In 2006, the Belgian government opted for surface disposal of short-lived low- and intermediate-level waste. The government charged the national waste management organisation ONDRAF/NIRAS to develop a stepwise, flexible and reversible process. At the same time, the federal nuclear safety authority (FANC) was charged to develop a specific regulatory framework for licensing disposal facilities. A proposal for this regulatory framework is currently under development. A stepwise licensing process is foreseen with consultation of the public.

What, when and how?

Flexibility

In the development of a repository, the application of the *optimisation principle* is the driving force towards safety in the long term. Since it consists of a stepwise process, the development of a disposal system is expected to evolve with time and with the experience gathered on site or on other sites. It is an ongoing process to be applied from the very beginning in the development of the disposal system, aiming at obtaining an optimum protection for workers, members of the public and the environment during the different phases and time frames of the disposal system, and taking into account existing circumstances.

For all types of repositories, ensuring *long-term safety* is the real challenge. The stepwise decision and licensing process associated with the development and realisation of a repository should be flexible, especially in view of the long time frames involved. This means that over time, decisions may be overruled and the process reversed for one or more steps if enough evidence is provided. The capability and the willingness to re-assess earlier decisions and the ability to reverse the course of action or decision to a previous stage are called "flexibility".

This reversal in process step(s) may be of different origin; it may be purely political, societal or economical, technical or environmental or it might be related to the safety associated with waste emplacement operations as such.

Flexibility essentially covers the whole time line of the development and implementation of a repository. From the technical and economical point of view the consequences of flexibility may be the highest during the operational period (construction up to closure of the facility), depending on the number of reversed steps and of the degree of implementation. Flexibility is closely linked to the national or international experience feedback and to the results of the periodical safety evaluations, as imposed in the license.

Reversibility, retrievability and recoverability (RRR)

These terms are, mainly for reasons of clarity and for communication purposes, restricted to radioactive waste movement operations (emplacement and retrieval/recovery). Up to regulatory closure/release, reversibility and retrievability may be considered as a part of flexibility.

"Reversibility" implies that the waste package can be taken back by means of essentially the same operations and with the same equipment it has been put in place. It is strictly related to the operational period, and more specifically to the exploitation phase within the operational period. The reasons for reversibility might be diverse, such as non-conformity of the disposal package or as the result of damage.

The federal nuclear safety authority considers that reversibility (taking back wastes from the disposal area), as part of good practices, must be taken into account in the development of the disposal system, and its feasibility must be demonstrated before starting emplacement operations.

Once the waste disposal packages are emplaced and embedded in an underground gallery for instance, and if, upon decision to take them back, specific operations and means different from the emplacement ones are necessary to bring back the disposal packages to the surface, then the term "retrievability" is used. The integrity of the waste container is supposed to be guaranteed as long as retrieval is envisaged.

It should be clear that retrievability is not a prerequisite in order to ensure long-term safety of a disposal system. Indeed, long-term safety relies on the characteristics of the disposal system (ultimately on the host formation in the case of geological disposal). The disposal system, by design, should be passively safe in the long term. As mentioned before, once the waste packages are embedded in the galleries and once these are sealed (even partially) they are considered to have reached their final configuration ("sealed final configuration") for which sufficient arguments and proof must be provided in the safety case to guarantee the long-term safety. When sealing operations are performed and approved as described in the license application, on the basis of which the license was issued, then for the regulatory authority, retrievability is not needed from a safety point of view (normal evolution scenarios) and hence should not be imposed by the regulator.

In all cases long-term safety should be of prime concern and provisions should not detract from safety or security, nor should they put unreasonable burdens on future generations. Developers or implementers of disposal systems should not use retrievability as an argument for safety in the long term, since this might create false expectations for the public (i.e. a false feeling of safety). The feasibility, performance and robustness of the disposal system and of its components must be argued and demonstrated. This is, from the technical point of view, essential for having confidence in the safety of the repository.

Retrievability (as well as reversibility) may however be imposed politically or for reasons of public acceptance, rather than based on safety arguments. For precautionary reasons (principle of precaution and principle of modesty), the FANC is of the opinion that, depending on the type of disposal facility and proportional to the total risk of the waste disposed of, the developer/implementer of the disposal system should make provisions in order to facilitate the possible retrieval of waste packages, by putting for instance specific requirements on integrity and accessibility of the containers for a specified period of time. Specific requirements related to retrievability may be included in the license. Reference time frames for geological disposal might be for instance up to the sealing of galleries or complete closure of the facility for Category B waste, or up to the maximum impact of the thermal phase for Category C waste.

In the far future, when integrity of the container or packages is lost, and if future generations, for whatever reason, decide to retrieve the waste, then we talk about "recoverability of waste". Recoverability differs from retrievability in the sense that the integrity of the waste package/container is not guaranteed anymore (loss of integrity). For closed repositories, retrievability and recoverability are comparable to mining activities, but the circumstances for recoverability are more difficult.

Once it is decided to take the waste back to the surface, then the *retrieval or recovery act must be justified and will have to be licensed*, taking into consideration radiological impact assessments and economic and social circumstances. Retrieval of waste packages or recovery of waste would imply surface storage facilities being in place. In the worst case new facilities would have to be developed, licensed and operated resulting in excessive costs and awaiting a new final destination for the wastes (new repository?).

Application of the concepts? When and for how long? – Restrictions

The stepwise development process must be flexible, allowing reconsideration of previous decisions whenever justified.

As already mentioned reversibility is a strict safety requirement during waste placement and is considered as a good practice. This requirement is valid for all types of disposal facilities.

For surface disposal facilities, retrievability, although not required, is quite easy to implement since the material is readily available at the surface and in view of the short half-lives of the radionuclides, the risks to the workers are considered "manageable".

Table 1 gives an overview of the expectations of the FANC in relation to the different periods and phases considered in the lifetime of a repository.

Table 1: Expectations of the FANC

	Pre-operational period	Operational period			Post-closure period	After regulatory closure/release
		Construction phase	Operation phase	Closure Phase		
Flexibility	+R	+R	+R	+R	+/–	–
Reversibility	–	–	+R	–	–	–
Retrievability	–	–	+	+	+/–	+/–
Recoverability	–	–	–	–	–	–

+R = requirement

\+ = provisions for making it possible in case of

+/– = provisions for making it possible in case of (waste type dependant time period)

– = not applicable

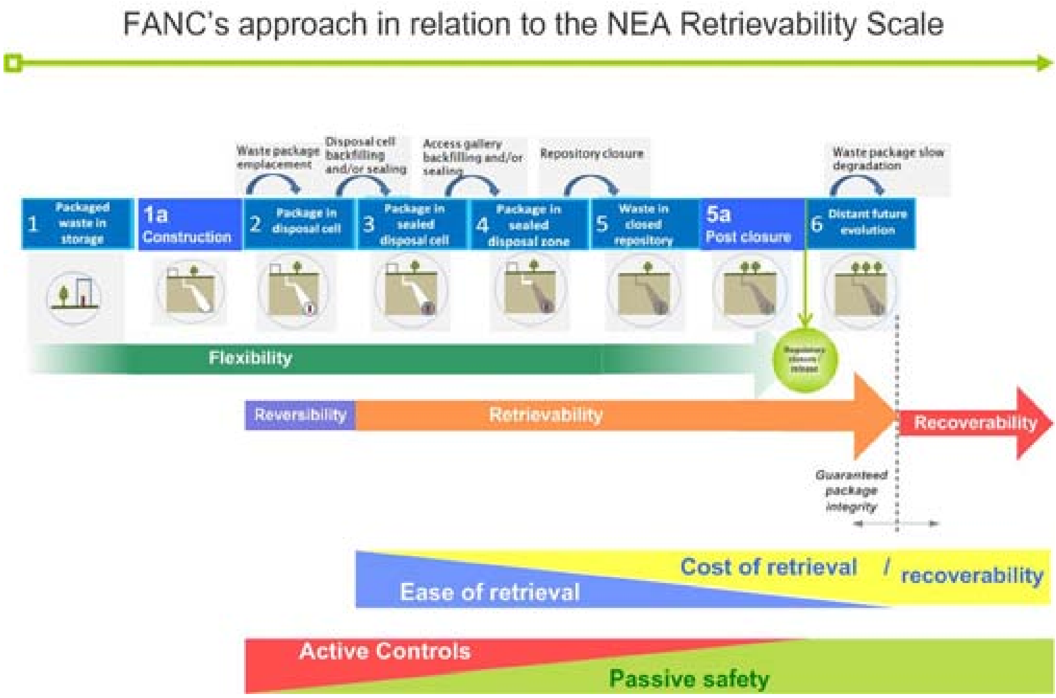
For deep geological disposal of long-lived medium- and high-level wastes the following should be considered:

- Maintaining forever a constant level of retrievability is not feasible.
- Ageing of equipment and components (inclusive wastes).
- The degree of integrity of the disposal packages.
- If decision-making and retrievability requirements lead to a delay in backfilling, sealing or closure of the facility or parts thereof, there may be an impact on safety and security. In its strategic note, the FANC clearly states that the disposal facility should reach its final (passive) configuration as soon as possible (confidence in the safety of the repository as prerequisite!).
- Even if the repository is technically closed, this does not mean that the repository site will be abandoned immediately and left without further surveillance/monitoring. There will be a continued regulatory control for a certain period of time. This will finally end with "regulatory closure/release" of the disposal facility later on.
- Complexity after emplacement and sealing/closure will become increasingly challenging. Retrievability will pose design challenges and retrieval would become progressively more difficult and resource intensive as implementation proceeds. If post-closure retrieval is effectively required, then it will likely be only at large expense to future society.
- Potential impact of retrievability on the remainder of the repository and hence on its long-term safety. Retrievability should not have a negative impact on short- and long-term safety.
- After final closure, safety and security/safeguard related considerations must be given priority over the principle of freedom of choice of future generations.

A graphical presentation of the different disposal package configuration stages for a deep geological repository is given in the R&R leaflet from the NEA as shown in Figure 2. The evolution of costs and feasibility of retrieving wastes is shown as well, together with a presentation of the shift from purely active controls towards a purely passive safe system as a function of time.

Figure 2: Stages in the life of a deep geological repository; evolution of waste package configuration, feasibility and cost of retrievability and safety assurance

In the context of this document Stage 2 is considered as reversibility; Stages 3 up to 5 are covered by the term retrievability whereas Stage 6 may be retrievability as well as recoverability



Conclusions

At present there are no requirements on reversibility or retrievability in the Belgian regulations.

The stepwise process of the development and the implementation of the repository should be flexible up to the regulatory closure/release of the facility.

The Federal Agency for Nuclear Control (FANC) considers reversibility to be required and limited to the operational phase.

Provisions to facilitate retrieval are recommended and the time period during which these are supposed to hold will be commensurate with the hazard of the waste. Retrieval (as well as recovery) is in principle a new process, requiring a new safety assessment and regulatory authorisation and needs to meet the justification principle.

Flexibility, reversibility and retrievability must not, in any event and at any time, threaten the operational safety and/or long-term safety of the disposal facility. Licence applications must specify, as applicable, the relevant arrangements and time scales for these various concepts.

Analysing the Consequences of Retrievability Requirements for Emplacement Concepts and Resulting Possible Constraints for Post-closure Safety Optimisation on the Example of a HLW Repository in a Salt Dome

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Background

Regardless of the controversial public debate on radioactive waste disposal which stands in the middle of the disputes on the use of nuclear power in Germany, the wide consensus on maintenance-free and non-retrievable disposal in deep geologic formations as the only long-term management option for radioactive waste has not been seriously questioned for more than four decades. Thus, retrievability has not been a regulatory requirement in Germany, neither has it been the subject of repository concepts considered.

Nevertheless, retrievability has been investigated in several studies, especially for the HLW disposal concept in a salt dome preferred so far. The first comprehensive investigation of this issue for safeguarding purposes was completed in 1995 (Pöhler) and demonstrated the general technical feasibility of retrieving SNF disposal casks of POLLUX-type which were to be disposed of in repository drifts in a salt formation. However, the repository concepts considered have not yet been adjusted to fulfil retrievability requirements.

In connection with the increased public and political awareness, safety concerns regarding radioactive waste that was disposed of in the Asse mine between 1965 and1975, retrievability has become a requirement increasingly supported by the public and politicians. As a consequence, the latest version of the *Safety Requirements Governing the Final Disposal of Heat-generating Radioactive Waste* published on 30 September 2010 by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BUNR, 2010) contains clear provisions regarding retrievability.

These safety requirements provide the regulatory basis for the preliminary safety analysis that will be performed for a potential HLW repository at the Gorleben salt dome in order to derive a site suitability forecast, recommendations for concept optimisation and guidelines for further site investigation. Thus, retrieveability becomes one of the challenging issues of this effort.

Regulatory requirements

As mentioned above, the regulatory basis is provided by the *Safety Requirements Governing the Final Disposal of Heat-Generating Radioactive Waste*. Regarding retrievability, Paragraph 8.6 stipulates:

> "Waste containers must fulfil the following safety functions, with due regard for the waste products packaged therein and the backfill surrounding them:
>
> For probable developments, handleability of the waste containers must still be guaranteed after 500 years in case of salvage from the decommissioned and sealed final repository. Care should be taken to avoid the release of radioactive aerosols.

During the operating phase up until sealing of the shafts or ramps, retrieval of the waste must be possible.

Measures taken to ensure the possibility of retrievability or the salvage of the waste must not compromise the passive safety barriers and thus the long-term safety." (BUNR, 2010)

Consequently, these requirements regarding waste and spent fuel containers as well as the retrievability procedure will be an integral part of any HLW repository license. In compliance with the Law on Nuclear Energy, demonstrated (tested) technologies can be licensed. Thus, the fulfilment of the retrievability requirements described above has to be demonstrated prior to applying for a license for the repository. A feasibility study would not be sufficient.

Consequences for disposal concepts considered

So far two alternative concepts for the disposal of HLW and SNF in a salt dome have been considered and their principle technical feasibilities have been demonstrated in above-ground full-scale tests. Self-shielding disposal casks of POLLUX-type loaded either with HLW containers or SNF rods are considered for disposal in drifts while unshielded HLW containers and containers with SNF rods are considered for disposal in up to 300-m deep boreholes. In both concepts, the disposal drifts and boreholes will be backfilled with crushed salt which will subsequently compact due to convergence and – together with the host rock – will ensure long-term safe containment.

In both concepts, a maximum rock temperature of 200°C provides a major design constraint. Corresponding thermal calculations showed that the salt rock will heat up to this temperature within only a few decades. However, mining operations at such rock temperatures are as yet unknown. Thus, additional feasibility studies will be necessary regarding retrievability at comparably high rock temperatures in compliance with various mining safety requirements as well as with the Mine Regulation on Microclimate which limits air temperature in manned drifts to 52°C. These studies may result in the need for concept modifications in order to reduce the maximum rock temperature, e.g. by increasing the distances between containers or casks or by reducing the heat and consequently the waste load.

Further conditions for retrievability are the accessibility of the waste containers and the feasibility of their safe handling during the retrieval operation. For the retrieval of self-shielding casks from disposal drifts, this has been investigated in Pöhler (1995) and demonstrated to a certain degree within the scope of an *in situ* test in the Asse mine (Bechthold, 2007), but recovery of unshielded containers from deep boreholes has not yet been sufficiently investigated.

Before an unshielded container can be loaded into a transfer cask which provides sufficient shielding, its recovery from the disposal borehole has to be performed by remote control. This may result in the need for lining disposal boreholes completely.

Possible constraints for optimising post-closure safety

In a HLW repository in a salt dome post-closure safety has to be ensured by safe containment. This is provided by the integrity of the main geologic salt barrier supported by shaft and drift seals in the short term and the increasingly compacting backfill of crushed salt in the longer term. This safety concept is not questioned at all by possibly necessary modifications of the disposal concepts to enable retrievability. Nevertheless, possible constraints for optimising post-closure safety have to be analysed carefully in order to exclude undue impairments of the safety functions of the passive safety barriers as required by the Safety Requirements.

If the maximum rock temperature needs to be reduced for retrievability purposes, this will result in a slower compaction of the backfill material due to lesser thermally-induced convergence. In this case, the extent to which this could affect the robustness of safe containment and how this could be compensated for, e.g. by increasing the durability of shaft and drift seals, must be carefully analysed.

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Figure 1: Borehole and drift emplacement options

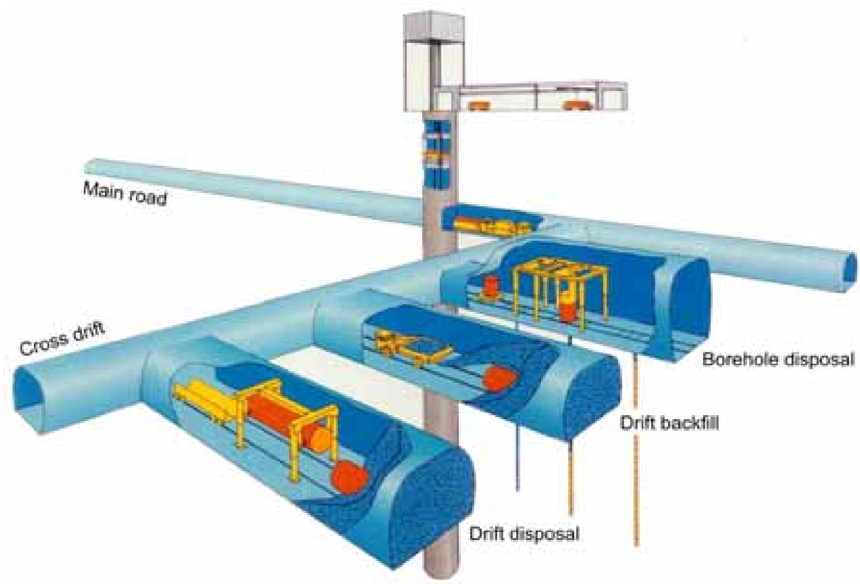


Figure 2: Emplacement of a POLLUX cask in a drift

Figure 3: Borehole disposal concept

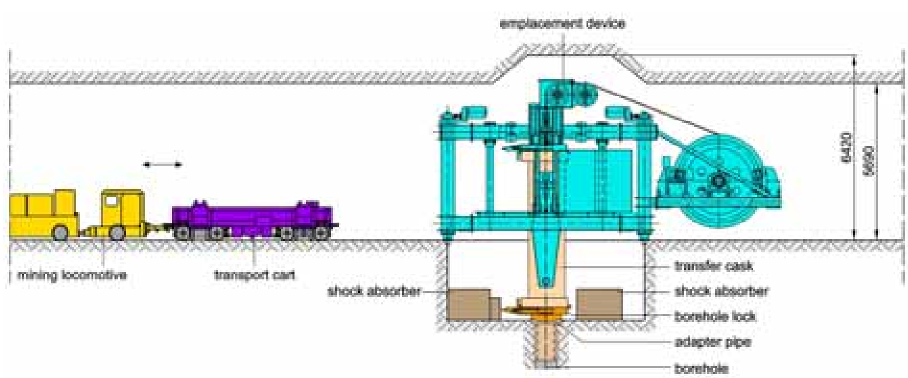


Figure 4: Testing of borehole emplacement

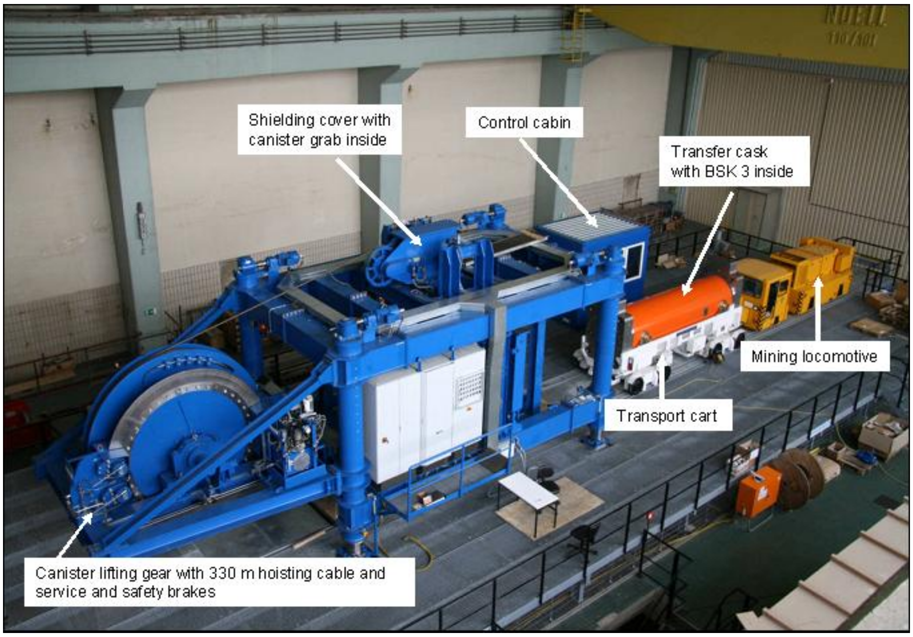
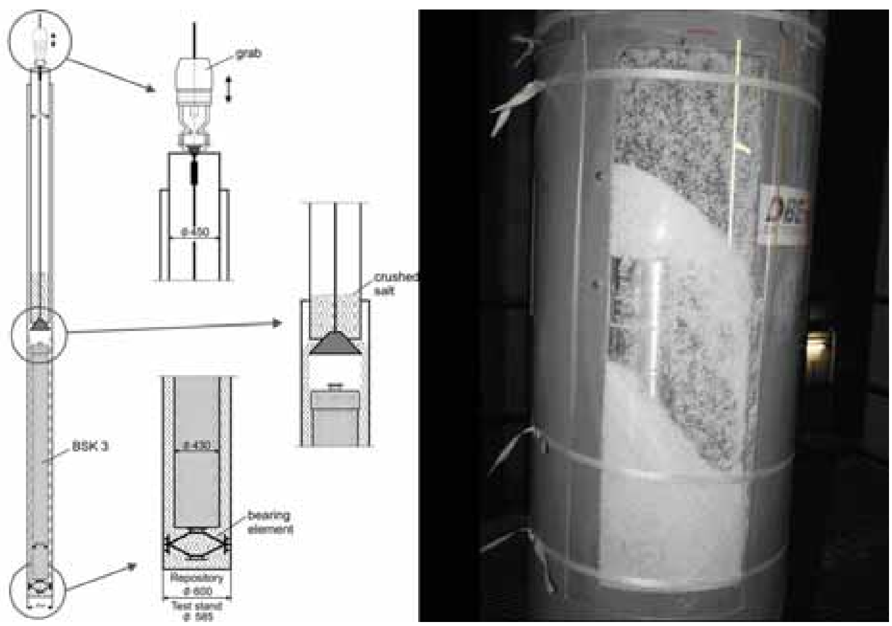


Figure 5: Testing of backfill operation



If it is necessary to line the disposal boreholes to enable remote-controlled recovery of unshielded disposal containers, the expected safety advantages of the borehole concept might be affected. Compared with the drift disposal concept, the expected safety advantages are a faster containment of the unshielded disposal containers in the near field due to the faster backfill compaction in the relatively small open borehole cross-section. In addition to this, due to the extremely fast compaction (within a few years) of the backfill in the gap between disposal container and borehole wall, practically no void volumes remain in the vicinity of the disposal containers where brines could accumulate.

Especially in the void space between disposal containers and borehole lining larger amounts of brines could accumulate in the unlikely case of brine inflow which, in turn, could cause corrosion and penetration of the disposal containers and which may be pressed out after it has been contaminated.

Necessary but undue lining of disposal boreholes may be prevented by using self-shielding disposal containers. However, safe emplacement of these relatively heavy containers into deep boreholes has not been demonstrated and its technical feasibility remains to be investigated.

Summary

Retrievability is not contradictory to the safety concept of a HLW repository in a salt dome, and its technical feasibility has been shown for self-shielding disposal casks emplaced in disposal drifts. However, retrievability requirements modify the boundary conditions for concept optimisation to ensure best achievable post-closure safety. In this context, new challenging tasks arise for developers and safety analysts.

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Expectations Expressed by Local Stakeholders and NGOs

Chair: Eva Simic

Clarification of the Notions of Reversibility and Retrievability*

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Reversibility as currently proposed by Andra (Dossier 2009 "Reversibility options") corresponds in fact to the recovery of packages during the operational phase of a repository (i.e. about 100 years after its opening). The disposal concept developed by Andra is progressively irreversible in the short term (in comparison to the period characterising the radioactive elements contained in the waste packages).

In view of true reversibility (that is, for 100 years, as foreseen by the 2006 Act, but to start as of the closure of the repository), work must be led on technical solutions concerning principally the disposal cells and the containers (choice of materials, thickness…), as well as on the question of monitoring/oversight and memory preservation.

It is appropriate, too, to distinguish the recoverability of packages (technically complicated, increasingly so over time) and the recoverability of the products contained in the waste packages (today impossible given that high-level waste is vitrified).

In the period leading up to the Public Debate and the discussion of the Law relative to conditions of reversibility (2015), the CLIS, through the commission it has set up to reflect on this subject, intends to clarify the notions of reversibility and retrievability and to make proposals for a true reversibility.

* The full paper being unavailable at the time of publication, only this short summary is included.

Reversibility and Retrievability in the Context of "Managing Radioactive Waste Safely" in the United Kingdom*

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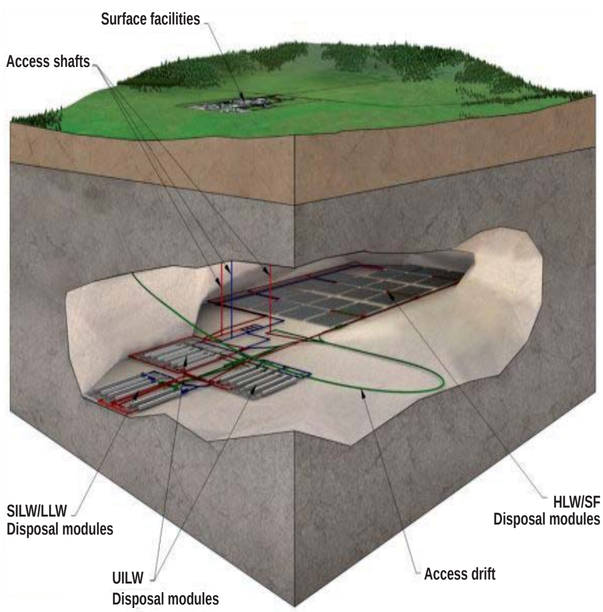
Introduction

This paper aims to outline the West Cumbria Managing Radioactive Waste Safely (MRWS) Partnership's role in the United Kingdom "Managing Radioactive Waste Safely" process. It will describe the issues focused on, and where reversibility and retrievability fit within that process.

Figure 1: Schematic of a potential future geological disposal facility in the United Kingdom



What is the United Kingdom process?

In June 2008, the United Kingdom government outlined its policy and a process for identifying a location for higher-level radioactive waste disposal in a white paper entitled *Managing Radioactive Waste Safely: A Framework for Implementing Geological Disposal* (Figure 2).

* This text was adapted by the NEA from the author's PowerPoint presentation at the R&R Conference.

Figure 2: Cover of the 2008 government White Paper

This government initiative is based on the principles of voluntarism, right of withdrawal and community benefits. Communities are invited to talk, *without commitment*, about the possibility of a geological disposal facility being located in their area. The process begins with an expression of interest from a local government in discussing the potential of formally participating in the process. The plan is voluntary in nature, and local governments may withdraw at any point during the discussion (until just before construction would begin). The process includes the understanding that as an incentive there will be substantial community benefits for any community that hosts such a facility. Figure 3 presents a schematic rending of the different stages of the process.

The decision-making process – even assuming it goes ahead – would be a lengthy one. Once an area has manifested an expression of interest the next stage is an initial desk-top geological study by the British Geological Survey, which will determine whether or not the area is suitable.

After further discussions and consultations, the councils then have to decide if they wish to participate in the government siting process, which formally starts at Stage 4 (see Figure 3).

Figure 3: The different stages of the UK process

Stage 1:	Expression of interest	2008
Stage 2:	Geological screening	
Stage 3:	Community consideration leading to decision to participate (or not)	
Stage 4:	Desk-based studies/ site identification	
Stage 5:	Sub-surface investigation	
Stage 6:	Repository construction	2025

If there is a decision to participate there would then be a series of desk-based studies looking at a whole range of social, environmental and economic criteria to narrow the focus to one or two possible sites.

Subsequently, detailed geological investigations would be undertaken on the sites remaining under consideration.

A community siting partnership would ensure that the populations most directly concerned are involved during the formal siting process.

Only after this series of steps – probably more than a decade later – would it be necessary for an area to make a final decision about whether to accept the facility. That would be just before underground construction could start.

The process is thus a long one, currently at its inception, and may be withdrawn from whenever the community so desires.

Why is West Cumbria involved?

In 2008 three local authorities – Cumbria County Council, Copeland Borough Council and Allerdale Borough Council – individually took decisions to express an interest. The expression of interest from Cumbria County Council is for the geographic areas of Copeland and Allerdale and not for the rest of Cumbria. More than two years later no other local authorities have expressed an interest, but the opportunity remains open across the United Kingdom.

The West Cumbria Managing Waste Safely Partnership was set up by the three local authorities in order to:

- consider the issues;
- make recommendations on whether or not to move to formal participation in Stage 4.

Why did these three authorities come forward? The Partnership notes that the local population is already at this time very familiar with the nuclear industry. Currently, around 70% of waste awaiting geological disposal is already in the area, at Sellafield. The communities will be affected, in any case, by whatever action is taken.

Partnership work

The key tasks of the partnership are to:

- develop a set of criteria;
- assess information against criteria;
- make recommendations to the three local councils;
- involve a wide range of community interests.

Key work streams of the Partnership

There are six key areas of work that are progressing in order to inform our recommendations on whether or not West Cumbria should participate in the next stage. These are:

1) *Safety, security and environment*, e.g. satisfaction that suitable regulatory processes are in place.
2) *Geology*, only insofar as it relates to the initial desk-top filter being carried out by the Department of Energy and Climate Change (DECC).

3) *Community benefits*, e.g. confidence that an appropriate community benefits package could be provided by the government.
4) *Design and engineering of a possible facility*, e.g. satisfaction that an appropriate design can be drawn up.
5) Ensuring that stakeholders are *happy with the process* of negotiation, research and planning between now and potential construction.
6) *Understanding public views* as best we can, cutting across all of the above topics.

Reversibility and retrievability

The independent Committee on Radioactive Waste Management (CoRWM) was established in 2003. In creating this body, the United Kingdom government sought "…a review of options for the long-term management of the UK's higher activity radioactive waste, and [a recommendation for] the option, or combination of options, that could provide a long-term solution, providing protection for people and the environment". (UK Government, 2006)

Among its recommendations, CoRWM advanced that "leaving a facility open, for centuries after waste has been emplaced, increases the risks disproportionately to any gains." (CoRWM, 2006)

In response it is clear from the MRWS White Paper that government supports closure as soon as possible. Indeed, the Department for Environment, Food and Rural Affairs stated that, "…the incorporation of retrievability into geological disposal should not undermine the long-term safety of a GDF. […] *…the environmental safety case would need to demonstrate that processes such as degradation of waste packages would not unacceptably affect the safety of people*." (Defra, 2008)

Though this is the position outlined by the government, all three local authorities involved in the West Cumbria MRWS have expressed support for phased geological disposal incorporating monitoring and retrievability for a significant period of time. The MRWS White Paper keeps the retrievability option open for future discussion with local communities and regulators. In the meantime, design and construction can proceed without expressly excluding it.

R&R has been seen by the Partnership as an issue that does not yet need to be addressed in detail. Though not considered a "deal breaker", it is understood that R&R could become a major subject of debate if the community moves to the next stage. Because there has been little discussion of the issue up to this point, the MRWS does not have a formal position on the subject. However, work has now begun to increase awareness of this issue.

Local authorities' policies

Now that the positions of the national players are reported, we move to the views of the local authorities. Their opinions have certainly had an influence in ensuring that government has kept the R&R option open for discussion.

Local authorities have their eye on several concerns. They seek to maximise the options for future generations. R&R could provide a means to take advantage of better technological solutions if these are developed at some point. Also, the local authorities are aware that standards and perceptions can change with time; as an example, disposal options that seemed acceptable only decades ago (Sellafield, National LLWR), no longer are considered in the same way.

Monitoring and testing performance are also issues of concern to the local authorities, becoming perhaps more crucial as the national approach is to seek "suitable" (i.e. not necessarily "best") geology with the repository to be designed to site circumstances. Access to potential future assets also draws attention as a potentially critical area for negotiating a solution acceptable to community and government in a region where many jobs are supported by reprocessing, and given that government intends to include spent fuel in the inventory and potentially may include plutonium and uranium.

Finally, local economic impacts are high on the community agenda and complete closure of a repository would provide little in the way of economic stimulation, particularly as compared to the opportunities which could be generated by the continued scientific research associated with monitoring and retrievability.

Summary

We have before us a very lengthy process which has only just begun. R&R options remain open for discussion. The local partnership has not yet debated or adopted a position on these options. However, it is observed that at the national level, the inclination is towards the earliest closure possible. Local authorities' policies tend towards favouring retrievability. In times ahead, we can expect some potentially interesting – and hopefully fruitful – debates.

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The Ongoing Debate on Final Storage of Radioactive Waste in Germany

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The controversial debate on the final storage of radioactive waste in Germany is clouded by the recent decisions of the present Federal Government on the lifetime extension of German nuclear plants and the continuation of the mining processes for investigation purposes at the Gorleben site. Decades-old conflicts, which seemed to have been settled by the consensus on the scheduled nuclear phase-out and the moratorium at the unsuitable site Gorleben, are now erupting again.

However, despite the different opinions on how and when, there seems to be a societal consensus on one point: the atomic age in Germany should be ended.

What remains is the discussion on the final storage of radioactive waste, an issue which critics of nuclear power can not at all discuss without reference to the ongoing production of more nuclear waste and the planned considerable increase of the amount of waste. Relevant experiences have been made in Germany with the storage of nuclear waste in salt domes which have considerable influences on the public assessment of the retrievability and reversibility of the planned final storage.

After German reunification, the salt mine Bartensleben near Morsleben in Saxony-Anhalt became all-German property. Morsleben, situated at the inner German border, had been chosen by the German Democratic Republic out of 10 possible sites for the final storage of all sorts of radioactive waste under conditions of planned retrievability (ERAM). Until the end of the GDR it had been filled with 14 000 square metres of solid and liquid waste from the operation of nuclear power plants in a chaotic way of dumping. The adjacent cavity was used for an underground chicken-fattening unit. Despite the missing proof of long-term safety and considerable security concerns and although the storage was even enjoined in the meantime, another 22 300 square metres of – also West German – nuclear waste was stored until 1998 on the basis of the old GDR operating licence under the then-Environment Minister Angela Merkel; medium active waste was, by the way, still dumped in an uncontrolled way. In 1998 further storage was stopped after legal actions by residents and initiatives. The succeeding governing coalition of Social Democrats and Greens opened the decommissioning procedure. In the beginning, the commissioning was limited to the prevention of hazards: apart from water intakes the mine was also in severe danger of collapsing. In 2001, several thousand tonnes of halite collapsed from the ceiling, and a similar incident occurred in 2009. Since 2003, ERAM is being stabilised by backfilling, incidentally using alkaline solutions from the chicken fattening. The cost for the decommissioning, which has to be borne by the tax payers, is put at EUR 2.2 billion. The initially projected retrievability or reversibility is no longer an issue in the public, only local initiatives claim an immediate removal of the highly radioactive waste and the consideration of the decommissioning alternatives retrieval and keeping the mines open. Forty-four years after the site decision, the procedure of public participation was finally started in 2009.

Another attempt with final storage in salt domes is made in the former salt mine Asse near Wolfenbüttel in Lower Saxony, only 50 km west of Morsleben. Although it has been known for a long time that alkaline solutions forced their way into adjacent cavities and also into Asse itself, the irretrievable final storage of radioactive waste was meant to be tested there. The repository was introduced to the public as an "exploratory mine" and reference object for a future repository in Gorleben. The dumping, dropping and stacking of spent fuel elements was tested until the storage was full. Liberties were taken with the origin and declaration of the waste. Early warnings of water ingress were dismissed and redounded to the disadvantage of critical scientists. The interested public was told – against better knowledge – that Asse was dry and absolutely safe. Against the background of the mandatory waste disposal precautions for the operation of nuclear power plants, 125 787 drums of waste have been piled up over time. Some have unknown contents and an initially undetermined amount of plutonium accumulated in the alkaline sludge. The vast majority of the waste originated from commercial nuclear power plants, but since it was transported to the salt mine via the nuclear research centre in Karlsruhe, it was declared waste from governmental research. In 2008, the occurrence of radioactively contaminated alkaline solutions was made public. As a consequence, the public and politicians became aware of the disastrous conditions which prompted then-Environment Minister Gabriel to withdraw responsibility from the operator. The Federal Office for Radiation Protection, which is now in charge of the site, assessed in a comparison of options that long-term safety can only be guaranteed by retrieval of the waste. EUR 2 billion are budgeted for the restoration, though experts put the actual costs at more than EUR 6 billion.

Predictions which were made for centuries became reality in Asse already after a few years. Hardly any of the statements of the former operating company and the supporters of the so-called "research" repository Asse proved true.

A committee of inquiry in Lower Saxony is currently investigating the incidents at and the history of the salt repository Asse. Several complaints have also been filed.

Recent news reports on a striking statistical cluster of cancer cases, both in the surrounding areas of Asse and Morsleben. Although nobody is yet able to explain these proven clusters, public authorities have already communicated that a connection to the nuclear waste dumps can of course be denied.

Against the background of these bad experiences, the number of people from different parties and groupings all over Germany demanding a permanently retrievable storage of radioactive waste is constantly growing. One integral element is the fact that the events described in Morsleben and Asse are only related to a minor part of radioactive waste in Germany. One single Castor container comprises 150 to 210 times the radioactive inventory of Asse.

However, the various stakeholders' intentions behind demanding retrievability could hardly differ more. In Lower Saxony they talk about retrievability and keeping the mines open during the operating phase, i.e. for some decades. Groupings critical of nuclear power assess this as an obvious deceit of the public. This option needs to be a matter of course as long as a final waste storage is not even closed yet. Others dream in their boundless belief in technology about retrievable storage until future generations will have developed a magic technology to render nuclear waste harmless. The attempt to keep the "nuclear waste asset" accessible to the industry for future reprocessing and military use is just too obvious here. This inept effort ignores the will of the considerable majority in Germany to finally end nuclear technology. Another position assumes that only some kind of large underground parking is required to park all the nuclear waste. Please spare me a comment; I would just like to refer to the durability of the storage containers. Permanent repacking and reshelving might be financially attractive for the industry dealing with these procedures, but the German people do not want this constant threat.

After the disastrous experiences gained with the final storage Asse which was disguised as an exploratory mine, opposition parties and non-governmental organisations also vehemently insist on a long-term or even permanent retrievability or at least revisability. The previous Environment Minister Gabriel tied the technological possibilities of storage containers to the call for medium-term retrievability of 500 years in the safety requirements. If I understood these paragraphs correctly, this was not about an emergency recovery but indeed about the actual

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stability and manageability of containers and their scheduled possible retrieval. However, this time limit does not answer the question of what will happen if the water ingress or a contamination of ground water occurs after 550 or 600 years.

But these are the questions the German public wants to be answered. To be honest, the damage at the relatively small amount of low and medium radioactive waste might be a stroke of luck. The events at Asse revealed structures and involvements which are not compatible with the need for security of the population and future generations. The enormous hubris of some institutions and scientists also became apparent, along with a lack of information and involvement of the public.

If we assume that different solutions are mutually exclusive, like permanent retrievability or the fear of proliferation due to future regimes of injustice – a fear which is unfortunately more than justified in Germany – all decisions have to be carefully considered. In this respect, the principles of consideration are of importance: it has to be made sure that these decisions are not taken on the basis of cost-benefit analyses or the ulterior motive of a subsequent reuse of the radioactive material but exclusively as a consideration of safety. In Germany I can especially refer to the considerations of the AK-End, although they were made prior to the disaster at Asse.

All previous thoughts are based on the passive, irretrievable inclusion in deep geological formations for at least one million years. The German term for disposal literally implies that you do not have to worry anymore, but also do not have to care, i.e. do not make any further efforts. However, the nuclear future does not seem to be *sans souci* ("without worry").

The concept of previous interim storage with subsequent final storage could turn into a concept of never-ending interim storage.

The miserable failure of the repository experiments in Germany were not only due to obvious sloppiness and disregard of warnings (which are probably relevant under criminal law, but are certainly politically relevant) but especially to insufficient considerations of the decisions on the concept and site selection. For the vast majority of the German population retrievability and revisability are not an option for the reuse of radioactive material, they only see them as a possibility for safety-relevant action in case of unexpected incidents. In this way they express their lack of trust in the choice of concept, the site selection and the responsible institutions. If serious, reasonable and reliable considerations will be made on the – relatively – safest site and the safest concept, the concerns of the population will fade into the background.

Tree-dwelling primates did not have to learn how to deal with their excretions in the course of evolution. Therefore orangutans in zoos are kept on grilles. We as ground-dwelling primates have an innate disgust for our excrement, apart from a short phase during early childhood. As long as anyone can remember, we just dumped or poured any other waste into the nearest waters, which already caused the fall of several ancient civilizations. The human invention of rubbish pits was a great cultural achievement – to the delight of archaeologists. However, burying waste in the ground is not an act of intellect but also an instinctive action.

More than 50 years ago the first German Minister for Atomic Issues proclaimed that thanks to this new technology all the waste would one day fit into a cigar box. When this proved wrong, the idea came up to throw everything in the closest deep waters. As soon as the waves would break above the waste and it would no longer be seen, it would be just gone. When this also turned out to be a not-so-clever solution, the next idea was to dig an incredibly deep hole, sink everything and close the hole, goodbye forever!

So far, I am not able to see any act of intellect to which we owe the name of our species. We completely disregarded the ancient assertion of Heraclitus: "everything flows". Although it seems very durable from our point of view, the lithosphere is no exception. It has not been very long that we understand its behaviour and geology sees itself as the science of the history of the mantle of the earth, i.e. its past. If it is supposed to make a forecast it uses – according to my knowledge – flow models which I as a gardener know from a completely different discipline: the weather forecast. And you can all imagine what to think of the weather forecast for next year.

At this point laypersons like to suggest sending everything to the moon, which is much more innovative than digging a hole. However, I dare say we will not be able to afford this solution. But it expresses our wish to store the radioactive waste strictly separated from our biosphere.

We have opened Pandora's box. Now we will need good remedies to stem the impacts and protect ourselves.

In my opinion, one of the necessary requirements is that radioactive material has to be retrievable from the inclusion in a passive geological multi-barrier system in case of unexpected incidents even after long periods of time. This should be a matter of fact, just like a car that is equipped with bumper, seat belt and airbag although it has two brakes.

The concern that future generations might one day abuse the radioactive material could be dispelled if all of us first confess that we were the ones who abused it.

An Environmental View of the Advantages and Disadvantages of Post-closure Retrievability for a Final Repository for Spent Nuclear Fuel

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Overview

In this paper, the long-term environmental safeguard challenges to final disposal of spent nuclear fuel are examined. First, we look at the ethical motivations of the notion of post-closure retrievability. An ideal post-closure retrievability scenario is discussed, i.e. the advantages of retrievability in a perfect simple world, followed by a more realistic examination of retrievability in a complicated world, i.e. possible disadvantages. In Sweden, the guiding principle is long-term safety. In order to make informed decisions regarding long-term safety, the long-term future of nuclear energy as well as anti-proliferation issues must first be considered. Finally, reflections are offered on moving forward in an uncertain world, and on alternatives that may foster greater long-term safety and security.

Long-term environmental and safeguard concerns for the final disposal of spent nuclear fuel

The main concerns in this regard are the long-term radiation risks (hundreds of thousands of years), nuclear weapons proliferation risks for over one hundred thousand years, and the possibility of chemical risks enduring over all future time.

Figure 1: Illustration of the long-term environmental and safeguard concerns for the final disposal of spent nuclear fuel

Simple ethics of post-closure retrievability

The underlying ethical principle in Sweden is that long-term safety is always the primary motivation. There are, however, also other issues that have an ethical bearing.

The Swedish National Council for Nuclear Waste (formerly known as KASAM), established in 1985, published in the late 1980s the following so-called "ethical principles" for a nuclear waste repository:

- A final repository should be designed to render controls and corrective measures unnecessary (i.e. no monitoring).
- A final repository should be designed so as not to render controls and corrective measures impossible (i.e. retrievability).

The underlying philosophy is to minimise burdens on future generations, which is in accordance with the principles behind sustainability that have since been integrated into Swedish environmental legislation. The KASAM principles were developed with the Swedish KBS (Kärnbränslesäkerhet/Nuclear Fuel Safety) method for spent nuclear fuel in mind. The KBS method envisages a mined final repository in bedrock at a depth of 500 m.

Post-closure retrievability in a perfect simple world – advantages

Under ideal circumstances, retrievability means that you can change your mind, making the entire decision-making process a bit easier. Retrievability also means that another, safer and perhaps more technologically advanced method for disposal may be implemented at a later time. Retrievability signifies that the spent nuclear fuel can be used for other purposes, even to create more nuclear energy. And, in the event of a damaged repository, retrievability provides the possibility to repair. Indeed, under this ideal scenario, retrievability is a most appealing and positive notion. Representing the scenario in this manner tends to reassure stakeholders and we have noticed that when retrievability forms part of the discussion of a spent fuel repository, what we would call "happy talk" thrives. Such "happy talk" discounts the possible more negative scenarios and the possible disadvantages associated with retrievability that stakeholders should, however, consider as well in their deliberations.

Post-closure retrievability in the normal complicated world – disadvantages

In our normal, complicated world all security concerns must be dealt with. All spent nuclear fuel in the world, wherever it is, is now under international safeguard because the fuel and the plutonium in the fuel pose a serious security risk – plutonium in spent nuclear fuel can be used for the construction of nuclear weapons. Seventy-five years after the beginning of the nuclear era, concerns over nuclear weapons, nuclear proliferation threats and risk of nuclear terrorism are still very high on the international political agenda.

Here, retrievability becomes a problem. After closure, according to the International Atomic Energy Agency (IAEA), a mined spent fuel repository must be kept under strict international safeguard as long as the international security situation makes it necessary. Indeed we need to keep control of the *de facto* "plutonium mines".

While monitoring and surveillance may not be needed for 100 000 years, the need for such control will clearly place a burden on future generations in many future civilizations.

But wait….

If disposal only concerns reprocessed high-level waste from which plutonium has been removed, does the optimistic situation prevail? Can the notion of a "plutonium mine" be discounted by reusing the plutonium for energy purposes?

Unfortunately, no. This positive scenario would only be possible with the establishment of a long-term plutonium energy economy, under which fourth-generation breeder reactors are put into operation. Whether this will ever happen is very uncertain and a "plutonium energy economy" implies both environmental and security risks.

If the plutonium from reprocessing is used only once as MOX fuel the spent MOX fuel still contains plutonium. It will have to be disposed of as ordinary spent nuclear fuel and the nuclear weapons potential would remain.

Long-term safety always comes first

In any discussion of retrievability, it is always emphasised that any modifications made to a repository in order to enhance retrievability must not affect the long-term safety of the repository in a negative way. "Long-term safety always comes first" is the more general ethical principal for the management of nuclear waste – and a concept that everyone can agree on.

But does safety include security (i.e. against the risk of nuclear proliferation, etc.)? The case can be made that safety and security must be dealt with on the same level. The future use of plutonium in nuclear weapons could have catastrophic environmental consequence, and the risk for such use is possible for the whole life of the repository, for tens of thousands of years.

The long-term future for nuclear energy (and weapons) is a deciding factor

What are the consequences for our thinking if retrievability thus may not be purely a "good thing"? It becomes much more important to have a notion of what the global energy future likely holds. Over the next 20 years, we will have good indications of whether or not a post-fossil fuel world will be based on renewable and thus sustainable energy resources or whether nuclear energy will also prevail.

The environmental movement is fully aware that a long-term nuclear future may be possible, but maintains that it does not meet the criteria for an environmentally sustainable energy future. Therefore a preferable (and also highly plausible) scenario is a post-nuclear world towards the second half of this century, in which both nuclear power and weapons… are history.

Moving forward in an uncertain world – deep boreholes and more

There is no reason to rush toward hasty solutions. Our first responsibility toward future generations is to make well-grounded decisions, not to start digging holes as soon as possible. While understanding that such decisions cannot be put off forever, we should at least make an effort to obtain a better understanding of what the global energy future holds.

In the meantime, alternatives that may provide higher long-term safety and security should be developed. Some possible avenues of exploration could be deep boreholes, perhaps combined with accelerator-driven transmutation. Pre-closure retrievability remains of interest.

Reflections on Reversibility and Retrievability by an “Intermediate” Stakeholder

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Introduction

The NEA request was to share a Swiss canton’s expectations regarding reversibility and retrievability (R&R) in nuclear waste management. The canton as a partial state of the Swiss Confederation is a public player “in between” the national and regional levels, which means, having to follow, and develop, the ongoing site-selection procedure as induced by the national nuclear waste programme as well as supporting and protecting its regions potentially to host a repository. The contribution explores the struggle, challenges and possibilities an intermediate position (between national needs and regional concerns) constitutes – with R&R as a Janus-faced, ambiguous tool.

“Terminology matters” – indeed!

NEA is right in emphasising that, especially with R&R, “terminology matters” [most recently in an NEA report (2011, pp. 20 *passim*)]. To specify this claim, it is helpful to state possible reasons why one may want to reverse actions or even retrieve waste. Maintaining R&R can be reduced to two main motivations (see Figure 1):

- having access to potentially valuable materials (e.g. uranium, plutonium or copper);
- evaluating safety (e.g. if the system does not behave as expected, like deviation supersedes a predefined threshold; this would be a case for remediation).

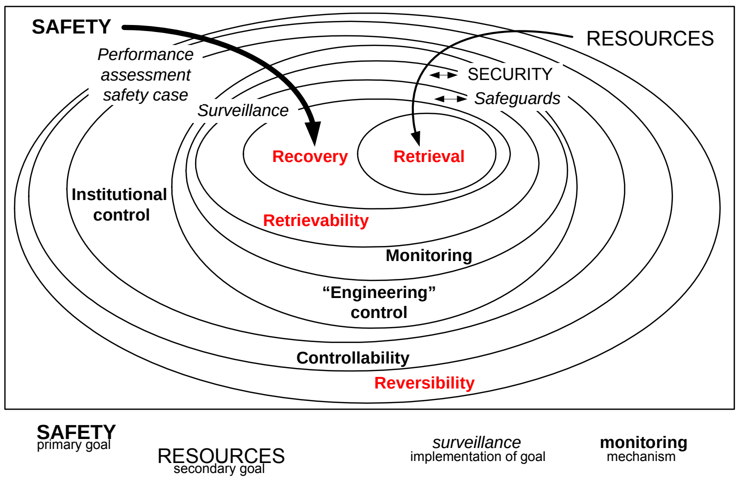
Retrievability in itself is not of top priority. The primary goal for radioactive waste repositories is long-term passive safety (bold arrow in Figure 1). In this approach, retrievability is the last logical step necessary if control via “living” safety case and surveillance shows that the system has failed and one should proceed with remediation. So there is a sequence of preconditions for a special case of retrievability, namely, recovery:

- controllability (the ability to control at all, i.e. retrievability and, therefore, controllability had to be and were foreseen in the disposal design);
- institutional control (including knowledge, technology and funding);
- effective (overall) engineering control;
- monitoring (to detect abnormal and non-tolerable situations);
- retrievability (concept effectively incorporated into the design);
- recovery.

This reason for retrievability would include all waste types.

Figure 1: Retrievability and reversibility with goal conflicts

Retrievability is, on one hand, a sub-goal of safety, as an ultimate step of monitoring and control in the case of grave system failure (remediation/recovery). On the other hand, retrievability may be an expression of a resource policy but being opposed to security, i.e. measures against the abuse of fission products. "Reversibility" extends retrievability to all or most system properties, measures and corresponding decisions. The onion ring metaphor is to make clear that individual goals or strategies are subsets of others or assume others.



Source: Flüeler, 2006, p. 79.

The resource perspective takes the opposite view: The material, especially plutonium and uranium, may not be considered waste but a valuable. This has to be a secondary goal because, otherwise, the substances should be kept in (interim, above-ground) storage. So far international consensus (in the technical community) favours "disposal" going along with the non-intention of retrieval. Opposed to the resource first notion is not only the main goal of (passive) safety but also the (political?) goal of security implemented with safeguard measures. The act to obtain the material would be retrieval.

Key notions in the Swiss concept: disposal as well as monitoring

The Swiss disposal concept places a higher value on – passive – safety, in agreement with both the international technical community and the public, as demonstrated by many surveys and in line with formal consultations (from as early as 1979, e.g. Stauffacher *et al.*, 2008; BFE, 2008). It extends, though, beyond the notion of "final disposal" as officially postulated until the 1980s with an out-of-sight, out-of-mind attitude. Upon technical and political discourse to step away from this unilateral perspective of passive (technical) safety, the rather static concept of "final disposal" began to shift as notions of passive safety moved toward those of active control. The paradigm change has been demonstrated through laying down in law of a hybrid concept, integrating active control into various requirements and mechanisms.[1] The Nuclear Energy Act of 2003, in force from 2005, adopted the so-called "monitored long-term geological disposal" as proposed by an interdisciplinary expert committee (EKRA, 2000). This is an extension of the traditional final disposal concept including effective control, monitoring and retrievability. Traditionally, disposal was merely designated to optionally set up environmental monitoring on the surface, and that under the caption "post-closure phase". The motivation behind this paradigm shift or, rather, modification, was to duly consider both aspects of sustainable development, namely protection and control (of freedom of action) by future generations (for an extensive analysis of the target conflict see Flüeler, 2001, 2006).

1. See presentations by M. Aebersold, W. Wildi and P. Hufschmied (these proceedings).

Controllability should be ascertained and demanded in the first place (built-in in the concept), to check against the main goal of long-term safety, prior to retrievability. Retrievability and retrieval would, in this sense, be control of second order if and when the controlling evidence necessitated such an action. In the Nuclear Energy Act retrievability of radioactive waste "without undue effort" is a requirement only until repository closure. This is a clear indication that the notion and goal of "final disposal" dominates other considerations.

Monitoring being decidedly safety-related, the 2003 Nuclear Energy Act states that the Federal Council can prolong or alter monitoring situations under several different scenarios. According to the respective Ordinance (of 2004) only if "the permanent protection of humans and the environment is ensured" will the Federal Council order repository closure. Even after closure, however, additional (environmental far-field) monitoring can be stipulated for a further limited period of time. Any active measures should never be used as an excuse for unsound scientific or technical actions or compromising safety.

Restricted to the monitoring period to be determined, not just environmental monitoring is foreseen but *in situ* control, and this by way of a so-called pilot facility (see Box 1). The technical goal of such control is a validation of the *ex ante* performance analysis, i.e. an extension of the safety case. Admittedly, much research and development remains to be done, for example:

- validity of pilot installation with regard to the main facility;
- establishment of indications/parameters, measuring techniques, duration;
- determination of the consequences of compliance or non-compliance.

Box 1: Protection and control in disposal – the Swiss approach

The key elements of the "monitored long-term geological disposal" laid down in Swiss law are three facilities: a test facility, a pilot facility and the main disposal facility. The test facility shall be erected during, or shortly after, site characterisation in the host rock, and serves as a rock laboratory for the investigation of safety-relevant processes, to specify the safety analysis and to adequately plan the design of the main facility. The test facility could be situated at the entrance to the main facility, whose caverns, containing about 95% of the waste, are to be backfilled as soon as the waste is deposited. The pilot facility is hydraulically isolated; the intent is to load it with a, say, 5% representative sample of the total waste activity. The pilot facility shall function as a so-called "demonstration facility" to assess the long-term behaviour of the technical barriers and the near-field of the entire disposal system. It is conceivable that the pilot facility could be kept open after the main/test facilities have been closed by backfilling. A carefully selected cavern structure and waste module technology facilitate retrievability from all facilities without compromising safety. For validation and surveillance purposes, several tunnels and shafts are foreseen to survey the facility near-fields and to carry out environmental monitoring in the surroundings of the host rock toward the biosphere. After the monitoring phase (period to be determined), the waste is retrieved (in the worst case of system failure) or the facilities are sealed (in case of a positive final safety analysis).

Actors, roles and responsibilities

The paradigmatic situation with regard to radioactive waste management is that federal authorities have imposed "solutions" upon sub-national actors (domestic final disposal, national site selection procedure, national decisions). The Canton of Zurich, for example, is an otherwise powerful state entity (e.g. in the finance sector), but disempowered with regard to radioactive waste, considered to be a national issue. A canton is both affected by this national issue and responsible for the health and safety of its residents, as well as providing them with an attractive environment (these principles are embedded in the mission statement of the Canton of Zurich, based on the cantonal constitution). Learning can take place in the interactions of all state levels (national, cantonal, regional). Even if potential siting cantons have no final say, they have some expert competence and are sought after especially in the ongoing selection procedure (sectoral plan) for technically sound yet socially accepted repository sites, an unprecedented long-term undertaking not only in Switzerland (see *www.radioaktiveabfaelle.ch*). Even though representatives from the potential host regions sit in technical committees of the sectoral plan, they have to trust the upper levels. In contrast, the cantons are resourced with experts and have close access to the (making of the) safety case. It is also their duty that participation on the regional level is more than just a buzzword or sophisticated public relations (Stauffacher *et al.*, 2012). Thus they may be intermediaries between national deciders/experts and local affected/ concerned laypersons.

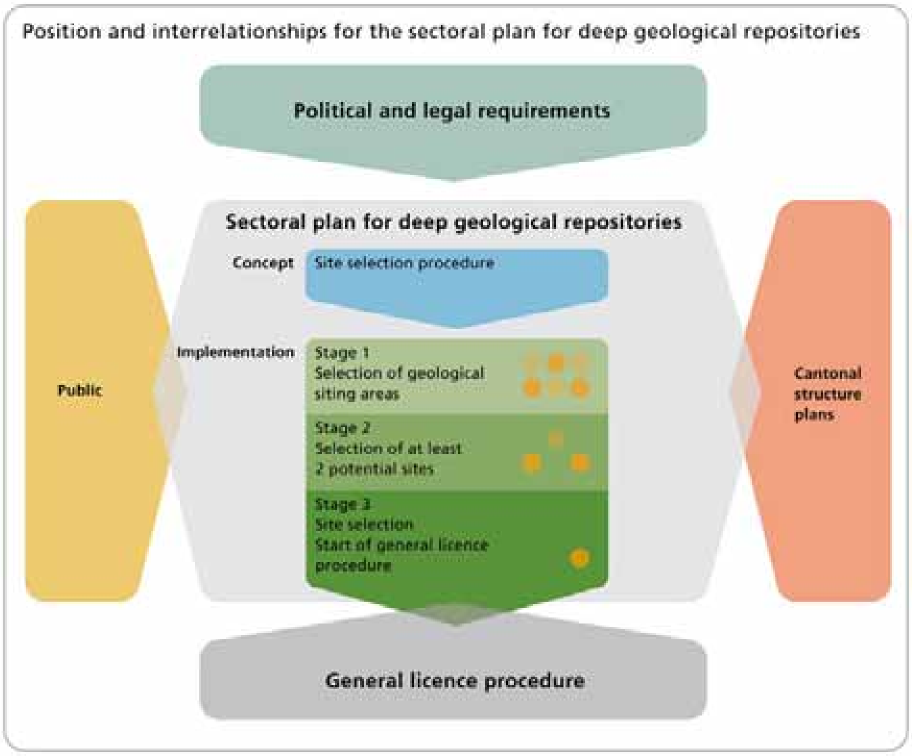
Long-term decision-making process

The long-term decision-making process of Swiss site selection, as established by the Federal Office of Energy (BFE), is illustrated in Figures 2 and 3. It is paramount that the process be phased, transparent and systematic so that all parties involved may follow, understand and, optimistically, accept the narrowing in from potential siting areas to two sites (for a high-level and a low-level radwaste repository). Requirements, responsibilities and rules must be clear from the beginning or, if necessary, adapted in agreement with all levels. The concept was developed in a broad and lengthy consultation process with cantons, political parties and a wide variety of interested organisations. In 2008 it was formally laid down by a Federal Council decision, which was the starting point of implementation (Figure 2).

The presence of milestones indicates that – limited – reversibility of interim decisions is built-in (Figure 3). So far the process leader BFE has been open to accept the learning (and pilot) character of the sectoral plan. Additional geoscientific investigations are under way and the participation of the six potential host regions is enlarged.

Figure 2: Long-term decision-making process

The selection of repository sites, which will last for more than a decade (from 2008), is stepwise and systematic. The end of Stage 1 is marked by a Federal Council decision on suitable geological siting areas (December 2011). Two out of three potential high-level siting areas and two out of six potential low-level siting areas are situated in the Canton of Zurich.



Source: BFE, 2008, p. 21.

Figure 3: Decision-making process with milestones

Stage 1 allows no fallback, Stages 2 and 3 constitute hold points with possible recourses. The evolution of the process has led to its prolongation (Stage 1 to 3 years, Stage 2 currently to 4 years, overall duration presumably beyond 2020). Extensive co-operation among all levels (national, cantonal, regional) has so far not led to actual reversals of (interim) decisions but more intensive (technical) explorations and (regional) participation.

Sectoral plan for deep geological repositories Preparation of conceptual part	Approval by Federal Council	2008
Sectoral plan for deep geological repositories Implementation	**Procedure according to Spatial Planning Act and Ordinance**	
Stage 1: Selection of geological siting areas (2.5 years)	• Cooperation • Hearings and participation • Settlement • Decision on object sheets	
Stage 2: Selection of at least two sites (2.5 years)	• Cooperation • Hearings and participation • Settlement • Decision on object sheets	
Stage 3: Site selection and general licence procedure (2.5-4.5 years)	• Cooperation • Hearings and participation • Settlement	
Decision of Federal Council (1.5 years)	Approval of object sheets	By 2016/18[1]

Source: BFE, 2008, p. 32.

Reversibility and retrievability: a "threat" that fosters quality assurance

If goal conflicts are settled (see above), R&R is a meaningful ultimate tool (beyond validation of the safety case also via monitoring) to exert pressure for better performance in the follow areas:

- development and maintenance of confidence (in the safety case) and trust (in responsible actors);
- review procedures (for technical and societal learning and improvement);
- compliance with rules defined at the outset (transparency, safety criteria, comparability of siting areas, etc.);
- examinations of fall-back options;
- "stretching" of actors.

In sum, R&R is a means for the canton to comply with its role of trustee of the (its!) local populations of potential siting areas. Integrated technical and political reviewing may lead to a better quality of the decisions and products; it may even increase trust in the socio-technical and, hopefully, the political system.

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Discussions on Expectations Expressed by Local Stakeholders and NGOs

A round-table discussion session was convened on 16 December 2010 at the Reims "R&R" Conference and International Dialogue, following eloquent presentations by local stakeholders and NGOs in the previous session. Conference participants broke up into six parallel groups, with the same composition as the prior round-table discussion. Certain groups rotated the roles of facilitator and rapporteur or chose new personnel. The breakout round-tables were encouraged to discuss the following three topics:

1) *Do the key expectations of the local stakeholders regarding R&R differ from country to country? What lessons should be drawn from specificities or commonalities?*
2) *Which opportunities are available for improving local participation in RWM within a stepwise decision-making process and in the long term (for example, in assessment, monitoring, financial provisions, memory preservation, etc.)? What are the limits to local stakeholder involvement?*
3) *Which place can or should be given to local stakeholders in the setting of policy related to RWM at the national and international levels?*

The rapporteur from each breakout group gave a brief summary of the discussions at the beginning of the following day's session. These reports were then agreed upon with the facilitator of the session, and are provided in the following pages.

Group A – Discussions on Expectations Expressed by Local Stakeholders and NGOs

Enrique Biurrun, Anne Bergmans

The group discussion first analysed the attitudes in different countries with regard to nuclear power use in general and to retrievability in a deep repository. While for instance in Canada opponents to nuclear power favour retrievability, pro-nuclear citizens are rather sceptical in regard to it. In Sweden it is the opposite, i.e. people with a positive attitude toward nuclear power use favour retrievability, whereas nuclear opponents also oppose retrievability. Germany has been an exception, with both pro-nuclear and opponents alike considering that a repository should not contain any provision to easy retrievability. This has recently changed, with a retrievability requirement being introduced into the Safety Criteria for Underground Repositories following a political requirement of the state of Lower Saxony.

As in the previous day's discussion, a stakeholder with a negative attitude towards nuclear power use pointed out her feeling that it is "immoral" to use nuclear power since it produces radioactive waste, a process she considers an irreversible potential danger. She elaborated further that retrievability is a surrogate to "sell" the repository as a solution for the waste. Therefore, the real question is not retrievability, but whether we should have a repository or not.

Other participants with a more positive attitude toward nuclear power pointed out that the use of fossil fuel is an also an irreversible process, and that it leads to discharging greenhouse gases into the atmosphere, with a negative impact on the planet climate. On the other hand, significant amounts of waste are already there, and irrespectively of the future use of nuclear power a solution must be provided for this waste. Moreover, the impact of a bigger or smaller repository is approximately the same.

The discussion then turned to the fact that there have been failures of first repository programmes in several countries, notably in Canada, Sweden, Belgium and the United Kingdom. Later efforts have been successful in Sweden and progress is also evident in Canada and Belgium. In all of these countries the role of the regulator is important and the regulators are trusted. Trust is essential, and must be earned. It does not develop by itself. A key element to achieve trust is the perception that the regulator is a really independent institution, with no conflict of interest and focusing only on protecting the citizens. Especially the repository operation and the operation supervision must be entrusted to institutions clearly and visibly separated. In some countries, most notably in Germany, there is no independent regulator but a mixture of partially contradictory roles assigned to actors with clear interdependencies. In such cases, trust in all actors is especially difficult to achieve.

A local stakeholder pointed then out that the French participation institution CLIS is an association of politicians and not of citizens. Then the discussion turned to consider that the differences between the countries on how the democratic structures work might heavily condition how local stakeholders can interact. The amount of people involved is also an issue that plays an important role in the ways and means for implementing local involvement. While in Nordic countries a relatively small amount of people live near any potential repository site, this is not the case in more densely populated continental Europe.

The Retrievability Scale developed in recent years is deemed helpful to visualise the problems involved and to communicate not only to the general public but also to a technically educated audience what reversibility and retrievability are all about. While discussing R&R is also important to keep in mind and to communicate that there are conflicting fields, as, e.g. safeguards. In this context it was pointed out that the physical and the administrative repository closure may well be up to many years apart.

Also in case of some particular repository host rocks, notably rock salt formations, the best long-term safety can be achieved by backfilling and closure of disposal areas as shortly after disposal as possible. Maintaining drifts and galleries open for easing retrievability is therefore in conflict with the optimisation of long-term safety. In any case, the group considered that R&R is an issue that needs to be considered, and that if not properly addressed and resolved, it would hinder rather than favour stakeholder involvement.

Finally, the group briefly considered that, if a decision to retrieve waste from a repository is ever made, it must comply with the justification principle of radiation protection. This is to say that it must be carried out to prevent a real and not a just perceived danger. The radiation exposure received by the workers and the public during the waste retrieval, its interim storage, and the later re-disposal must be lower than the doses avoided through the retrieval operation. Moreover, retrievability will not be credible if the fate of the retrieved waste, its necessary storage and later re-disposal are not a part of the considerations.

Group B – Discussions on Expectations Expressed by Local Stakeholders and NGOs

Claire Mays, Gloria Kwong

Key differences or commonalities among local stakeholder expectations

We did not review or were not struck by differences among local stakeholder expectations or requests as portrayed by the country presentations we heard. We were more struck by the fact that there seems little difference between ideas expressed by civil society and those explored by institutional actors. Therefore it seems useless to make a strong distinction between these two levels. At the same time, we recognised that it is illusory to think that any stakeholder category is a "block" characterised by unified ideas or expectations.

We did notice one cultural difference: sensitivities about NGO funding sources. In Sweden a national waste fund can provide funding for NGO activities, whereas in Germany (where there is no such fund) it would be "suicidal" for an NGO to be thought to "take money from the government".

The role that could or should be played by local stakeholders in policy making

The fact is that local stakeholders already are deeply influencing policy:

- Such a conference as this one traditionally would be reserved for technical experts; now it is open to and attended by local stakeholders whose input is major.
- Structured, useful ideas emerge from civil society engagement processes like the Belgian Consensus Conference.
- West Cumbria realised that local authorities are influencing national policy and therefore, they must develop their own policy views on R&R.

We note the effects of globalisation: local communities participate in national and international RWM inquiries. There is a much greater access to information, and more opportunities to make local views known. This is a new norm (supported by the Aarhus Convention) and it is growing. Conferences like this one in Reims contribute to the trend.

Role to be played by local stakeholders in R&R (if those are part of national policy)

The local level does differ from the institutional level in an important way: local people are actually affected by the implementation of policies and principles that are discussed on a generic level by other actors. Therefore local stakeholders have a role to play in tuning this implementation.

We observed the spread of competence-building activities and partnership arrangements that empower stakeholders in this role:

- sharing local knowledge of the terrain (e.g. water flows, civil uses of landscape);
- participation in creating and preserving memory of the installation.

There was a strong feeling that *responsibility* for memory preservation should not be delegated to the local level. This must remain the responsibility of major, durable institutions. However, the community should participate in designing and determining how memory can be preserved effectively. Civil society is placing a strong accent on the need for maintaining knowledge, memory and nuclear know-how; concrete proposals in this regard were among the conditions set by the community of Dessel for accepting to host a LILW repository.

What are the limits to local stakeholder participation in R&R?

The example was brought of "conflict of competences" (not of "interests") in a multi-stakeholder design process, when storage facility design proposals were discussed and reviewed by local partners and sometimes modified. This was worrisome to a technical participant. While local stakeholders can make important inputs to architectural design, architects and engineers must remain empowered and responsible for assuring structural stability.

For others, the net outcome of such collaborative processes is positive (an example was brought of how a farmer "solved an engineer's problem" by transferring knowledge about the local terrain). It is simply necessary to distinguish roles and competences within a partnership framework or process. Partnerships need rules for how different arguments and requests will be justified and taken into account. In this way, what might look like "anarchy" then can be "knowledge transfer". We noted again that the borders are shifting and that dialogues between different stakeholders that seemed impossible a decade ago are now part of the norm.

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Group C – Discussions on Expectations Expressed by Local Stakeholders and NGOs

Beate Kallenbach-Herbert, Peter-Juergen Larue

Group C recognised that expectations regarding R&R do differ from country to country. The group singled out a number of different dimensions on which these differences can be observed. There are *top-down and bottom-up driven approaches* to discussing R&R, e.g.:

- Sweden: national players were not interested in a discussion on R&R, stakeholders did not pick themselves up.
- Germany: discussion on R&R was mainly brought from the bottom up due to problems in Asse repository.

There are *national processes and local/regional processes* for the development of the disposal concept:

- The R&R concept in Switzerland was discussed and developed on the national level as a result of former failures in site selection and the decision to start the disposal process anew.
- In the United Kingdom a concept on R&R has not yet been developed. It might come up as an issue of discussion with stakeholders of the potential sites.

Overall the status of R&R as a "big" issue appears to depend on the policy of the country. Still, it is interesting to consider whether R&R can make decisions easier. The group noticed that there are no parameters/indicators presented as of yet as a basis to decide on the necessity of retrievability.

Regarding the opportunities for improvement of stakeholder involvement and the limits thereto, the group observed that participation has to start at a very early stage of the disposal process. However, (early) concentration on potential regions/communities can impede a national discussion on relevant aspects.

It is important to set out rules (technical and procedural) at an early stage. They can improve transparency regarding the basis for decisions in different situations (at least in an ideal process). The existence of a defined set of technical safety criteria and a clear procedural framework, providing a traceable basis for decision making, is a precondition for trust; without these, people cannot verify that rules are correctly followed. Another important factor for trust and confidence is a clear position at the level of national actors and government.

The group also considered which place can/should be given to local stakeholders in the setting of policy related to RWM at the project level. (Neither the "national" nor the "international" level was focused on in discussion; reasons might be that "local" stakeholders may more frequently be associated with site or project specific issues, and that the international level may not be so salient for the majority of stakeholders.) It was found that:

- There are limits in stakeholder involvement with regard to decisions on "purely technical issues". These have to be taken by the responsible institutions.
- For example, the Swiss "sectoral plan" foresees local stakeholders' rights to influence decision making on surface but not on subsurface facilities.
- Care should be taken not to raise wrong expectations regarding objectives of stakeholder involvement. The options and limits of stakeholder involvement should be well defined and should be clear for all stakeholders involved.

Different levels of participation (information, dialogue, decision making, etc.) can be foreseen for different phases and different issues of a disposal project:

- Retrieval of drums from WIPP is an example of a decision driven by regional interests, not by safety.
- Communities have veto rights in some countries, e.g. on decisions for site investigations (which can be overruled by government in Sweden).

Group D – Discussions on Expectations Expressed by Local Stakeholders and NGOs

Philippe Lalieux, Holmfridur Bjarnadottir, Christina Necheva

Group D started by examining "who's in and who's out as stakeholders?" When considering a repository, is everyone at stake? Or principally the local population? At least the possibility for the widest possible participation should be offered by a national programme, not limited to the "affected" population – although local stakeholders should be given more weight in the decision-making process. The veto right at local level is an example of possible empowerment.

Local involvement was recognised as key for maintaining long-term momentum. It could be more long-lasting than expert involvement, and it has a potential role in transfer of knowledge.

The group went on to consider tools to support local or public participation. A wide spectrum of tools can be used (and have been used). However there is no "off the shelf" solution that fits all situations. Those tasked with engaging the public should pick up the most appropriate tools according to:

- the decision at hand;
- the objective targeted by involvement (this could range from getting ideas through to co-design of repository aspects);
- the level of development of the repository project;
- policy vs. local implications;
- the stakeholders' profile and preferences.

Another tool that can add to societal confidence in RWM plans is counter-expertise. This should be organised such that it can bring forward alternative perspectives rather than simply statements in favour or against the existing plans. The point is to seek pluralism. The public should be able to develop its own opinion based on a range of views, publicly expressed. It is important for stakeholders groups to have the possibility (human resources, funds) to develop their own expertise and ask for other views/perspectives than those proposed by the centralised institutions. Openness of individual experts will count as well. But these local stakeholders may have difficulties in finding "independent" knowledgeable experts, especially in small countries.

Finally, Group F judged that despite its multifaceted content, R&R cannot, and should not, be singled out from the general long-term radwaste management discussion.

Group E – Discussions on Expectations Expressed by Local Stakeholders and NGOs

George Hunter, Shawn Smith

The questions set acted to stimulate discussion rather than limiting discussions to formulating answers to those questions.

The topics discussed can be divided into six subject areas: geology, location of stakeholders, trust, information, finance and culture.

Geology

Clearly different geologies cause some differences from country to country. It was suggested that it was perhaps more correct to indicate that it was the "disposal concepts for particular geologies" which differed between particular geologies.

It was suggested that issues important to a particular geology might only be recognised by a potential host community with such geology rather than if such geologies were considered in general terms. Examples of this were issues examined at Mol where consideration of clay micro-layer structure had been looked at rather than assuming a monolayer. Some views were expressed that salt was a very difficult host from which to retrieve waste and that recent information relating to Asse had destroyed confidence required for acceptance of other areas such as Gorleben.

The discussions tended to suggest that some from host communities with a particular geology would prefer other geologies.

Location of stakeholders

It was suggested that in Japan opposition to siting came mainly from those residing outside the host community rather than from the local area.

It was noted that in Finland local stakeholders seemed more confident with technical and procedural issues than those from the wider community.

It was also suggested that in the hamlet of Gorleben the attitude was more favourable than wider afield, perhaps due to financial "compensation" of the hamlet.

While it was suggested that acceptance locally might reflect better knowledge, particularly where nuclear facilities were already hosted, an alternative point was made that those further away were not ignorant.

Trust

Trust was seen as important if the concepts of R&R were not to be seen as a "Trojan horse" for gaining public acceptance.

It was suggested that where trust between local communities and nuclear operators had already been built up acceptance of disposal sites seemed more likely. It was noted that Bure was in an area where such an historic relationship had not been established, while Mol had a well-established relationship.

Information

Some experience in Japan suggested that the provision of accurate information was essential if other technically inaccurate information was to be countered.

At Mol stakeholder groups had been provided with resources in order to obtain independent expert advice which was observed as having worked well.

Finance

It was suggested that there was not a simple relationship between possible compensation for hosting a waste repository and community acceptance. The view was expressed that at Mol this was not the main driver to acceptance.

It was suggested that more harmonious relationships had been established in countries where implementers were less influenced by the need to generate profits for shareholders.

Cultures

It was suggested that some countries, such as Switzerland, Finland and Sweden, had procedures and cultures which led to generally harmonious relationships between stakeholders and implementers.

It was suggested that Germany did not display this sort of culture for complex reasons and indeed that there was not really a “site selection process” as such.

On several occasions the need to show respect for stakeholders and to treat them on an equal level was noted.

 R&R IN PLANNING FOR GEOLOGICAL DISPOSAL OF RADIOACTIVE WASTE, ISBN 978-92-64-99185-9, © OECD 2012

Group F – Discussions on Expectations Expressed by Local Stakeholders and NGOs

Jantine Schröder, Claudio Pescatore

Where does the idea of R&R actually come from?

From a public ("involved citizens") level?

- If so, then it is something that tries to answer to a real concern.
- This real concern is the long term and on what could go wrong, not necessarily only pre-closure and normal conditions.

From a political (national) level?

- Could R&R be something to appease/hush up the real debate and "to get the pill swallowed"?
- Or something in fact to make decision making more democratic and less heavy-handed?

From a scientific level?

- Building-in stepwise decision making and options so as to apply corrections is a natural choice for projects of this novelty and scale.

To what is R&R actually applicable?

Do we discuss R&R for waste disposal or simply for storage? If waste is conditioned in such a manner as to prevent re-usability (vitrification), can R&R actually be taken seriously then? What is ultimate waste? The logical and legal response might be "material for which no use is foreseen or foreseeable". However, even this definition is open to question: the meaning of "foreseeable use" can be influenced by economic or technical considerations. In this way, the notion of "foreseeable use" is based on current economics and knowledge.

Memory

Should society seek to remember about RWM disposal as long as possible or forget as soon as possible? How long, how and what can we remember? In the United States, there is research on permanent markers; WIPP includes a mausoleum-type building on the surface with archives inside it. This simple statement raises questions in turn: Over what time scale can constructions be considered "permanent"? Should we rely on monuments, will they be interpreted in the same way over the ages? (Consider the pyramids; these sacred places were invaded time and again as treasure houses.) What should archives contain: documents, samples…?

Should we not rely on people to transmit a living memory? If this option is chosen, then the repository has to be coupled to the rest of the economic development of the region. This memory will remain indirect: deep underground is not a place where you would otherwise come.

An example was given about a sinkhole phenomenon along the TGV (high speed train) line due to the collapse of cavities underneath the tracks. Among the explanations for this collapse is the presence of underground works remaining from the time of World War I. This underground activity, like other mining works, was in fact well mapped and documented, but nobody bothered to check… This demonstrates that archives alone are not enough. There must be a culture of memory and a willingness and skill to read them.

Optimal Choices and Duties to Future Generations

Chair: Michael Sailer

Reversibility: An Engineer's Point of View

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I have been invited by the Nuclear Energy Agency (NEA) to present an engineer's views on reversibility. I am convinced that a repository must be reversible. Reversibility is the most consistent option in a democratic country. However reversibility may also have several drawbacks which must be identified and mitigated.

Reversibility: a relatively new notion

Reversibility of a geological repository is a relatively new idea in France. The 1991 law dedicated to nuclear waste management considered reversibility as a *possible option*. Fifteen years later, the 2006 law mandated that a deep repository *must* be reversible and that the exact content of this notion should be defined by a new law to be discussed by the Parliament in 2015. Reversibility was not a concern put forward by engineers. It clearly originated from a societal demand sponsored and formulated by the Parliament.

Since 1991, the exact meaning of this mandate progressively became more precise. In the early days, reversibility meant the technical and financial capability to retrieve the wastes from the repository, at least for some period of time after being emplaced. Progressively, a broader definition, suggested by Andra, was accepted: reversibility also means that a disposal facility should be operated in such a way that a stepwise decision-making process is possible. At each step, society must be able to decide to proceed to the next step, to pause or to reverse a step.

Advantages

Several benefits can be expected from a reversible repository. Some technical safety concerns may be only recognised after waste emplacement. Radioactive wastes may become a resource whose recoverability is desirable. Regulations may change, alternative waste treatment or better disposal techniques may be developed, or the need to modify a component of the facility may arise. Looking back at how chemical or domestic wastes were managed some 50 years ago easily underscores that it is not unreasonable to hope for significant advances in the future.

For scientists and engineers, reversibility proves to have several other merits. To design and build a good repository, time is needed. The operator of a mine or of an oil field knows that exploration of a site is a long undertaking. Information has a cost: it is collected first through geophysical measurements performed at ground level, followed by the digging of exploration boreholes to provide more precise data. However, definite assessments of rock mass properties

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and behaviour often are available only after several years or decades of operation. Repository reversibility allows for the stepwise assessment of the state of knowledge, of the experience gained, of the data that still are missing, and it provides a sound basis for setting the agenda of the decisions to be taken.

Drawbacks

Reversibility also has several obvious drawbacks:

- *A reversible storage might be less robust*. Engineers building a repository prefer a cul-de-sac design, which favours slow ground water movements, but such a design makes access to canisters more cumbersome and retrievability less easy. Effective seals between the geological layers have been slowly built by natural processes at work over millions of years, and their continuity will be breached by shafts, access wells and underground galleries. Engineers prefer that these weak points be few, narrow, easy to plug, that the remaining voids between a canister and the surrounding host rock be small, and, preferably, that these voids vanish as soon as possible – provisions that make retrievability more difficult.
- *An older repository is becoming less safe*. Making a repository reversible for too long a period of time may compromise long-term safety. The argillaceous Callovo-Oxfordian layer in the departments of Meuse/Haute-Marne, where disposal of the French nuclear wastes is considered, is a geologically stable formation that has not experienced dramatic changes over the past 150 million years. French repository design is inspired by a sense of caution. The perturbation brought to virgin rock mass by excavation, ventilation or heat production must, within the limits set by the law of physics, remain as small and as short as possible. Too long a period of reversibility may conflict with this principle. Galleries left open for too long will experience a thicker damaged zone, and too long a ventilation period means that de-saturation, oxidising, cooling and microbiological activity will be given more time to change the favourable virgin conditions that reined within the rock mass.
- *Procrastination will become an issue*. Some people believe that a repository should be made indefinitely reversible and that there is no need to prepare for closure of the disposal site. This is a good recipe for postponing any future decision. There is a serious risk that a reversible repository, left uncompleted, surreptitiously becomes an interim underground storage – an option ruled out by the 2006 law – as it will be easier to transfer to the next generation the difficult decisions – and, incidentally, the heavy financial burden they imply. The technical and financial load may become tremendous when wastes must be retrieved from a repository deeply affected by rock damage. An older repository is also becoming less reversible.

  A reversible storage must be closed some day. Full freedom of choice must be left to future generations: they may decide, after due consideration, that indefinite storage is the best option, even if it is not the option we favour. Our duty, however, is to design a reversible repository in such a way that it can be closed – the safest option – if, some day, future generations judge that time has come.
- *Ranking the objectives*. Reversibility and the safety of the workers and of the public during repository operation, and of future generations in the long term, are not inherently compatible. This possible contradiction requires that objectives be clearly ranked. The repository must be designed in such a way that it could cease to be reversible at some time. Repository closure must be prepared from the start. The safety of the workers and the public during the operational period must be ensured to a level at least equal to the standard required for any other nuclear facility. Once this condition is met, a reversible storage facility must be at least as safe as an irreversible storage facility would have been. Closure must be made possible, and the last word must be given to long-term safety.

Optional Choices and Duties to Future Generations – Swedish Views

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Safety first!

According to present Swedish regulations retrievability of deposited HLW is not a mandatory requirement. The *Swedish Nuclear Power Inspectorate's Regulations Concerning Safety in Connection with the Disposal of Nuclear Material and Nuclear Waste* states:

> "7 § The barrier system shall comprise several barriers so that, as far as possible, the necessary safety is maintained in spite of a single deficiency in a barrier.
>
> 8 § The impact on safety of such measures that are adopted to facilitate the monitoring or retrieval of disposed nuclear material or nuclear waste from the repository, or to make access to the repository difficult, shall be analysed and reported to the Swedish Nuclear Power Inspectorate." (SKI, 2002)

In consequence with these regulations, retrievability of HLW has received limited attention by SKB. Nevertheless, SKB has emphasised that even if retrievability is not required, it is still a possibility not only before, but also after closure of the repository (SKB, 2004).

The Swedish Council for Nuclear Waste (former KASAM) has addressed the question on retrievability numerous occasions. In 1999 KASAM – jointly with the IAEA – arranged an international seminar. The seminar was documented in a detailed report (IAEA, 2000). Three possible reasons are given initially for retrievability (at different points in time):

- It must be possible to take remedial actions if it would appear that the repository does not perform according to expectations.
- New technologies or new economic conditions may lead part of the waste, particularly spent fuel, to be considered a useful resource.
- New technologies may be developed which can make the radioactive waste less dangerous or even harmless.

Needless to say, these arguments in favour of retrievability must be weighed against the disadvantages.

This has been underlined in the Council's state-of-the art-reports in 2004, 2007 and 2010. These disadvantages include: *i)* the extra costs for adapting a final repository so that future retrieval is possible, as well as the costs of retrieval itself. Another problem discussed at the seminar concerns: *ii)* the consequences for long-term safety.

Does the adaptation of the final repository for possible retrieval necessitate certain compromises with regard to long-term safety? The question is an ethical one. What should be

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prioritised? The freedom of choice of future generations or their safety? In its 2004 state-of-the-art report, KASAM's argument is made from the standpoint that if there is a conflict between freedom of choice and safety, the choice should fall on safety (KASAM, 2004).

In its review of *RD&D Programme 2004*, KASAM pointed out the necessity of analysing safety in connection with a retrieval of fuel canisters from the final repository. No such analysis has yet been reported by SKB, but has been anticipated as a system variant in a future system analysis (SKB, 2004).

The Swedish National Council for Nuclear Waste has returned to the issue of retrievability and reversibility in its latest state-of-the-art-report in February 2010 (KASAM, 2010). There are several reasons for this:

- Increasing international attention (for example, the R&R project of the NEA).
- New reactor technology offers potential for reusing spent nuclear fuel.
- Discussion of deep boreholes as an alternative to KBS 3 has forced retrievability into the foreground.
- The Swedish population has become more positive to retrieval.

The report considers the technical possibilities of retrieval, the legal conditions and the ethical questions. The position of the council can be summarised in three different points:

- Provisions for pre-closure retrieval and reversibility have the potential to strengthen the final repository's long-term safety.
- Future possibilities of transmutation and the fourth generation of nuclear reactors make waste retrieval *before closure* increasingly significant.
- Long-term security and safeguards must take precedence before the principle of autonomy for future generations. When the last canister of HLW is deposited, effective closure without unnecessary delay is required.

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Choix optimaux et devoirs envers les générations futures*

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I'll happily join the discussion as an elected official of a French department that is quite concerned by radioactive waste management issues, and as president of the association "Décider Ensemble", which has recently reflected on RWM governance and is a supporting organisation for this conference. My point of view thus is not that of an engineer, but of a territorial-based observer.

Secrecy was the habit during the time in which France made energy choices favouring nuclear power. Prime Minister Pierre Messmer, in March 1974, decided to launch the civil nuclear programme without consulting Parliament, but on the sole basis of conversation with the director at that time of Electricity of France, Marcel Boîteux, who later recounted that episode. This led to legitimate distrust and sometimes radical opposition to state decisions in this area, all the more so regarding the management of waste related to this technology.

The Chernobyl catastrophe of 1986, notably, rendered the rigid position of decision makers untenable *vis-à-vis* the public. This is why we can see since that time a trend towards greater transparency and greater involvement of citizens in this complex issue, through the progressive engagement of parliamentarians and then civil society in the decision-making process. There is still a long way to go, however, before trust among stakeholders will be re-established and before citizens will really take hold of these complex questions.

As an elected official of the Meuse Department in which the research into deep geological disposal is ongoing, I fully weigh how much citizens need answers to their legitimate questions. Serving the population's needs requires significant efforts to inform and to popularise scientific content. We are moving forward in this, and Andra's work in this area is remarkable. True participation by citizens is required as well, as the Aarhus Convention (foremost among several international treaties) reminds us.

The concepts of reversibility and retrievability are at the intersection of scientific and ethical concerns. To reach a decision on these issues implies that the two concerns be compatible. In other words technology must respond (in terms first of safety but also, if possible, in terms of cost) to the ethical guidelines we set ourselves. The concept of reversibility implies that we have the responsibility to leave the possibility to future generations to go back on our decisions if they wish. But this does not go without saying in the case of nuclear waste: for example, engineers tell us that it is very difficult to know in advance whether the safety of a reversible installation can be guaranteed. Thus the question of expertise arises, that is: "How to be sure that what we foresee today will indeed take place in the future?"

Still, France chose reversibility by enshrining this notion in the law of 2006 – although without giving a precise definition, as the conditions of reversibility must be set in a new law to be adopted in 2016, after holding a Public Debate foreseen for 2012. The question thus becomes:

* Translation provided by the NEA Secretariat.

How to define the concept of reversibility in concert with our fellow citizens, giving them all the keys to grasp the issue? Moreover, we must ask ourselves what means should be put into place to ensure the availability over time of reversibility – and its corollary, retrievability.

Of course the issues of reversibility and retrievability do not concern France alone, but also each country that must manage radioactive waste. The way we treat these questions on our national level is thus likely to have a strong impact on the rest of the world. This is why, whatever the final outcome of the debates that we must conduct in order to clarify these concepts, I would like to recall some rules that must be observed when taking a complex decision:

- Call on independent and pluridisciplinary expertise.
- Provide transparent information such that citizens and the general public have the capacity to understand the complex issues.
- Engage discussions among all the involved actors – elected officials, socio-economic representatives, members of associations – stressing the importance of local actors for their on-site expertise.
- Report on the discussions in the final decision, given that the role of discussion is notably to inform the choice by the decision maker.

We must face the obvious: dialogue around radioactive waste management is very difficult. In a centralised country in which powers are little delegated, we pay the price of past errors from the time when decisions about the nuclear option were constantly taken "beforehand". It is of prime importance to resolve this problem of trust. If we want to durably reconcile decision makers and the scientific community with our co-citizens, then we must change our decision-making processes. I am convinced that it is through dialogue that stakeholders will arrive at reasonable, accepted and shared solutions, because a decision put together on the basis of a good discussion is that much more legitimate. For this the whole set of actors must consent to "play the game" of dialogue.

Comments on Retrievability

Erik Van Hove
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Comments on retrievability

On 14-17 December the OECD Nuclear Energy Agency organised an international conference and dialogue on the possibilities to implement reversibility and retrievability in nuclear waste disposal sites. We understand reversibility to be a necessary element of the planning, construction and operational phase of a nuclear waste disposal site: it is hard to imagine a responsible process without the possibility to reverse some steps in the process. Another matter is retrievability of deposited waste. This is often seen as a political exigency that could actually compromise safety. This note argues that in all likelihood retrieval of what is considered waste now will happen sometime in the future and that we should take that into account when planning repositories. History teaches us only so much: the decision to retrieve or not is beyond our control.

Lessons from history

First lesson from history

No matter what position is taken now by the developers of nuclear waste disposal sites, chances are great that at some time in the future attempts will be made to explore and retrieve materials from a disposal site.

No one made a greater effort to secure irretrievability than the pharaohs of ancient Egypt. Their graves were a succession of natural and engineered barriers to prevent access and the penalties for doing so were much more severe than anything a present-day disposal agency could muster. Grave robbers not only lost their lives, but also all possibility of eternal life by the complete destruction of their bodies. This did not prevent grave robbers doing their evil deeds. Even worse, with the passing of time those very same grave robbers became first, admired adventurers, second, legitimate explorers and eventually, respected scientists: archaeologists. Given that archaeologists are now exploring without any qualms graveyards dating from the great plagues, one can estimate that about 500 years will do the job of invalidating any original planning or instructions.

Second lesson from history

The elements of our material culture that survived the ravages of time are most often those that still have a place in the daily life of our communities. Structures that are still in use like many churches and even dwellings, can easily survive a thousand years. Unused constructions quickly come to ruin. A disposal site, to be safe from neglect and oblivion, should have a persistent use and utility associated with it. This is of course primarily a problem for surface disposal facilities as, after all, deep disposal sites are supposed to be safe under conditions of utter neglect. Oblivion is another matter. We can expect the quest for commodities to intensify with the depletion of obvious sources. Uninformed exploration and mining of deep depositories could be very unsafe.

Third lesson from history

The soft aspects of our culture persist much longer than the hard aspects. It is very difficult to imagine what technological wonders, if any, will still be relevant in 50 years; parental and brotherly love and caring for each other will persist. We have no problem at all in understanding the cuneiform tablet where the father Shamshi-Adad of Assyria admonishes his rather rakish son Yasmakh-Adad or the one where his elder brother gets him out of the umpteenth scrape.[1] Shakespearean love sonnets prove useful to this day. We can expect an expression of appreciation of beauty, filial piety or motherly love to find direct empathy hundreds of years from now when our learned treatises or technological manuals will only find derision.

Fourth lesson from history

Not that long ago was prehistory. Until the 19th century the prevailing view was that the period worth knowing about extended to Greek and Egyptian antiquity, altogether only 5 000 years. Our Victorian explorers have added a few thousand years to that. Still, in our nuclear calendar this is but a wink.

The actual disposal models do not provide for an articulation of long-term disposal in relevant and more manageable shorter term periods. Nevertheless, the first hundred or thousand years of disposal are quite different in risk assessment and management than the time beyond. A hundred or a thousand years is within the scope of human historical imagination and memory building, beyond is the beyond.[2]

Safety planning

We have no control over what will happen to disposal sites in the far future. This does not, however, excuse us from applying the principles which are supposed to guide us. Among those are:

- placing no undue burden on future generations;
- assuring the safety of the site in all eventualities.

Even if we build a disposal site requiring no active maintenance, we still have to assure that site integrity is preserved, certainly in the first most critical period.

In the short term this can be achieved by security guards and other such adversarial systems like fences and access restrictions. The problem with those systems is that they are very difficult to maintain over longer periods than a few years and have a negative effect in the long term. They disassociate the local community from the site and create antagonism.

The alternative to this is the value-added approach where the effort is made to make the site relevant and useful to the local community in as many ways as possible: aesthetically, at the symbolic level, economically or culturally. This way the site becomes an asset to the community that is cherished and cared for. The integrity of such a site is better assured.

Preserving the memory of a site is not only a matter of keeping alive the required technical knowledge and information. A site should be inscribed in the landscape, be part of local life and traditions.

Interesting signage studies have been made in the context of the WIPP repository project (Waste Isolation Pilot Plant, PO Box 3090, Carlsbad, NM 88221). An inner and outer perimeter of 25-feet high granite monoliths will be build. Further, an inner elevated "room" with diagrams

1. Jean-Marie Durand, *Documents Épistolaires du Palais de Mari*, Tome I-III (1997-2004).
2. Safety case exercises that purport to make statements about safety for periods extending over hundred thousands of years have little predictive value on what really will happen: they are standardised abstract models allowing for adjudicating the comparative merit of different solutions. They are the equivalent of mileage scores of cars: useful for comparison, less so for predicting the actual mileage that will be achieved.

and warnings in different languages and, all over the site, buried warning disks with "danger" pictograms are envisioned.[3] If anything, this Stonehenge-like structure will certainly attract the attention of future explorers and lead to endless speculation about its meaning and even provoke, who knows, religious fervour. Why not make it into something which also now has monumental, educational and even commercial value?

Planning retrieval? Perhaps/Planning for retrieval? Certainly

If we accept the premise that eventually retrieval attempts will be made, we have to take this into account in our designs. We have to secure as much as possible the safety of those future "perpetrators" who most likely will not be considered perpetrators at all. This implies that designers should consider the possible breach scenarios and what they can do now to mitigate the danger.

Warning signs are part of the response, not so much of the "keep-out" variety as of the informative kind. Culture independent, universal non-verbal symbols that would be valid over thousands of years probably do not exist. Nor are they needed. Our generation has been able to decipher messages written 5 000 years ago in long extinct languages that use totally unfamiliar scripts. Why would future generations be less inventive? Not only should warnings be installed on the perimeters of sites. Canisters and galleries should carry informative labels as durable as the entity they label.

It is unlikely that the engineers now implicated in repository design could have the imagination and creativity to cover the full range of human panache involved in the future adventures of repository breach. They would do well to get extreme sports types involved and other strange birds like performance artists to develop the scenarios for which they would have to formulate a safety response. Planning for retrieval has much wider scope than planning retrieval.

3. Thanks to David Brazier for leading me to these studies. For more information: *wipp.carlsbad.nm.us*.

Panel on “The Place of R&R in Regulatory Policy”

Chair: Carmen Ruiz

The Place of Reversibility and Retrievability in Regulatory Policy: Experience in the United States

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Environmental Protection Agency (EPA)
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Background

Beginning with the Nuclear Waste Policy Act of 1982 (NWPA), which laid out a process for development of a geologic repository for spent nuclear fuel and high-level waste, the concept of retrievability has always been an explicit component of United States policy:

> "Notwithstanding any other provision of this part, any repository constructed on a site approved under this part shall be designed and constructed to permit the retrieval of any spent nuclear fuel placed in such repository, during an appropriate period of operation of the facility, for any reason pertaining to the public health and safety, or the environment, or for the purpose of permitting the recovery of the economically valuable contents of such spent fuel. The Secretary [of Energy] shall specify the appropriate period of retrievability with respect to any repository at the time of design of such repository, and such aspect of such repository shall be subject to approval or disapproval by the [Nuclear Regulatory] Commission as part of the construction authorisation process under subsections (b) through (d) of section 10134 of this title." (United States Code, Title 42, Section 10142)

This requirement was carried through into generally applicable standards established by the United States Environmental Protection Agency (EPA) and licensing requirements established by the United States Nuclear Regulatory Commission (NRC) for the proposed repository at Yucca Mountain, Nevada.

Disposal systems shall be selected so that removal of most of the wastes is not precluded for a reasonable period of time after disposal. [EPA standards at 40 CFR 191.14(f)]

The geologic repository operations area must be designed to preserve the option of waste retrieval throughout the period during which wastes are being emplaced and thereafter, until the completion of a performance confirmation programme and Commission review of the information obtained from such a programme. To satisfy this objective, the geologic repository operations area must be designed so that any or all of the emplaced waste could be retrieved on a reasonable schedule starting at any time up to 50 years after waste emplacement operations are initiated, unless a different time period is approved or specified by the Commission. [NRC licensing requirements at 10 CFR 63.111(e)]

It should be noted that EPA's standards extended the requirement for retrievability beyond the operational period, as envisioned by the Nuclear Waste Policy Act, to apply after closure of the facility (including sealing and backfilling of mined shafts). In establishing this requirement, EPA noted that, "The intent of this provision was not to make recovery of waste easy or cheap, but merely possible in case some future discovery or insight made it clear that the wastes needed to be relocated." (Federal Register, Volume 50, p. 38083, 19 September 1985)

Current status

With the decision to remove Yucca Mountain from consideration as the site for a geologic repository, the United States must re-evaluate the need to include the concepts of reversibility and retrievability in statute, policy and regulation. After focusing solely on the Yucca Mountain site for nearly 25 years, the United States programme will have to consider the applicability of these concepts to other geologic and climatic settings (although the initial requirements for retrievability were issued prior to selection of Yucca Mountain as the only site to be considered) and the potential for other disposal concepts to be less amenable to retrievability (e.g. deep boreholes). In addition, because the concept of retrievability has always been present, it is unclear how important this issue will be for public acceptance.

In early 2010 the Secretary of Energy established a Blue Ribbon Commission on America's Nuclear Future (BRC) to examine alternatives to the direct disposal of spent fuel in a geologic repository at Yucca Mountain. As part of its charge, the BRC is collecting information on advanced fuel cycle technologies that would involve reprocessing or recycling spent fuel. Commercial reprocessing in the United States took place for only a short period of time and ended in the early 1970s, leaving a significant legacy of environmental contamination at the West Valley site in New York. However, the potential for spent fuel to again be considered a resource instead of a waste has implications for geologic disposal policies. Although this was clearly indicated in the NWPA as a potential reason for retrieval of spent fuel, if there is a real possibility that spent fuel will be reprocessed, it is probably wiser to maintain above-ground storage for extended periods than to emplace it in a permanent repository underground where it may still be possible but more difficult to retrieve. The mere possibility that future generations will opt for reprocessing at some indeterminate point in the future, however, does not relieve the current generation of the responsibility to take actions consistent with its best judgment, including permanent disposal of spent fuel if deemed appropriate. The BRC recommendations may be significant in resolving this question.

Why retrievability?

A retrieval capability is probably most important in addressing unanticipated conditions in the repository that have the potential to affect long-term performance. Such situations could happen for a number of reasons and may occur despite the best efforts of the implementer and regulator. In such cases, stakeholders will likely expect that appropriate steps will be taken to address the situation. Analysis of the situation may show that the disposal system is still operating in accordance with the specified safety criteria, and is likely to do so in the long term. If it is not, it may be the case that retrieval efforts will present a greater hazard to the workers than would leaving the repository as it is. There also needs to be a viable alternative for managing the retrieved waste, whether re-emplacement, placement in interim storage or emplacement in a different repository, each of which may also prove unworkable. Stakeholders are more likely to understand and accept these conclusions over having no contingency plan at all. This suggests that implementers, in consultation with regulators, should give some consideration to the need for removal of some or all of the waste packages in the early stages of design, even if there are no statutory or regulatory requirements to do so. Such consideration will provide at least a starting point for action in the unlikely event that retrieval becomes necessary.

Recent experience at the Waste Isolation Pilot Plant (WIPP) in New Mexico illustrates the usefulness of retrievability even when the situation is not significant from a long-term performance or public health and safety perspective. The state of New Mexico, which retains some regulatory authority over operational aspects at WIPP, requested that DOE remove a waste package because of concerns about excess liquid content. DOE successfully located and removed the waste package from the repository, and returned it to the generating site for further processing. Although this single action cost more than USD 12 million, the benefits are likely to be measured primarily in improved DOE credibility with the public and the state's bolstered confidence in its regulatory authority. DOE both fulfilled its regulatory agreements and demonstrated its ability to retrieve individual drums. Even so, the process for retrieving a drum of contact-handled transuranic waste during the operational period is relatively straightforward compared to a post-closure retrieval or a similar effort to retrieve spent fuel. In such situations, intangible benefits such as those gained in this case are more likely to be outweighed by the additional effort and cost involved in retrieval (in terms of time, money, lost productivity and risk to workers). The decision to retrieve might be very different under those circumstances.

Reversibility and stepwise processes

It should be understood that reversibility always exists to some extent – the challenge is to constrain it within reasonable bounds to avoid unpredictable outcomes. Although it does not explicitly address reversibility, the process laid out in the NWPA included milestones and points at which decisions could be reconsidered and, if necessary, reversed (such as the designation of Yucca Mountain as the selected repository site). In addition, as DOE's design for the repository and understanding of the site evolved, there were numerous opportunities for stakeholders to comment and for decisions to be examined anew. Reports produced by DOE for public review include the Science and Engineering Report, the Viability Assessment, and the Environmental Impact Statement, all of which showed an evolving conceptual design and performance assessment. These documents and others were produced prior to DOE's formal entrance into the regulatory process with the submission of its license application to NRC in June 2008.

Even if a formal process is introduced, however, reversal of previous decisions may not always enhance public confidence or the repository development process. Further, the ability of outside actors to exercise authority in unpredictable ways creates additional tension in efforts to garner public support for the programme. Numerous changes were introduced during the Yucca Mountain development period that actually damaged the credibility of the government among key stakeholders. For example, although both EPA and NRC had issued generally applicable regulations for geologic repositories, Congress directed that new regulations be developed specifically for the Yucca Mountain disposal system. This led to charges that the requirements were being manipulated to ensure the repository would be licensed. On a more technical matter, in the early 1990s DOE pursued the concept of a multi-purpose canister (MPC) that would allow spent fuel to be transported and disposed without additional handling at the repository site. This concept was later dropped, and the Yucca Mountain surface facilities were designed with the expectation that spent fuel would be repackaged prior to emplacement. In 2006, however, DOE revised its thinking to again incorporate the concept of a single container that would eliminate the need for repackaging at the site (known as a Transportation, Ageing and Disposal (TAD) container). Not only do such containers require NRC approval, but this conceptual change required the redesign of surface facilities at a time when the license application was nearing completion. Congress and other stakeholders expressed concern about why the concept was being revived if it was initially deemed unsuitable, and in some cases used this example to question DOE's competence to manage the project. Finally, the designation by Congress of Yucca Mountain as the only site to be considered for a repository represented a reversal, or at least a truncation, of the NWPA process to identify a final site only after characterisation of multiple sites.

Interestingly, the decision to eliminate Yucca Mountain from consideration has also illustrated an apparently inadvertent restriction on the reversibility of the repository development process. In March 2010, DOE filed a motion to withdraw its license application from NRC's regulatory process. After consideration and testimony from interested parties, the Atomic Safety Licensing Board (ASLB) (an independent adjudicatory body that hears NRC licensing cases) denied DOE's motion on the grounds that, once the license application has been accepted by NRC for review, the NWPA does not envision an outcome other than a formal decision on the merits of the application. The full Commission can override the ASLB ruling, but has not done so.

Within the regulatory process, however, there may also be opportunities to modify previous decisions to account for new information collected during the operational period. Such situations should follow a clearly described process to ensure transparency and adequate review. At WIPP, DOE may apply to EPA to make changes to operational or design aspects. EPA approved the shipment of remote-handled waste several years after the facility began operating. DOE is requesting approval for use of shielded containers to allow remote-handled waste to be emplaced on the floor, rather than in the walls. DOE is also expecting to request approval for changes to its closure design to improve the efficiency of the closure process. These requests will be considered by EPA in an open and systematic regulatory process.

Reversibility and Retrievability:
A Critical Assessment of Contribution to Confidence Building

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The Nuclear Safety Commission has been actively involved in the Japanese geological disposal programme from the inauguration of the siting process specified in the Final Disposal Act. The Commission has initiated discussion to further promote safety communication to support a range of stakeholders and allow them to make decisions in the stepwise development of a repository. It is often claimed that "reversibility and retrievability" (R&R) are requirements from stakeholders. To form the basis of further discussions on development a framework for safety communication, it is useful to examine this claim in the context of safety communication in a structured manner. This is done using an argumentation modelling approach, which clearly distinguishes the different roles of reversal and retrieval and the topics where dialogue needs to be initiated.

Introduction

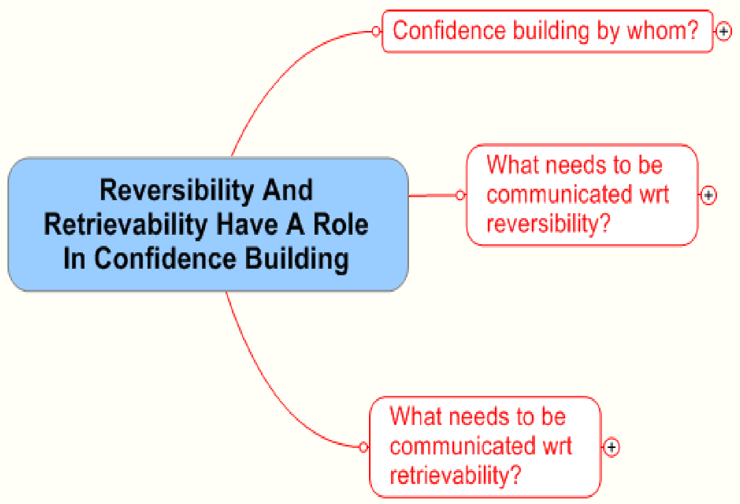
A stepwise approach has been implemented in the legal framework for the Japanese geological disposal programme as specified in the Final Disposal Act. Building confidence in the safety of geological disposal amongst stakeholders is a key to making decisions, if the programme will progress from step to step as defined in this approach. The Nuclear Safety Commission (NSC) of Japan has been defining environmental requirements to be applied in the selection of candidate sites, in addition to developing the basic guidelines to establish safety regulations for geological disposal. The Act ensures a kind of reversibility in the stepwise approach and the basic guidelines requires retrievability during repository operation, up to its closure when the long-term safety is finally confirmed through updated safety assessment (Shiroya, 2010).

Recognising that societal acceptance is crucial for geological disposal, the Commission organised the Subcommittee on Safety Communication for Geological Disposal under the Advisory Committee on Geological Repository Safety, to facilitate communication on the safety of geological disposal involving relevant stakeholders. Reversibility and retrievability (R&R) have been identified as essential components to the safety communication and the Subcommittee has been discussing R&R in the context of the framework for safety communication (Shiroya, 2010).

The topic of reversibility and retrievability is often introduced by the claim that this is a requirement of stakeholders – particularly the general public. It is worth considering the basis for such a claim. Certainly, if opinion polls ask the question "would you like waste to be retrievable?" the majority of respondents would answer in the positive. But does this really show that it is a requirement for gaining public acceptance? Analysis of this question is useful to further develop regulatory policy that is widely acceptable by the stakeholders.

A useful way of answering the question is to formulate it within an argumentation model, using the discussion at the Subcommittee as a basis. This starts by developing the issue as a statement, e.g. "reversibility and retrievability have a role in confidence building" and then considering what issues this leads onto, which are expressed in the form of questions (Figure 1).

Figure 1: Start of the argumentation model

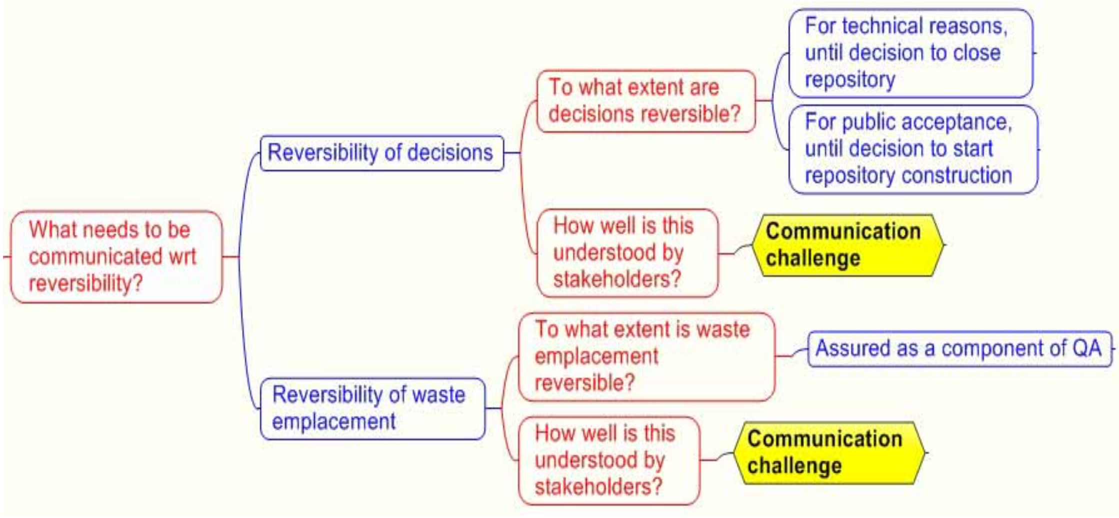


The first question is relatively easy to answer – it simply requires a list of all key stakeholders. The general public are very important, but here we should also explicitly consider politicians and opinion leaders, the media, academic and professional institutions, etc. The other two questions need a bit more detailed consideration.

Reversibility within confidence building

A starting point in considering reversibility is to distinguish between reversibility of the decision-making process and technical reversibility of implementation activities – in particular disposal of waste (Figure 2). In both cases, this leads in turn to further questions, which need to be answered. In Japan, with a volunteering approach to siting of a deep geological repository (NUMO, 2004), the reversibility of decisions is of key interest. A stepwise process of decision making has been established and, in principle, a decision or series of decisions can be reversed at any time if there is a good reason to do so. It is the role of the regulator to ensure that no decision is made without full justification and, in the event of surprises, past decisions are

Figure 2: Roles of reversal



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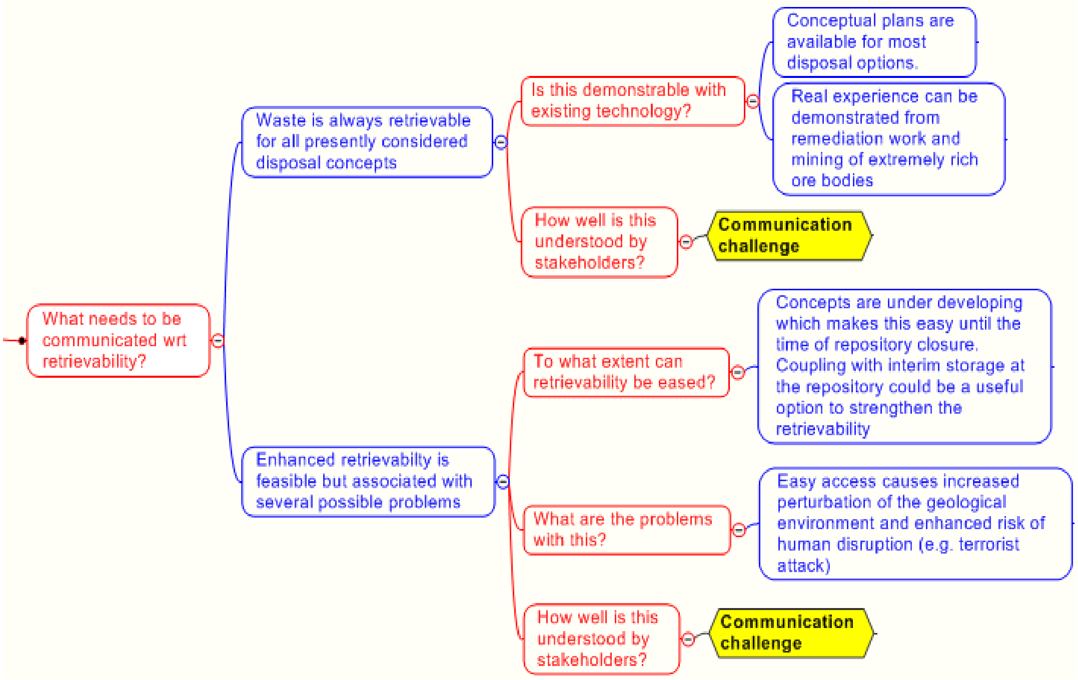
reassessed. The decision made by a community to volunteer is also reversible, but here a caveat has to be added that, as the programme advances and, especially after agreement has been reached to initiate construction through licensing process, reversal is constrained due to the large commitment of resources is involved. This situation has to be well communicated – especially to potential host communities.

The ease of physical reversal of waste emplacement is a critical design requirement that will be increasingly addressed as progress is made towards implementation. The post-closure safety case depends on the quality of the engineered barrier system, which must be assured and, in case of any significant deviations from specifications, the emplacement process reversed. In a first-of-kind facility in Japan, it is unreasonable to expect that 40 000 packages can be emplaced over four decades without any problems, so it is prudent to ensure that the reversal process is easy to implement without introducing hazards to operators. This requires not only good design, but also well tested technology with an associated monitoring system. Demonstrating this to both technical and non-technical stakeholders is critical to establishing the credibility of the implementer (Tsuchi, 2010).

Retrievability within confidence building

A critical communication challenge in discussion of "retrievability" is presentation of the fact that, for all current disposal concepts, waste is always retrievable (Figure 3). Poor use of terminology and, in particular, the assumed equivalence of "retrievability" with "ease of retrieval" causes widespread confusion of non-expert audiences. If the arguments to show that this retrievability is possible with existing technology are made sufficiently strongly, many stakeholder concerns can be addressed. Unlike the case of reversal, there should be no need to actually demonstrate the technology, as it needs to be made clear that retrieval is not a component of the safety case.

Figure 3: Roles of retrieval



The issue of technologically enhanced ease of retrieval is a much trickier issue. There are certainly many design variants that make retrieval easier for long periods of time, but these inevitably involve increased hazards for operators, environmental perturbations and risks of diversion of nuclear materials. The conflicts between different requirements involves ethical components associated with treatment of risks and responsibilities to current and future generations and, as such, is a valid area for all stakeholders to be involved in dialogue with the aim of reaching a consensus. Such dialogue can have great value as it allows many "what if?" questions to be addressed and the robustness of the post-closure safety case to be seen in the context of other practical and socio-political constraints on repository implementation. Indeed, after consideration it may well be concluded that making retrieval as difficult as possible might be a sensible goal for the disposal of HLW.

Conclusions

R&R provide good access points to initiate dialogue with stakeholders and, indeed, for the case of eased (or technologically more difficult) retrieval, is an area where direct involvement in the decision-making process could increase the buy-in to repository projects. In this regard, promoting safety communication is a critical role for regulators.

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R&R: The ASN Point of View

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Process for reversible geological disposal authorisation in France

Taking into account the difficulties related to the implementation of a geological disposal, the French Parliament initiated the reversibility approach to answer a societal demand.

Reversibility is a legislative requirement, according to the radioactive waste management Act of 28 June 2006. Disposal must be reversible for a period that cannot be less than 100 years.

As compared to other "installations nucléaires de base" (installations needing a nuclear license), the process for the authorisation of a geological disposal has its own specificity.

The authorisation process is defined by the law of 28 June 2006, and the parliament will play a central role:

- The geological disposal will be authorised by the government.
- The Parliament will:
  - establish the conditions for reversibility (minimum 100 years);
  - authorise the closure of the disposal.

General principles in terms of reversibility

What follows corresponds to the current view of ASN.

Definitions are essential

Reversibility is not defined in the law. ASN suggests the following definitions:

- *Reversibility* addresses the process of questioning, at each step of the disposal implementation and operation, the decisions taken in the previous steps and of allowing for revision or readjustment of earlier decisions made. These decisions can be related to the design, operation, emplacement, partial closure…
- *Retrievability* is the possibility to retrieve safely the waste packages after they have been put in place.

General principles

The process of development and implementation of a geological disposal facility is a social and political process that has to be shared with a number of institutional and non-institutional stakeholders. Reversibility is one element of this process.

1) The provisions taken to ensure reversibility must not jeopardise safety during operation, nor safety after closure of the disposal facility.

2) The reversibility period must be limited. A closure of the disposal too long deferred could challenge the very notion of disposal and safety during operation and after closure of the installation, as well as security:

   – So, a maximum period during which reversibility does not impact safety in operation and after closure should be submitted and justified in the application for the authorisation of creation of the disposal.

   – The law which will set the reversibility conditions should define a duration for the reversibility period or the conditions under which an end will be put to reversibility.

3) The feasibility and conditions of reversibility during the maximum period mentioned above will have to be reassessed periodically. The absence of impact of reversibility of all or part of the disposal on safety during operation and after closure will have to be documented.

4) Reversibility can be implemented in a stepwise process.

   The disposal construction and operation in a reversible way will have to be implemented under clear decision-making processes taking into account:

   – periodical reassessments of reversibility feasibility to justify the reversibility options, the conditions of their implementation and to assess their impact on safety during operation and after closure, in particular when safety reassessments are performed;

   – technical decision-making criteria;

   – clear regulatory processes;

   – consultation processes with the stakeholders.

   When a disposal design is modular, the closure of the disposal can be planned unit by unit within a clearly established decision-making process. This will allow taking advantage of the feedback from the experience of previous steps for future ones.

5) During the whole reversibility period, there must be:

   – Appropriate supervision of the disposal system (temperature, pressure, deformation…), which will provide in particular the necessary elements to the decision-making process mentioned above. The means and ways of supervision will be completed, if necessary, during the disposal operation.

   – Maintenance of the equipments necessary to ensure the safety during operation and after closure such as ventilation, sensors and gallery retaining structures, for example.

6) During the whole reversibility period, provisions have to be implemented in order to ensure that the necessary and useful information is collected, stored and accessible (on the package itself and on the conditions of its emplacement). Moreover, provisions for knowledge transfer related to reversibility management will have to be defined for the commissioning of the facility.

7) If the law on reversibility includes provisions on retrievability of the waste packages:

   – funding of the retrieval would have to be specified;

   – facilities have to be designed to store the packages and to re-condition them safely.

   From the safety point of view, retrievability can provide a possibility to retrieve a package already put in place and to re-condition it, should an anomaly be seen on it.

   But ASN stresses that before any retrieval is performed, an analysis of the risks in terms of radiation protection and safety during operation and in the long term as compared to awaited benefits will have to be performed.

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Conclusion

Reversibility is a complex issue which has to be shared socially and politically and which deserves to be thoroughly addressed. We consider that the flexibility and margin introduced by the reversibility principle, except major technical evolution not identified today, will decrease with time, in particular because of the evolution of the packages and of the facility with time.

The Place of R&R in Regulatory Policy in Switzerland*

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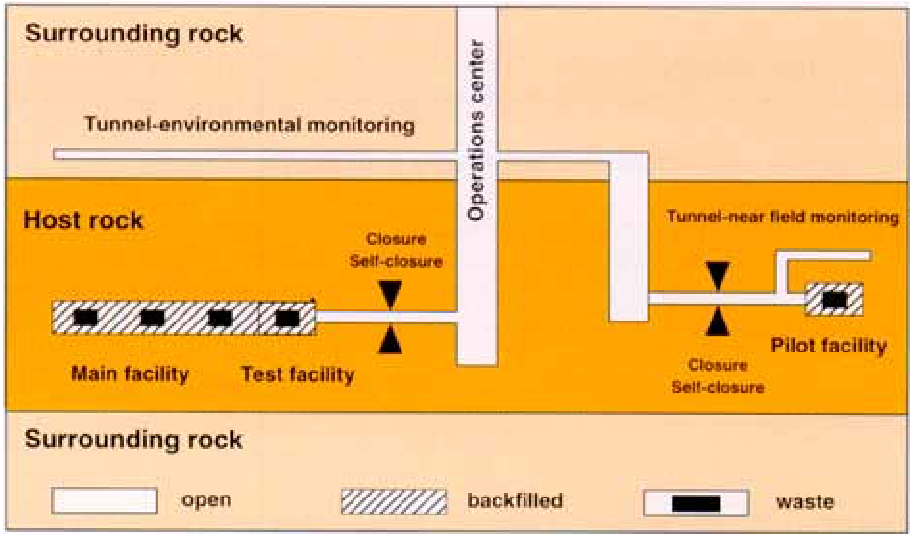
The technical concept of EKRA

The EKRA technical concept for long-term monitored geological disposal (depicted in Figure 1) formed the basis for the new Swiss regulatory policy in 2003 defined in the:

- Nuclear Energy Act;
- Nuclear Energy Ordinance;
- ENSI guideline G03 for Swiss nuclear installations;

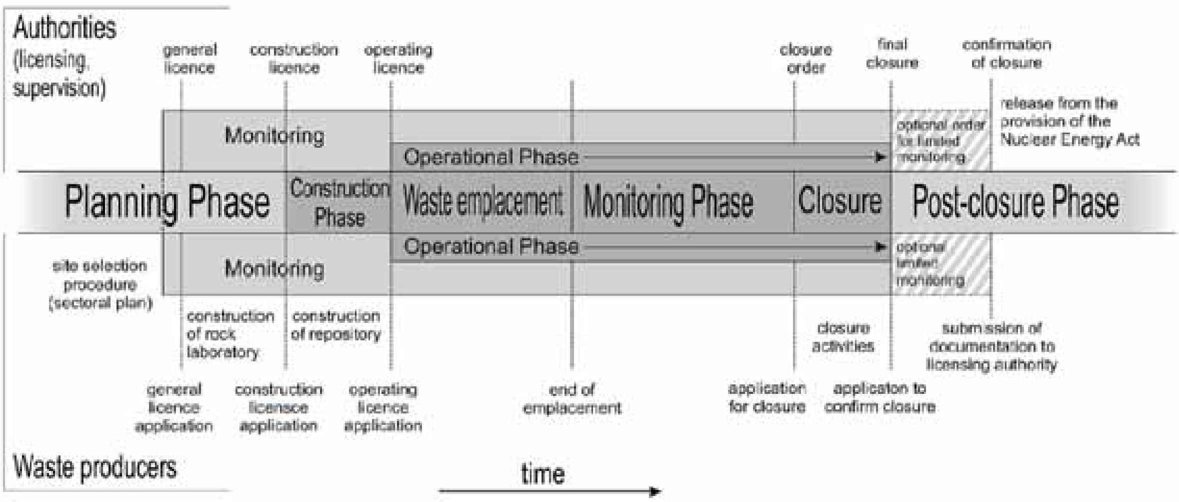
The EKRA concept included the replacement of Cantonal veto in the decision-making process for repository selection (see Figure 2) by a broad-based local/regional participation process.

Figure 1: Long-term monitored geological disposal



* This text was adapted by the NEA from the author's PowerPoint presentation at the R&R Conference.

Figure 2: Simplified schematic representation of the process involved in planning, construction, operation and closing of a deep geological repository



Retrieval without undue effort

Under the Nuclear Energy Act, up to the time of repository closure, retrieval of waste has to be possible without undue effort (Article 37). The mechanical stability of the disposal containers therefore has to be such that they can be retrieved without undue effort up until the end of the monitoring phase. The Nuclear Energy Ordinance further states that measures taken to secure retrieval may not compromise the passive safety barriers and hence the long-term safety of the repository (Article 11, paragraph 2c).

The concept for retrieval of the waste must be presented to ENSI for review and approval together with the construction licence application for the repository. The retrieval concept has to contain an estimate of the expected radiation exposure of operating personnel and the local population.

In order to obtain the operational license, safety-relevant technologies for emplacing the backfill material (or its removal if retrieval is necessary), for retrieving waste packages and for sealing of caverns and tunnels have to be tested and their operational reliability demonstrated (Nuclear Energy Ordinance, Article 65).

Also as outlined by the Nuclear Energy Ordinance, the backfilling of the disposal excavations must correspond to requirements relating to long-term safety and the retrieval of waste packages without undue effort (Article 67).

If there are indications of failure of the barrier system during the operational phase, and if adequate repair is impossible and the long-term safety of the repository can thus no longer be assured, the waste packages have to be retrieved.

The documentation has to contain information on interim storage and any subsequent conditioning of waste packages insofar as this relates to properties of the waste packages that deviate from the documented standard design and the information is relevant for possible retrieval of the waste or for long-term safety.

Post-closure phase

The requirement of “retrieval with undue effort” ends with the final closure of the repository and its release from the provision of the Nuclear Energy Act.

Questions to be addressed

Despite the regulatory dispositions detailed above, questions concerning reversibility and retrievability may arise. These could include:

- How (based on what information) do we determine the necessity and time of retrieval?
- How do we cope with the safety and security risks related to having the repository accessible for a long time?
- How do we monitor the safety-related long-term processes in the repository over a very long period of time?

Reversibility and Retrievability in Finland

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The spent nuclear fuel disposal project in Finland proceeds in stepwise manner. The site selection process continued with several stages from 1984 to 2000, including a country-wide site screening of potential sites and finally the investigations of four final candidate sites. Licensing of a nuclear facility includes three steps:

- The Decision in Principle, which can be made if a "…construction project is in line with the overall good of society". The decision is made by the government, requiring endorsement from the Parliament. Host municipality consent and a positive preliminary safety evaluation by the nuclear regulatory body, STUK, is required.
- Construction license – granted by government, a positive safety evaluation by STUK is a prerequisite.
- Operating license – granted by government, a positive safety evaluation by STUK is a prerequisite.

The decision in principle for the Olkiluoto disposal facility was ratified by the Parliament in 2001. An application for a construction license is expected to be submitted in 2010 and for operation license in 2018, with the goal for start of operation in 2020. The closure of the facility is expected early in the next century. The stepwise decision process and the long time frame allow consideration of new developments and information.

When the Decision in Principle for the Olkiluoto repository was made, retrievability-related requirements did exist in the regulation. The applicable government decision and regulatory guide in force at the time stipulated the following:

- Disposal shall be planned so that no monitoring of the disposal site is required for ensuring long-term safety and so that retrievability of the waste canisters is maintained to provide for such development of technology that makes it a preferred option.
- In the post-closure phase, retrieval of the waste canisters from the repository shall be feasible during the period in which the engineered barriers are required to provide practically complete containment for the disposed radioactive substances.
- The disposal facility shall be designed so that retrieval of waste canisters, if needed, is feasible with the technology available at the time of disposal and with reasonable resources.
- Facilitation of retrievability or potential post-closure surveillance actions shall not impair long-term safety.

Today, retrievability is not explicitly required in the regulation. But, as there is a retrievability requirement included in the Decision in Principle for the Olkiluoto repository, it has to be considered. In practice:

- Documents on technical feasibility and cost of retrievability and reversibility will need to be included in construction and operation license applications.
- Technical steps must be reversible for safety reasons, e.g. if a canister is not placed correctly in a disposal hole, there must be technical means to remove bentonite and retrieve the canister.
- Research and monitoring during operation and advances in science are taken into account in periodic safety reviews.
- Safety must not be compromised. To minimise groundwater disturbance and the amount of oxygen near the disposal canisters, open volume must be minimised, meaning prompt closure of emplacement tunnels.

According to the plans of the implementer, disposal at Olkiluoto would continue for more than 100 years and emplacement would be done in stepwise manner, with a limited disposal volume open at a time. This will allow relatively easy retrieval. Retrieval is possible after closure, but the cost of retrieval would increase.

The International Retrievability Scale: A Tool for Stakeholder Communication

The International Retrievability Scale*

Jean-Noël Dumont
French National Radioactive Waste Management Agency (Andra)
R&R Working Group

Objectives and method

The International Retrievability Scale has been developed with two main objectives: to support dialogue with stakeholders and to establish a common international framework.

The notion of establishing an international retrievability scale (R-scale) was being tested even before the launch of the R&R project. Once the project was established, further development of the R-scale was undertaken by a dedicated working group, which was equally tasked with the drafting of a leaflet. More than 18 months were spent testing and improving the leaflet and the R-scale, both within the working group and beyond. It is hoped that discussion during the R&R Conference will lead to further refinement; feedback from interested parties is encouraged and appreciated.

The R-scale

The R-scale is presented in schematic form in Figure 1. For added clarity, a tabular version of the R-scale is also provided in Table 1.

As can be seen at the top of Figure 1, the different *stages of waste disposal* can be reduced to a series of common steps. The duration of steps is variable according to specific national programme provisions.

After the visualisation of stages, the second part of the R-scale allows us to examine conceptually the *ease and cost of retrieval* at each stage. Again, the duration of each block, and the relative proportion between ease and cost, will depend on the national programme in place.

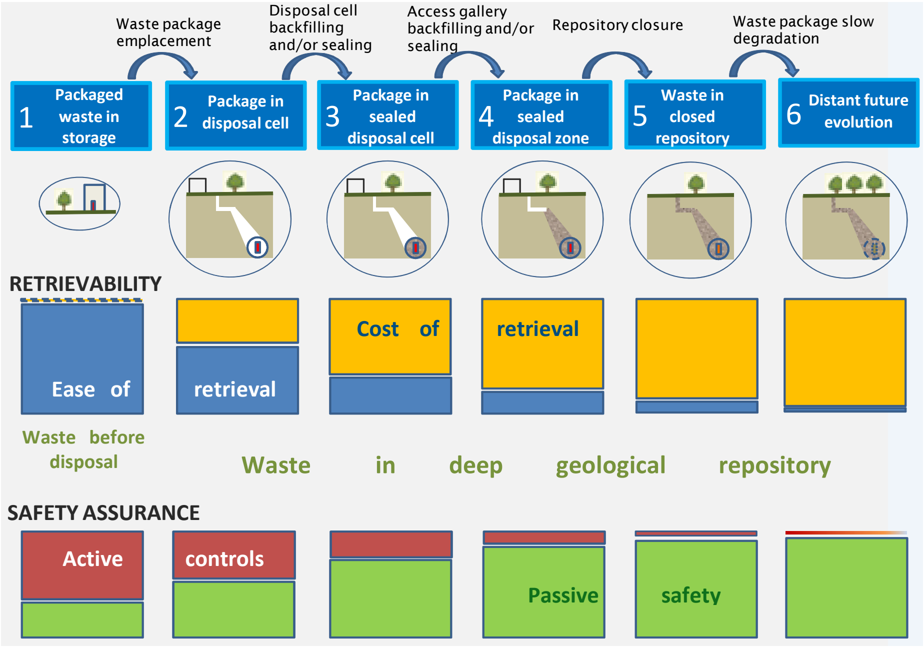
In the third part of Figure 1, the character of safety assurance at each stage is represented through the relative weight of active and passive controls.

The leaflet

A four-page leaflet entitled *International Understanding of Reversibility of Decisions and Retrievability of Waste in Geological Disposal* was prepared for distribution at this conference. The leaflet is divided into three sections.

* This text was adapted by the NEA from the author's PowerPoint presentation at the R&R Conference.

Figure 1: The R-scale indicating retrievability stages; relative ease and cost; safety assurance



Section 1 – Repository objectives and life phases

This section provides a general description of the geological disposal process, and addresses topics such as the objective of a geological repository, the lifecycle stages of the repository, the role of observation along the process and the decisions to be made (see Figure 2).

Figure 2: Repository life phases and examples of major decision points

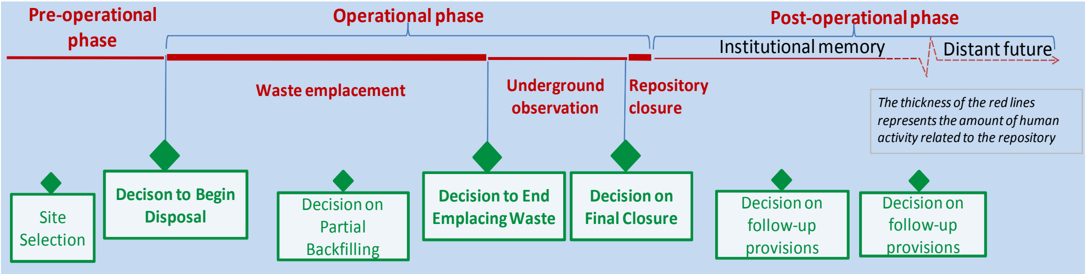


Table 1: The R-scale in table form

Stage and location of the waste*		Ease of retrieval	Specific elements of passive safety	Specific elements of active control
1	**Waste package(s) in storage**	Waste package retrievable by design.	Waste form and its storage container.	Active management of storage facility including security controlled area.
2	**Waste package(s) in disposal cell****	Waste package retrievable by reversing the emplacement operation.	Waste form and disposal container. Hundreds of meters of rock. Engineered disposal cell.	Active management (including monitoring) of disposal cells and disposal facility. Security controlled area.
3	**Waste package(s) in sealed disposal cell**	Waste package retrievable after underground preparations.	As in previous stage, plus backfill/sealing of disposal cell.	Monitoring of disposal cells possible. Active management of access ways to disposal cell seals. Security controlled area.
4	**Waste package(s) in sealed disposal zone**	Waste package retrievable after re-excavation of galleries.	As in previous stage, plus backfill/sealing of underground galleries allowing access to cells.	Monitoring of disposal cells potentially possible. Security controlled area. Detailed records and institutional controls for a specified period, including international safeguards.
5	**Waste package(s) in closed repository**	Waste package retrievable after excavating new accesses from surface. Ad hoc facilities to be built to support retrieval.	As in previous stage, plus sealing of shafts and access drifts to ensure long-term confinement of the waste within the underground facility.	Maintaining records. Regular oversight activities as long as possible (e.g. environmental monitoring, possibly remote monitoring, security controls and international safeguards).
6	**Distant future evolution**	Waste package degrading with time. Waste ultimately retrievable only by mining.	Geology and man-made barriers. Reduction in level of radioactivity.	Specific provisions for longer-term memory preservation, e.g. site markers.

* During the operational phase, not all waste packages present in the facility will be at the same life cycle stage.

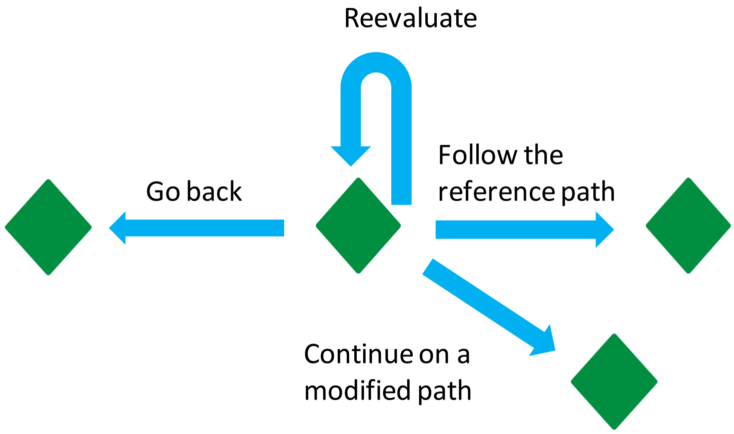
** Depending on the national programme and on the type of waste, the waste package emplacement room may be a vault, a cell, a section, etc. The term “cell” used here is generic to all these cases.

Section 2 – Reversibility, retrievability: what are they?

Section 2 of the leaflet provides clear definitions of the terminology employed, in an effort to avoid confusion during debate and decision-making processes. The leaflet defines reversibility as “decision-making during project implementation [which] involves ensuring that the implementation process and technologies maintain flexibility so that, at any stage of the programme, reversal or modification of one or a series of previous decisions may be possible if needed…” In applying the reversibility principle, “[e]ach major authorisation […] can be seen as an assessment of whether the process can continue as foreseen or whether one of the reversibility options should be exercised.” (NEA, 2011) The range of decisions under the reversibility principle is depicted in Figure 3.

Retrievability, on the other hand, is defined as “the ability to retrieve emplaced waste or entire waste packages.” Retrievability is a notion that may increase confidence in the entire waste repository process, though it should not be considered part of the basic safety concept of waste disposal in a final repository. With time, research and development may provide ways to reduce the degree of difficulty of retrieval.

Figure 3: Potential outcomes of options assessment, including reversal



Section 3 – A retrievability scale for stakeholder dialogue

This section of the leaflet presents the International Retrievability Scale. "[It] has been developed to illustrate qualitatively the degree and type of effort that is needed to retrieve the waste according to the stages in its life cycle before and after its emplacement in a repository." (NEA, 2011) (Figure 1, Table 1) It is hoped that this tool will facilitate dialogue and decision-making processes.

Using the R-scale and the leaflet

Testing of the R-scale and leaflet has commenced within the community of experts in radioactive waste management, and is being applied through the R&R project, and by the larger community of NEA groups (FSC, IGSC, …) and other contacts. The R-scale has been presented to local and national stakeholders in France and the United Kingdom, and was a topic of discussion in a 2010 state-of-the-art report of the Swedish National Council for Nuclear Waste.

Feedback

The R-scale is a potentially useful dialogue tool between people who do not share the same experience and language. Such groups include experts of various fields (nuclear, economics, technology, environment), local stakeholders and implementers of various national programmes. Providing a common vocabulary and a framework for discussion can, at a minimum, clarify the debate.

The leaflet has been an efficient tool for exchange within the R&R project team, and has evolved towards a synthesis of the findings of the R&R project. For these findings to be useful at each national level, translation of the leaflet should be performed. [A French translation is available at the NEA website, and other countries are encouraged to produce their own translation.]

Conclusion

The French poet Paul Valéry (1871-1945) stated that "If it is simple, it is inaccurate; if it is not simple, it is not helpful".[1] Our ambition was to develop a helpful tool for dialogue, simple but not inaccurate; the exercise has not been without difficulty!

1. « Tout ce qui est simple est faux, tout ce qui ne l'est pas est inutilisable. »

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Nuclear Energy Agency (2011), *International Understanding of Reversibility of Decisions and Retrievability of Waste in Geological Disposal*, Informational leaflet, OECD/NEA, Paris.

Swedish National Council for Nuclear Waste (SNCNW) (2010), *Nuclear Waste State of the Art Report 2010 – Challenges for the Final Repository Programme*, SOU 2010:6, SNCNW, Stockholm.

Appendix 1: Final Programme of the International Conference and Dialogue on Reversibility and Retrievability in Planning for Geological Disposal of Radioactive Waste

Organised by the OECD Nuclear Energy Agency

Chaired by **Claude Birraux (MP)**
President of the French Parliamentary Office for Technology Assessment (OPECST)

14-17 December 2010
Reims, France

Day 1	Tuesday, 14 December 2010
07:00	**Technical visit** (limited to 40 people): Andra's Meuse/Haute Marne Underground Research Laboratory and Technical Exhibition Facility
07:00-20:00	**Registration**
18:00-20:00	**Icebreaker**
Day 2	**Wednesday, 15 December 2010**
08:00-09:00	**Set up of posters** for the duration of the conference; **registration**
09:00-09:30	**Session 1 – Welcome addresses**
	Chair: Claude Birraux, MP, OPECST (France)
	Assisted by Richard Ferch, Consultant to the R&R Project (Canada)
	1. Jacques Meyer, Deputy Mayor of the City of Reims 2. Luis Echávarri, NEA 3. François-Michel Gonnot, Andra 4. Piotr Szymanski, DG-ENERGY, European Commission 5. Irena Mele, on behalf of Tero Varjoranta, IAEA
09:30-10:30	**Session 2 – Setting the scene**
	1. Claude Birraux, MP, President of the French Parliamentary Office for Technology Assessment (OPECST) 2. Claudio Pescatore, NEA, Co-ordinator of the R&R Project: "Personal Observations and Findings from R&R Project"
10:30-11:00	**Break – First Poster Session**
	Visit posters and discuss with presenting authors
11:00-13:00	**Session 3 – Country situations at policy level**
	Chair: Kathryn Shaver, NWMO (Canada)

Government representatives (high-level civil servants) or high-level country figures deliver 10-15 minute talks on:

- what "reversibility and retrievability" mean in their countries;
- the main drivers in policy approaches (e.g. legal requirement, government policy, option taken independently by the implementer, no R&R at all, etc.);
- the meaning of the words "disposal", e.g. final disposal, long-term management with a view to final disposal, etc., and "waste", e.g. when are the relevant materials classified as "waste"?
- **Countries/speakers:**
  - Finland, Ministry of Trade and Industry – Jaana Avolahti
  - Switzerland, Ministry of Energy – Michael Aebersold
  - Germany, Ministry of Environment – Georg Arens
  - United States, NRC Office of Nuclear Material Safety and Safeguards – Catherine Haney
  - Belgium, National Implementing Organization – Jean-Paul Minon
  - Sweden, Ministry of the Environment – Ansi Gerhardsson
  - Japan, Nuclear Safety Commission – Seiji Shiroya

13:00-14:30 **Lunch Break**

14:30-16:20 **Session 4 – Key messages from the angle of policy studies and the social sciences**

Chair: Dan Metlay, US Nuclear Waste Technical Review Board (USA)

This session covers a wide-ranging set of topics, several of which may be new to many of the attendees. Look for fresh ideas, different angles on the topic of R&R.

Speakers:

1. Luis Aparicio, Andra (France): "Results of the Nancy Conference of 2009"
2. Carl Reinhold Bråkenhielm, U. Uppsala (Sweden): "R&R Under Mode 2 – Knowledge Production"
3. John Whitton, NNL (UK): "UK National Stakeholder Group Meetings" (*under reserve of replacement*)
4. Claire Mays, OECD/NEA FSC: "Reversibility and Retrievability: A View and Review from the NEA RWMC 'Forum on Stakeholder Confidence'"
5. Sandrine Spaeter, U. Strasbourg (France): "Economic Theory in R&R"
6. Walter Wildi, U. Geneva (Switzerland): "The EKRA Studies and the Formulation of the Swiss 'Long-term Monitored Disposal' Concept"
7. Gerrit Rauws, King Baudouin Foundation (Belgium): "A Citizens' Perspective on Reversibility; Observations from the Citizens' Conference on the Long-term Management of High-level and Long-lived RW in Belgium"

16:20-16:50 **Break – Second Poster Session**

Visit posters and discuss with presenting authors

16:50-18:30 **Session 5 – Round-table discussions on key messages from the angle of policy studies and the social sciences**

Participants break up into small mixed groups (see listing) with a facilitator assisted by a reporter, and discuss the following questions:

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1. Which key message(s) from policy studies and the social sciences are worth remembering? Why?
2. The various countries show specificities and commonalities on aspects such as the symbolic dimension of R&R, policy-building approaches, local stakeholders' involvement, etc. Which are valuable lessons to retain?
3. Governance of RW has been made possible by the distinction of roles and the independence of actors taking part in the decision-making process: evaluators, regulators, representatives of the interested parties and the public, operators… Is there any specific role to be played in this process by the social sciences and humanities, by economic research?

18:30	**Adjourn**
Day 3	**Thursday, 16 December 2010**
08:45-09:15	**Reports on Day 2 sessions**
	Brief report on Round-table discussions from each table facilitator of Session 5
09:15-10:00	**Session 6 – Perspectives on R&R from institutional players**
	Chair: Bernd Grambow, École des Mines (France)

The session deals with the practicalities and implications of providing for retrievability.

- Can retrievability be an add-on or does it need to be taken into account from the beginning?
- Are there any challenges to the regulatory framework?
- What kind of implications for monitoring, institutional control and memory keeping? Over what time scales?
- What kind of organisational structure does reversibility imply?
- To what extent should one provide for retrieval of waste?

Speakers:

1. Steve Wagner, SNL (USA)
2. Jean-Michel Bosgiraud, Andra (France)
3. Erik Setzman, SKB (Sweden)

10:00-10:30	**Break – Third Poster Session**
	Visit posters and discuss with presenting authors
10:30-11:45	**Session 6 (cont.) – Perspectives on R&R from institutional players**

4. Brendan Breen, NDA (United Kingdom)
5. Hiroyuki Tsuchi, NUMO (Japan)
6. Jean-Michel Hoorelbeke, Andra (France)
7. Walter Blommaert, FANC (Belgium)
8. Jürgen Krone, DBE (Germany)

11:45-12:10	**Session 7 – Additional questions to the speakers from the audience**
12:10-13:30	**Lunch Break**
13:30-14:45	**Session 8 – Expectations expressed by local stakeholders and NGO**
	Chair: Eva Simic, NEA Forum on Stakeholder Confidence and SSM (Sweden)

Local stakeholders are understood now to be vital partners in the long-term management of radioactive waste, and throughout the world RWM programmes are building in specific roles for them. Their voice can be very useful in highlighting practical and ethical implications of R&R.

Speakers:

1. Roland Corrier, Jean-Paul Lheritier, CLIS de Bure (France)
2. Councillor Timothy Knowles, Chair of the West Cumbria Managing Radioactive Waste Safely (MRWS) Partnership (United Kingdom) (*presented by Fergus McMorrow*)
3. Martin Donat, Atomausschhuss Lüchow Dannenberg (Germany)
4. Johan Swahn, MKG – NGO Office for Nuclear Waste Review (Sweden)
5. Thomas Flüeler, Department of Public Works, Canton of Zürich (Switzerland)

14:45-16:15 **Session 9 – Round-table discussions on expectations expressed by local stakeholders and NGO**

Participants break up as before into smaller groups (see listing) to discuss the following questions:

1. Do the key expectations of the local stakeholders regarding R&R differ from country to country? What lessons should be drawn from specificities or commonalities?
2. Which opportunities are available for improving local participation in RWM within a stepwise decision-making process and in the long term (for example, in assessment, monitoring, financial provisions, memory preservation, etc.)? What are the limits to local stakeholder involvement?
3. Which place can or should be given to local stakeholders in the setting of policy related to RWM at the national and international levels?

16:15-17:00 **Break – Final Poster Session**

Visit posters and discuss with presenting authors

(Posters will be removed by 18:00)

17:00-18:30 **Session 10 – Optimal choices and duties to future generations**

Chair: Michael Sailer, Oeko-Institut (Germany)

In 1969, the United States National Academy of Sciences, in its report to Congress entitled Technology: Processes of Assessment and Choice, observed that: “Other things being equal, those technological projects or developments should be favoured that leave maximum room for manoeuvre in the future. The reversibility of an action should thus be counted as a major benefit; its irreversibility, a major cost.” Should this principle or one variant of it inform the implementation of a geological disposal facility? Which are its strengths and limitations?

Panellists:

1. Pierre Berest, LMS, École Polytechnique (France)
2. Carl Reinhold Bråkenhielm, U. Uppsala – Theology (Sweden)
3. Bertrand Pancher, “*Décider Ensemble*” (France)
4. Erik Van Hove, retired, U. Antwerp (Belgium)

18:30 **Adjourn**

18:45 **Departure for conference dinner by bus from Conference Centre**

Day 4	Friday, 17 December 2010
09:00-09:30	**Reports on Day 3 sessions** Brief report on table discussions from each table facilitator of Session 9
09:30-11:15	**Session 11 – Panel on "The Place of R&R in Regulatory Policy"** *Chair: Carmen Ruiz, CSN (Spain)* There are two aspects to regulation: the process (which overlaps to some extent with policy), and safety requirements. Process: How does the stepwise regulatory process relate to the overall stepwise decision-making process? Are they the same, or distinct? Is a stepwise regulatory process sufficient? Safety: some regulators may say that they are indifferent to whether R or R is present (unless, of course, it is a legislated requirement) as long as the basic safety requirements are still met. Is this really true? Are the current regulatory (safety) requirements predisposed in one way or the other, i.e. do they bias the discussion? Are regulators' views similar to those of society, or to those of implementers, or distinct from both? **Panellists:** 1. Daniel Schultheisz, EPA (United States) 2. Hiroyuki Umeki, NSC (Japan) 3. Marie-Pierre Comets, ASN (France) 4. Peter Hufschmied, ENSI (Switzerland) 5. Risto Paltemaa, STUK (Finland)
11:15-11:30	**Break**
11:30-12:00	**Session 12 – The International Retrievability Scale** *Presentation: Jean-Noël Dumont, Andra and R&R Working Group* A presentation on the R-scale (leaflet distributed to participants in conference pack) is followed by a discussion in plenary. This is an opportunity to get feedback from a wider audience, and to further refine the scale and the leaflet.
12:00-13:30	**Lunch Break**
13:30-14:45	**Session 13 – Stock-taking** • Session rapporteurs recap their sessions. • Conference Chair Claude Birraux (MP) surveys the key points emerging from the conference and the most important areas where consensus or divergence were revealed. This information will be documented and will be used to update and finalise the NEA R&R project report.
14:45	**Closing of the Conference**
15:00	**Adjourn – End of the Conference**

Appendix 2: List of Participants

Belgium		
BERGMANS	Anne	University of Antwerp
BERNIER	Frederic	The Federal Agency for Nuclear Control (FANC)
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CLAES	Jan	Mols Overleg Nucleair Afval (MONA) vzw
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SZYMANSKI	Piotr	European Commission (EC)
ELLIS	Allun	International Association for Environmentally Safe Disposal of Radioactive Materials (EDRAM)
GONZALEZ	Jose Luis	International Association for Environmentally Safe Disposal of Radioactive Materials (EDRAM)
LARDOT	Nicolas	International Association for Environmentally Safe Disposal of Radioactive Materials (EDRAM)
MCKIRDY	Bruce	International Association for Environmentally Safe Disposal of Radioactive Materials (EDRAM)
NASH	Ken	International Association for Environmentally Safe Disposal of Radioactive Materials (EDRAM)
SCOTT	Gary L.	International Association for Environmentally Safe Disposal of Radioactive Materials (EDRAM)
MELE	Irena	International Atomic Energy Agency (IAEA)
NACHMILNER	Lumir	International Atomic Energy Agency (IAEA)
VARJORANTA	Tero	International Atomic Energy Agency (IAEA)
ECHAVARRI	Luis	OECD Nuclear Energy Agency (OECD/NEA)
GAS	Serge	OECD Nuclear Energy Agency (OECD/NEA)
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International organisations (*cont.*)

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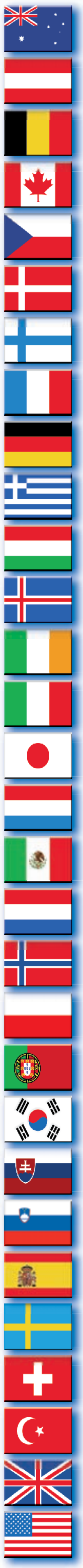

Reversibility and Retrievability in Planning for Geological Disposal of Radioactive Waste

Deep geological repositories of radioactive waste are designed and licensed based on a model of long-term safety which does not require the active presence of man. During the period of stepwise development of such repositories, reversibility of decisions and retrievability of the waste are widely thought to be beneficial. Reversibility and retrievability are not requirements for long-term safety. They are instead about implementing a process that responds to ethical and precautionary obligations without compromising safety. How are the concepts of reversibility and retrievability understood in the various nuclear countries? How do they appear in national waste management legislation, regulation and operational programmes, and how can they be implemented?

The "R&R" project of the OECD Nuclear Energy Agency (NEA) culminated in an International Conference and Dialogue on Reversibility and Retrievability in December 2010. This open meeting brought together regulators, policy makers, elected officials, experts in social sciences, and representatives of civil society and stakeholder groups in addition to waste management professionnels. These proceedings include the texts of 50 presentations and the "International Retrievability Scale" – a tool to support dialogue with stakeholders and to help establish a common international framework.

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