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RADIOACTIVE WASTE MANAGEMENT COMMITTEE

REVERSIBILITY OF DECISIONS AND RETRIEVABILITY OF WASTE CONSIDERATIONS FOR NATIONAL GEOLOGICAL DISPOSAL PROGRAMMES

Final draft of a brochure to be published in December 2011 by the OECD Nuclear Energy Agency Radioactive Waste Management Committee (RWMC) (in English and in French). This interim file is placed on line as a courtesy to interested readers. The brochure is based on the Executive Summary and the Conclusions of the final report of the "Reversibiity and Retrievability" (R&R) project (published concurrently as NEA/RWM/R(2011)4). It delivers the key findings and observations on reversibility and retrievability made by the RWMC working group, as well as a brief outline of the project activities (2007-2011). A list of NEA publications (including the R&R project documents) is included.

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REVERSIBILITY OF DECISIONS AND RETRIEVABILITY OF WASTE CONSIDERATIONS FOR NATIONAL GEOLOGICAL DISPOSAL PROGRAMMES

FOREWORD

The most widely adopted policy for the definitive management of high-activity radioactive waste involves its emplacement in deep geological repositories whose safety should not depend on the active presence of man. This broadly accepted policy of concentrating and confining the waste in a repository creates *de facto* a situation of potential availability of the waste for future retrieval. To what extent retrieval can or should be further facilitated in designing a repository, if so over what time scales, and the larger corollary question of determining when and how to reverse decisions, are issues of continued interest in OECD Nuclear Energy Agency (NEA) member countries.

In 2007 the OECD/NEA Radioactive Waste Management Committee (RWMC) launched a 4-year project on these topics. The Reversibility and Retrievability (R&R) project aimed to improve awareness amongst the RWMC constituency of the breadth of issues and positions regarding these concepts. The goal of the project studies and activities was to acknowledge the range of approaches to 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. Major milestones in the project have been the compilation of a bibliography, a survey among NEA member countries of positions on R&R, the development of a leaflet to facilitate discussion of R&R with stakeholders, and exchanges among an ever-widening group of interested parties that culminated in an International Conference and Dialogue held in Reims (France) in December 2010. The project is documented on line at www.oecd-nea.org/rwm/rr/.

The present brochure is based on the Executive Summary and the Conclusions of the R&R project full report (published concurrently). It delivers the key findings and observations on reversibility and retrievability made by the working group, as well as a brief outline of the project activities. A list of NEA publications (including the R&R project documents) is included.

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INTRODUCTION

Interest in reversibility and retrievability (R&R) in geological disposal of high-level radioactive waste and spent fuel disposal has been increasing steadily since the late 1970s. In 2008 the NEA Radioactive Waste Management Committee (RWMC), an internationally established group of high-level experts with regulatory, industrial, R&D and policy backgrounds from the OECD countries, concluded that: "There is general recognition that it is important to clarify the meaning and role of reversibility and retrievability for each country, and that provision of reversibility and retrievability must not jeopardise long-term safety."

In 2007-2011, the RWMC conducted a project on reversibility and retrievability with the goal of providing a neutral overview of relevant issues and viewpoints in OECD countries. The initiative included intellectual contributions from 15 countries plus the International Atomic Energy Agency (IAEA) and the European Commission (EC) as well as other working parties of the RWMC: the Forum on Stakeholder Confidence (FSC), the Integration Group for the Safety Case (IGSC) and the Regulators' Forum. There were five project meetings involving about 50 persons, and one major International Conference and Dialogue involving over 180 participants. The R&R project benefitted from inputs by and exchanges among representatives of implementer organisations, regulatory agencies, policy making bodies, and civil society at large, including social scientists and community leaders.

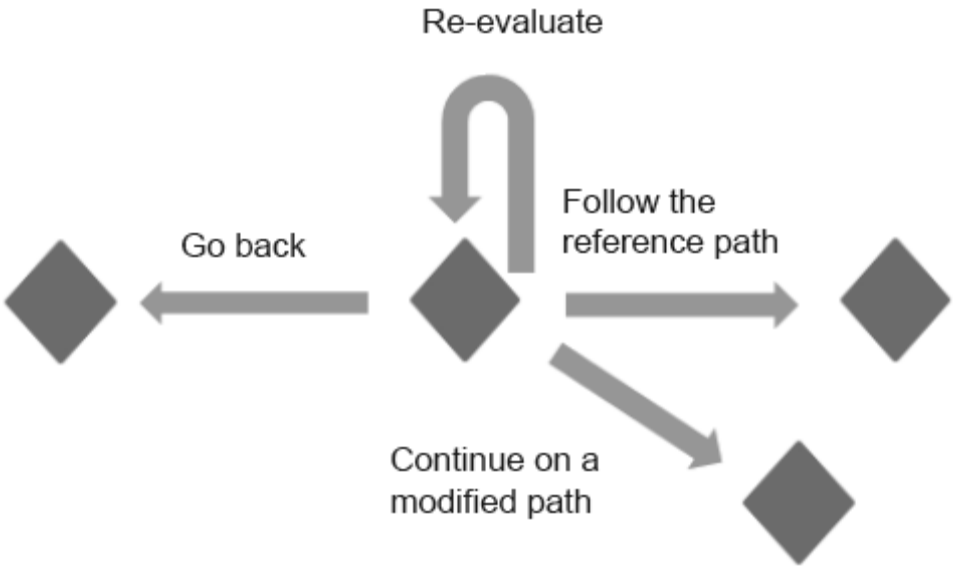
The project revealed that while reversibility and/or retrievability are important aspects of policy or legislation in an increasing number of national programmes, there is a wide variety of approaches to the subject. Indeed, no two programmes appear to be the same in this respect. The social, legal and technical environments within which programmes are situated vary from place to place, and also change as time passes. It is clear that there is no "one size fits all" approach that can be applied to all situations. Nevertheless, there are some factors and aspects that are common to many, if not all, programmes. Moreover, some of the considerations about R&R in geological repositories may be pertinent also in regard to sub-surface disposal.

TERMINOLOGY

Terminology matters a great deal when discussing R&R and geological repository concepts. For the sake of clarity, the project produced definitions of key terms:

Reversibility describes the *ability in principle* to reverse decisions taken during the progressive implementation of a disposal system; **reversal** is the actual action of going back on (changing) a previous decision, either by changing direction, or perhaps even by restoring the situation that existed prior to that decision. Figure 1 illustrates how a given decision may be re-evaluated, and indicates the various options that may be identified, including reversal ("go back").

FIGURE 1: Reversibility of decisions - Potential outcomes of options assessment, including reversal



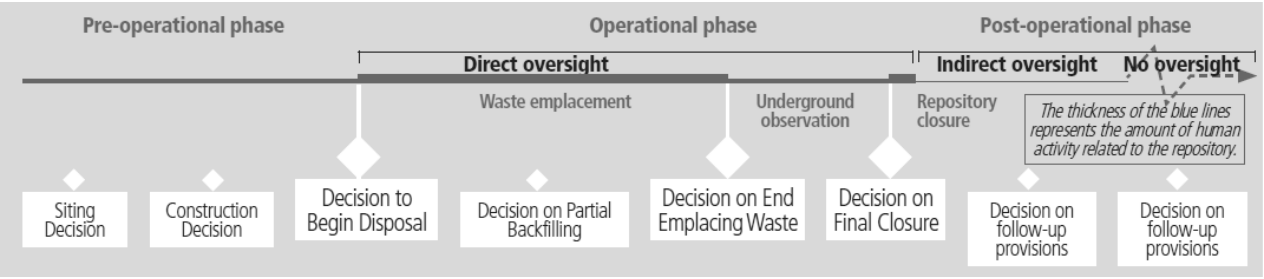
Retrievability is the *ability in principle* to recover waste or entire waste packages once they have been emplaced in a repository; **retrieval** is the concrete action of removal of the waste. Retrievability implies making provisions in order to allow retrieval should it be required.

OBSERVATIONS ON REVERSIBILITY

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.

Reversibility implies a willingness to re-evaluate previous decisions and a culture that encourages such a questioning attitude. Reversibility can best be accommodated within a stepwise decision-making process. While always ensuring that safety requirements are met, such a process should also allow for adaptations or changes in direction, taking into account information gained during the implementation process. Examples of some of the many decisions that may be taken during the lifetime of a geological repository are shown in Figure 2.

FIGURE 2: Repository life phases and examples of associated decisions



For stepwise regulatory and policy decisions to be credible, they must be reversible or at least 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. Whether expected or not, modification of any given decision always exists as a contingent possibility, even when the decision maker's intention is clearly to eliminate all but the selected option. The question is whether to incorporate planning for this contingency within a defined decision-making process, in analogy with emergency preparedness, or to choose to discount or ignore this possibility, which, in case of surprise reversal, could lead to loss of confidence in the foresightedness 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. One may conclude on this basis that reversibility should be framed by a transparent, predefined process.

In stepwise decision making the decision maker normally identifies hold points at which a deliberation should be made whether or not to reverse earlier decisions, and the resulting determination be recorded. Criteria for this determination ought to be agreed to ahead of time. The societal reason for introducing reversibility into waste management arrangements should not be to make reversal painless; it should be so that "*if you do determine you need to reverse, the amount of effort needed to reverse is reasonable*". In the same vein, reversibility of decisions implies, for the organisations implementing disposal, to build in waste retrievability provisions so as not to pose unnecessary obstacles to retrieval.

A major contributor to flexibility, reversibility also provides opportunities for continued dialogue, co-ordination and shared decision making. However, it must be recognised that the flexibility introduced by reversibility decreases with time, and in the interest of transparency this must be communicated to stakeholders.

OBSERVATIONS ON RETRIEVABILITY

Geological disposal, as currently envisioned in all national programmes, is in principle always a reversible technology. Even long after institutional oversight may have ended, and beyond the time when the integrity of waste containers can be assumed, waste recovery would still be possible, although it would be a major engineering endeavour that would require high resolve, resources, and technology.

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 waste retrieval is feasible, assuming a future society that is both able to carry it out and willing to do so (*e.g.*, having determined that retrieval is financially viable). Those programmes that include retrievability mention three main reasons: (a) having an attitude of humility or open-mindedness towards the future; (b) providing additional assurance of safety; and (c) heeding the desires of the public not to be locked into an "irreversible" situation.

No national programme has been identified that requires retrievability after closure of a repository for basic safety reasons, *i.e.* as a fundamental safety feature of waste disposal. However, some national programmes require that a geological repository concept include provisions for retrievability before closure for operational safety reasons. The regulations for these programmes do not require that retrieval be demonstrated in practice. They require only that retrieval could be exercised in principle.

During the operational phase of a repository, reversibility and retrievability translate into practice a prudent approach to waste disposal (*i.e.*, a response to uncertainty regarding the adequacy of our disposal arrangements). During all repository life phases, waste retrieval is facilitated by the very fact of confinement (non-dispersion) and containment of the waste in a limited volume, which is part of the concept of any geological repository. In the distant future, waste will be still retrievable, although with greater effort and expense as time passes. Retrievability is thus a matter of degree, rather than of the presence or absence of any possibility to retrieve the waste. Actions today may be taken to facilitate to some extent the ability to retrieve (retrievability), and research and development may in future provide ways to improve retrievability and reduce the degree of difficulty of retrieval.

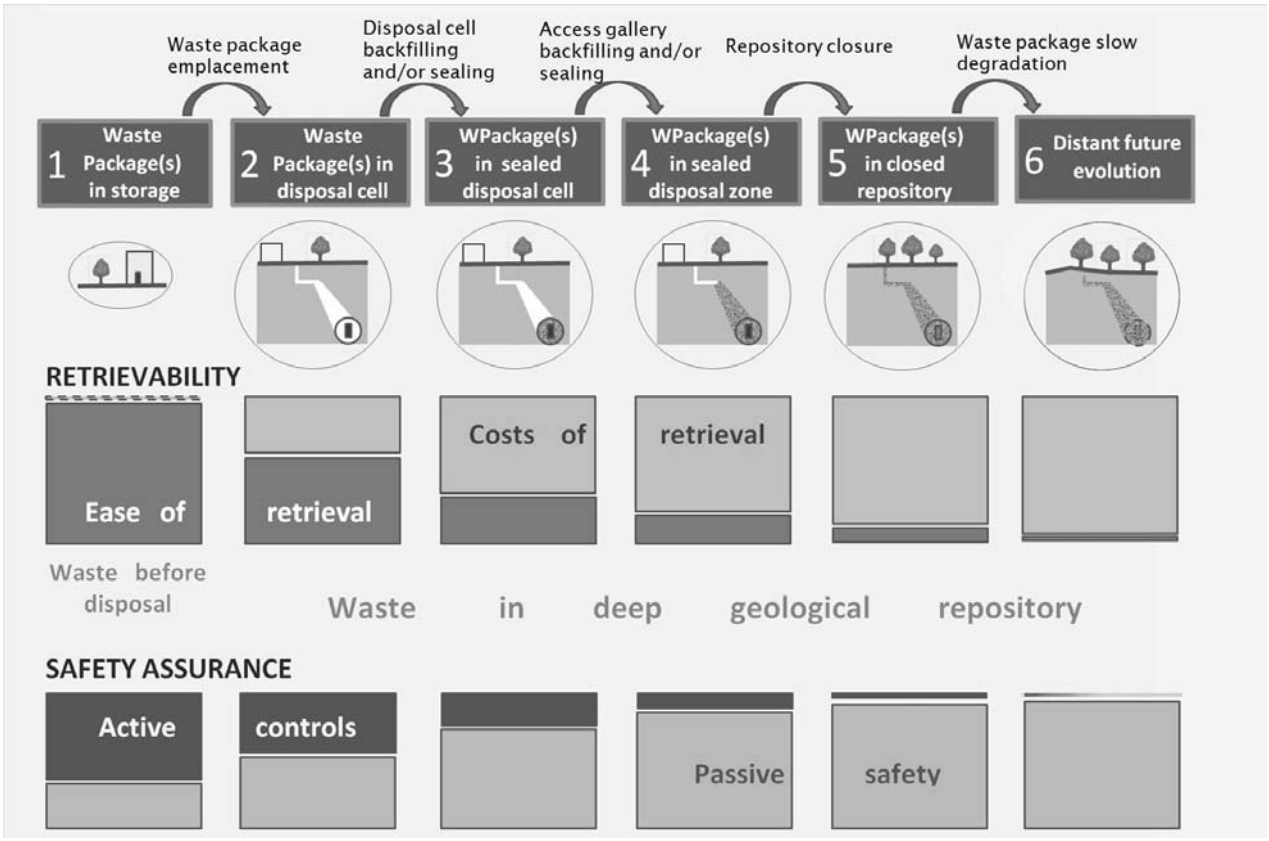
At the technical level, the application of retrievability provisions will depend on such factors as the host geology, engineered barrier concepts, and the life cycle phase(s) of the repository during which retrievability is desired. The incorporation of retrievability into a repository design will require a willingness to question whether proposed 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.*). At the same time, any choices that could facilitate retrieval must also be such that they would not jeopardise the integrity of the facility. Examples of provisions increasing retrievability include: more durable waste forms and waste containers, longer periods granted before closing galleries and the final repository, and buffer and backfill materials that are easier to remove.

Although the long-term safety case must be able to stand on its own without post-operational institutional oversight (*i.e.* must demonstrate passive safety), 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.

A mechanism for communicating the relationship between retrievability and the phases of development of a repository has been developed within the project, and tested in a number of national programmes. This "R-scale" provides a graphical depiction of the phases of development of a repository and demonstrates the evolution of the ease of retrieval, elements of passive safety and elements of active control as the repository evolves. This scale has been found to be a useful communications tool when applied in some national programmes.

FIGURE 3: "R-scale": Lifecycle stages of the waste, illustrating changing degree of retrievability, passive *vs.* active controls and costs of retrieval in a deep geological repository. During the operational phase, not all waste packages present in the facility will be at the same lifecycle stage.



Note: exact proportions of illustrated rectangles may vary depending on the repository design.

When considering the incorporation of retrievability into a repository programme, it is understood that retrieval would become successively more difficult as the repository takes on its final shape and function. In particular, safety considerations, as well as obligations related to physical protection and safeguards, impose constraints on the degree to which retrievability provisions may be incorporated into a repository programme. Retrieval of more than few waste packages, if carried out at some point, would be a major decision. If decided upon at later stages of a disposal programme, handling of the retrieved waste would pose radiation hazards to workers, and new facilities may have to be constructed to contain and process the wastes safely. Retrieval would be a new, regulated activity and it would require the same high-level societal scrutiny and authorisations that were needed originally to permit the emplacement of the waste in

the repository. Justification and optimisation would be required, as for any other activity involving radiological hazard. These points must be communicated and taken into consideration when making decisions about retrievability provisions.

PRINCIPAL PROJECT ACTIVITIES

The R&R project was framed by two outreach activities: a questionnaire sent to NEA member countries in 2008 at the beginning of the project, and the Reims International Conference and Dialogue in December 2010 near the end of the project.

Between these two activities there was a series of meetings at which working group members and invited experts defined terms and discussed a variety of topics related to reversibility and retrievability. Their findings are detailed in the project full report, published in 2011. An extensive stand-alone bibliography was compiled. In parallel, as described above, the "R-scale" graphical depiction of repository development was discussed and tested with stakeholders of various countries. The four-page leaflet "International Retrievability Scale" is being translated into several languages. Each of the project documents (including a summary of questionnaire responses and the Reims Proceedings) may be obtained on line at http://www.oecd-nea.org/rwm/rr/.

The R&R Questionnaire

The responses to the 2007 questionnaire revealed a wide diversity of approaches to R&R in national policy and legislation, ranging from requirements in law for reversibility or retrievability in some countries, to no formal mention in others. Nevertheless, even in those countries where R&R were not enshrined in law or policy, the institutions involved generally recognised these to be potentially important issues. Some of the differences seen between countries could be attributed to technical differences in host geology and reference repository design (affecting, for example, the ability to keep galleries open for extended periods after emplacement). Perhaps more importantly, the variations appeared to reflect the distinct histories of repository development in different countries, as well as their particular social, cultural and legal environments. Given these underlying differences, the diversity in approaches to R&R is not unexpected. The analysis of the questionnaire and later discussions revealed however that, at the policy level, 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 potential resource. By definition, "disposal" implies no intention to retrieve. If there is some *intention* to retrieve, the situation calls for interim storage, not final disposal. In a disposal programme, retrieval is at most a contingency, and retrievability is the means to plan for that contingency;

- The regulations on the protection of man and the environment are complied with. This means that disposal rooms in their final configuration, or a closed repository, must be licensed as safe without consideration of retrievability. 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 involved appropriately.

Some of the above terms are not given identical meaning in different programmes. Care is thus advised to define the above terms clearly in programme documents and to use them consistently. In

particular, it is important that provision of the *ability to retrieve* (retrievability) should not be confused with the *actual process of retrieval*. The section of the present brochure entitled "Terminology" clarifies these terms.

Reims International Conference and Dialogue

The International Conference and Dialogue on Reversibility and Retrievability (Reims, France, December 2010) brought together over 180 participants from 14 countries, including regulators, policy makers, experts in social sciences, representatives of civil society and stakeholder groups in addition to waste management implementers. The meeting of these diverse "communities of interest" greatly aided in elaborating viewpoints on theoretical and practical issues. Conference discussions helped communicate the work of the project to a wider audience and facilitated new understanding within the R&R working group. In particular the dialogue produced a heightened realisation that reversibility is not so much about reversal of decisions itself as it is about ensuring continued participatory decision making. The discussions at Reims also highlighted the importance of integrating expertise on the social sciences into the repository development, R&D and decision-making processes. The spirit of conference findings was captured in the following statement: "R&R are not a destination, but a path to be walked together"

Like the initial questionnaire, the International Conference and Dialogue revealed the diversity of terminology between programmes and communities of interest. It once again demonstrated the importance of distinguishing clearly among the concepts of reversibility, retrievability and retrieval, and of developing shared understandings on concepts.

CONCLUSIONS OF THE R&R PROJECT

The most widely adopted policy for the definitive management of high-activity radioactive waste involves its emplacement in deep geological repositories that are designed to be robust to a large spectrum of events and to prevent the release of their radioactive contents in amounts that would be harmful to man and the biosphere. The final licence of a repository is granted on the explicit judgement that, in principle, no active oversight or intervention is needed in order to assure long-term protection of man and the environment.

The implementation of a disposal project has increasingly come to be viewed as an incremental process in a series of successive steps, likely requiring several decades to complete. In addition to the original concept of passive protection of future generations, this changing vision also includes an assumption of the involvement of succeeding generations in the process of decision making and a need to preserve, as much as practicable, their ability to exercise choice. As a result of this evolution, reversibility of decisions and retrievability of waste have come to the fore as important concepts for countries to address and refine. The principle of providing subsequent generations with the possibility to exercise choice, which is found variously in the literature, can be interpreted as implying a progressive rather than an abrupt shift from active control to passive safety. In practice, reversibility and retrievability give recognition to the fact that preferences and intentions can change and that mistakes can happen during implementation. R&R in this way can facilitate the considered release of controls.

The policy of concentrating and confining radioactive waste in a final repository creates *de facto* a situation where the waste could be retrieved over very long time scales, extending over millennia, albeit likely at great effort and expense. If provisions meant to favour potential retrieval are incorporated into a repository design, *i.e.*, if the retrievability of the waste is enhanced, this is not done in order to demonstrate long-term safety nor do such provisions imply a clear intention to retrieve the waste in the future. The intent is merely to avoid making potential future retrieval unnecessarily difficult if future society were to decide to retrieve the waste for some reason.

As used in the R&R project, reversibility describes the ability *in principle* to reverse or modify decisions taken during the progressive implementation of a disposal system. Reversibility affects the entire process of repository development from its inception to final closure, *i.e.* until the absence of any remaining need to retrieve the waste is confirmed by the final regulatory approval to close all access to the repository. Reversibility can be seen as a means to provide flexibility during repository implementation prior to closure. 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. Reversibility of decisions can also contribute to the credibility of the decision-making process, and in some cases may even be a prerequisite to acceptance of these decisions. Reversal, however, must not be carried out capriciously and it should always be part of a considered and transparent process.

One important reason why there is difficulty in discussing reversibility and retrievability nationally or internationally is that relevant basic terms and concepts, such as “disposal”, are understood differently by different national stakeholders and/or used differently in different countries. It is important from the outset

for national programmes to be clear on what is considered waste, for which there is no intention of retrieval, *vs.* what is considered as a potential resource to be stored in anticipation that it will be used in the future. For clarity, it is important to designate a "repository" as a final facility and its contents as waste. In cases where retrievability is not chosen as a matter of basic policy and in the absence of a clear designation of finality, retrievability may still be considered necessary by some to the extent that a repository, before closure, may be viewed as a hybrid between a storage facility and a final disposal facility.

Social Policy Issues

Decision making and decision-making processes invoke domains of study and competencies that are far removed from the scientific and engineering disciplines that at one time appeared to dominate discussions on disposal. It is becoming increasingly clear that expertise in several domains in the social sciences also needs to be brought to bear on the decision-making processes for these complex projects.

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; hence the continued interest in these topics. The social pressures for reversibility and retrievability may be more in the direction of avoiding irreversible steps and of keeping active a continuing participatory decision-making process, 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 may in some cases 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 may preclude different actions in the future. Some of these drivers may decrease or change over time as the level of familiarity and confidence in a programme increases. An extended period of control may increase willingness to accept passive/intrinsic safety. In this context, the inclusion of reversibility and retrievability provisions in the national programme 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.

In considering a policy of reversibility and retrievability in order to respond to the guiding principle of preserving options for future generations, two relevant questions arise: "How should options be preserved?" and "For how long a time is it considered reasonable or desirable to preserve these options?" The answers to these questions depend upon technical, political and social factors, and are therefore variable from country to country. Some of the tradeoffs that may need to be considered 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.

- Increased cost of more robust containers and underground structures *vs.* safety benefits as well as retrievability.

- Increased cost of R&D to support retrievability, risk of increased perception of problems *vs.* benefits of improved knowledge.

- Increased difficulty of safeguards *vs.* benefits of retrievability.

- Ability to access materials that may become valuable at a future time *vs.* the need to ensure safety without imposing a burden of direct oversight.

In addition to such technological factors as the nature of the material to be disposed (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 on decision making (*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, so the diversity of approaches to reversibility and retrievability across different countries is not unexpected.

Technical and Safety Issues

With respect to the technical issue of retrievability, no national programme requires retrievability as a necessary element of the safety case for waste disposal either pre- or post-closure. National programmes that require retrievability mention three main reasons: (a) an attitude of humility towards the future; (b) providing extra assurance of safety; and (c) heeding the desires of the public and political leaders to avoid being locked into an "irreversible" decision from the moment of waste emplacement. Accordingly, the regulations for these programmes do not require that retrieval be demonstrated in practice. They require, at most, that it be argued that retrieval could be exercised. There is, however, a trend, independent of regulation, to confirm experimentally the possibility for effective retrieval of containers disposed in a repository, as such confirmations contribute to the credibility of the commitment to providing for retrievability. Experiments have been devised and run successfully and R&D is ongoing in several countries.

There exist means to enhance the potential for waste retrieval, *e.g.* by implementing more durable containers and waste forms, or by stipulating longer periods for observation before emplacing backfill materials or sealing galleries or the whole repository. There is, however, a delicate balance to consider, *i.e.* whether enhancing retrievability may or may not jeopardise safety and/or the continued ability to ensure physical protection of nuclear materials, both for present and for future situations. Cost is also a factor, as more durable containers may be more expensive, and as keeping a facility open or having stronger safeguards and physical protection measures implies ongoing costs. On the other hand, a better ability to potentially retrieve the waste can be seen as providing further assurance of reaching a final safe configuration, in that, during the operational phase, intervention to correct problems is possible and, in the post-operational phase, waste can be more safely attained should the need arise or if it were decided to regain access to the waste for reasons other than safety.

It is in no-one's interest to use retrievability provisions as an excuse to implement an immature programme. It must be understood that any decision to retrieve wastes after even partial closure would imply a major undertaking. Retrieval would be costly and would pose safety hazards; the cost of retrieval is likely to increase progressively as the system evolves towards its final configuration. If future standards are similar to today's, as we must assume for today's decision making, then retrieval would be a regulated activity. A regulatory approval to remove wastes would require that facilities exist to accept and manage the retrieved wastes safely. 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, *i.e.* not to render it unnecessarily difficult, assuming a future society that is both willing and capable of carrying it out.

If retrievability is a pre-requisite in the disposal programme, the repository licence may include retrievability conditions that may apply during specified periods of time, *e.g.* during the emplacement phase, or prior to closure. Retrieval of individual packages for operational reasons during the emplacement phase is often considered to be part of good operating practice, and would be funded as part of the basic programme. Retrieval of a part or the whole of the inventory for other reasons is generally treated as a new activity, requiring a new licence, and that would be funded only at the time it was decided upon.

During the operational phase, parts of the repository may be backfilled and sealed while other parts are still open. For those parts of the repository that remain open, the operational safety case may rely upon retrievability, for example in order to permit correction of problems arising during implementation. However, the safety case for closed portions of the repository, like the safety case for the post-operational phase, should stand on its own, *i.e.* without the need to rely upon retrievability to ensure safety. In practice, during the emplacement phase, unless there are serious problems with the repository concept or its implementation, retrievals are likely to be rare events and would likely be carried out only for a small number of containers (if any) and only for operational reasons. The likelihood of retrieval following the completion of emplacement would be expected to be even less.

Although the long-term safety case must be able to stand on its own without them, specific post-operational institutional oversight provisions, such as monitoring and records 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.

General Observations

The NEA's R&R project has touched on and developed many of the issues related to reversibility and retrievability, but it can hardly be considered the final word on the topic. At the end of this project, it is clear that the development of these and related topics will continue. While it is perhaps risky to speculate on where future discussions may lead, a review of the topics discussed during working group meetings and at the 2010 Reims International Conference and Dialogue suggests a number of possibilities, among them: continued consideration of decision making and a move towards more concrete discussions on this topic, with the help of expertise from domains such as political science and decision science; more concrete consideration of costs, perhaps with input from economics (*e.g.* "real options theory"); greater involvement of regulators and decision makers; more direct involvement of civil society stakeholders in discussions; further consideration of the relationship between retrievability and "green" societal trends (participatory decision making, increased emphasis on renewability and recycling); studies of management and governance culture as they pertain to disposal programmes; continued study of whether and how reversibility and retrievability relate to optimisation of the systems of disposal and repository evolution; and further study of the relationships between retrievability and the requirements for safeguards and physical protection of nuclear material.

The current predominating view is that reversibility of decisions and retrievability of the waste can be beneficial features of any deep disposal programme provided the limitations of the concepts are recognised. The position of many national programmes is that, from a technical point of view, flexibility in implementing the repositories is a recognised management approach, and represents a means for process optimisation. Reversibility can be a major contributor to this flexibility.

During the course of the NEA's R&R project, awareness grew that in a long-term undertaking such as a repository for high-level or spent fuel waste, the end-result of the undertaking may well be different from the original design, taking into account changes that may be introduced during the development phase for various reasons. There must be continued research and continued questioning and, because of that, adaptability to new learning. Intermediate decisions must be, to some degree, reversible or modifiable if

they are to be credible. The sensible approach to this situation is a stepwise process of learning, testing, questioning, implementation, and more questioning. Reversibility is an intrinsic part of this process, and retrievability is a technical means for achieving reversibility.

Reversibility and retrievability are tools that can contribute to a responsible approach to repository development and aid to achieve the final safety objectives through a considered and coordinated process. At the engineering level, they may help achieve the final configuration for the waste to be disposed of, but long-term safety does not rest on retrieval being possible. At the project level, reversibility may be associated with a prudent approach of verification of specific design features so that they do not unnecessarily impair or preclude fallback options. At the policy level, reversibility can be associated with a culture of stepwise decision making by requiring that the validation or the reversal of major decisions is discussed before proceeding to the next step. As well as being requested by interested parties in some programmes, reversibility is also a feature that provides opportunities for co-ordination and co-decision amongst those parties. A sequence of shared decisions confirming at each step that there were no safety reasons for retrieval could ease any decisions on moving forward and eventually closing the facility.

Deep geological repositories of radioactive waste are designed and licensed based on long-term safety not requiring the active presence of man. Reversal of decisions and retrieval of the waste are not design goals. Reversibility and retrievability, however, are attributes of the decision-making and design processes that can facilitate the journey towards the final destination of safe, socially-accepted geological disposal. Having reviewed the literature on reversibility and retrievability and reflected on how these concepts have been discussed and introduced in connection with national waste management programmes, it can be concluded that countries should have a position on these concepts.

FURTHER READING

"The Retrievability and Reversibility (R&R) Project", http://www.oecd-nea.org/rwm/rr/ (web site containing a description of the project and links to project and related documents)

OECD NUCLEAR ENERGY AGENCY (2011) *Reversibility and Retrievability (R&R) for the Deep Disposal of High-level Radioactive Waste and Spent Fuel*, NEA/RWM/R(2011)4, OECD, Paris (full report)

OECD NUCLEAR ENERGY AGENCY (2012) *Reversibility and Retrievability in Planning for Geological Disposal of Radioactive Waste. Proceedings of the "R&R" International Conference and Dialogue held from 14 to 17 December 2010 in Reims, France,* OECD, Paris (in press)

OECD NUCLEAR ENERGY AGENCY (2010) *Selected International Bibliography on Reversibility and Retrievability to Support the Current NEA Project*, NEA/RWM(2010)11/REV, OECD, Paris

OECD NUCLEAR ENERGY AGENCY (2008) *Moving Forward with Geological Disposal of Radioactive Waste: A Collective Statement by the NEA Radioactive Waste Management Committee (RWMC),* NEA-6433, OECD, Paris

OECD NUCLEAR ENERGY AGENCY (2011) *Stepwise Approach to Decision Making for Long-term Radioactive Waste Management - Experience, Issues and Guiding Principles*, NEA-4429, OECD, Paris

OECD NUCLEAR ENERGY AGENCY (2001) *Reversibility and Retrievability in Geologic Disposal of Radioactive Waste – Reflections at the International Level*, NEA-3140, OECD, Paris