Implementation of Safe Geological Disposal in Japan

International Review of NUMO's Approach and Programme Readiness: 2010

Neil Chapman (Switzerland)
Joonhong Ahn (USA)
Alan Hooper (UK)
Juhani Vira (Finland)
Piet Zuidema (Switzerland)

February 2011

Contents

1 Background and Context

1.1 NUMO was established in 2000 with the remit of implementing geological disposal of HLW and, more recently, of TRU waste. It has been developing its strategic approaches to geological repository siting, design and safety assessment, along with the associated technologies for disposal, for the last ten years and has incorporated input from R&D done by several other Japanese organisations. In a report published by the Atomic Energy Commission of Japan it was suggested that NUMO should produce a report (the '2010 Report') of its progress in technical developments since 2000. In addition to summarizing technical progress, NUMO decided to introduce its implementation strategy for the geological disposal (GD) programme. This is a key stage in the Japanese GD programme and an important assessment point for NUMO. The government has consequently asked NUMO to commission a review of the 2010 Report by independent specialists. NUMO thus decided to organise the international review of the 2010 Report alongside peer review by independent experts representing the Atomic Energy Society of Japan (AESJ).

1.2 The independent international review has been carried out by a small Panel of experts in geological disposal and its implementation, from Europe and the United States. The Panel was asked to use its experience of other national programmes to assess NUMO's state of preparedness (in terms of both strategy and availability of appropriate technologies) for carrying out the initial stages of repository implementation. These stages involve assessing potential sites, carrying out site investigations, identifying appropriate repository designs and safety concepts, assessing long term and operational safety aspects, and selecting a site (or sites) which fulfil both the legal requirements and NUMO's requirements for HLW and TRU disposal.

1.3 In carrying out the review, NUMO has also asked the reviewers to provide any general advice that might assist in more effective programme implementation, as well as to advise on a number of specific issues. This report contains the results of both the general review and the advice provided by the Panel.

2 Procedure for the Review

2.1 The main '2010 Report' is an extensive document of over 700 pages and, at the time of the review, was only available in Japanese. The principal information evaluated by the review Panel was a summary of the key strategic aspects of the main report, in English, prepared specifically to assist the Panel. Consequently, it was important for the reviewers to get a broader picture of the scope and content of the main report so that they could be aware of the depth of the work that is reported on. The process thus began with a two-day information meeting hosted by Nagra, in November 2010 in Switzerland, where the reviewers were introduced to each of the main sections of the main report by NUMO staff and were able to ask questions, as well as provide initial comments and views on the NUMO approach to the geological repository programme.

2.2 The English language summary was provided to the review Panel in January 2011. The Panel reviewed the information contained in this document and met at Imperial College in London, UK, on 16th and 17th February 2011 to discuss their views and prepare this review report. Members of NUMO staff also attended this meeting and were able to provide further clarification of issues that the Panel discussed. The input of NUMO staff to this report was confined to the correction of misunderstandings and factual inaccuracies.

3 General Comments

3.1 The 2010 report describes an extensive and comprehensive programme of work carried out by NUMO and other R&D organisations in Japan over the last decade. The scope and content of the information introduced to the Panel are impressive and give a

good picture of NUMO's capabilities and the thought that has gone into developing the present strategy.

3.2 Because the volunteer repository siting process in Japan could lead to potential repository sites emerging in almost any part of the country (that is not excluded by the evaluation factors for qualification), NUMO has to keep open a range of possible designs and approaches to site evaluation. Whilst this situation may be considered to introduce poorly constrained uncertainties into programme management, it has not proved to be the case and is an area where NUMO is not alone: the UK is currently moving forward successfully, with similar boundary conditions on its GD programme. The reason that progress can be made is because the internationally recognised approaches to ensuring the safety of GD facilities are at a more generic level and can be applied as a framework for the overall concept of GD of HLW and TRU waste, regardless of siting issues. This has allowed NUMO to make much progress, based initially upon the milestone H-12 study, which will be sufficiently generic regardless of how the volunteer programme develops. NUMO has thus developed a comprehensive, staged plan for development of Japan's first geological repository by summarizing the legal and regulatory frameworks and the technological state-of-the art.

3.3 The Japanese repository development programme is currently founded upon:

- the generic scientific feasibility of geological disposal that has been established (and is now accepted[1]) internationally by more than 30 years of intensive work and was specifically demonstrated in Japan by the H-12 report, in 1999;
- a legal (and progressively developing regulatory) framework formulated by the Nuclear Safety Commission, the Atomic Energy Commission and the Ministry of Economy, Trade and Industry in the last decade;
- the solicitation programme for volunteer municipalities and the proposal by the national government to be a host community;
- cost-sharing schemes involving the national government and the electricity companies;
- a range of fundamental scientific and engineering studies, including the Underground Research Laboratories (URLs) in Horonobe and Mizunami.

NUMO has developed its programme by integrating these cornerstones into a detailed plan. The main concepts and parts of the plan have been adopted from experiences in other countries and international generic developments. Based on the success of other national programmes, it is reasonable to expect that the development could be successfully carried out by NUMO within this plan, with timely revisions based upon conditions specific to Japan (provisions for which are also included in the plan).

3.4 The information provided gives a clear impression that NUMO is well aware of the task that lies ahead and of all of the detailed activities that will need to be undertaken to implement safe disposal. In the last ten years, together with the R&D organisations NUMO has studied the tasks to be conducted and has also followed and contributed to developments at the international level. Not all the details of their work could be described in the summary documentation, so it cannot be judged whether or not NUMO's preparations are complete, but the overall description allowed the Panel to grasp the enormous amount of work that underlies the report. The description of the implementation of the disposal project is structured clearly and captured in a series of activities and steps to be conducted, as illustrated by the roadmaps.

3.5 NUMO has continued the development of the H-12 type repository concept and is now able to present a number of possible designs for its practical implementation. Some of

[1] In November 2010, the proposed European Union (EU) Council Directive on the Management of Spent Fuel and Radioactive Waste stated that: *"Following 30 years of research, it is broadly accepted at the technical level that deep geological disposal represents the safest and most sustainable option as the end point of the management of high level waste and spent fuel considered as waste. Thus moving towards implementation of disposal should be pursued."*

the technical developments are based on international projects, but a lot of important technical work has also been carried out in Japan. The Panel agrees that the H-12 concept is a reasonable basis for planning of the initial stages of the site characterisation programme - and may turn out to be the best choice for the further development as well. However, the Panel also points out that the implementation of a H-12 type concept puts certain demands especially on the hydraulic and geochemical conditions of the host rock. NUMO is aware of these constraints and envisages that, in the end, the repository concept and design have to be adjusted to the specific conditions of the candidate sites. The Panel concurs, but, referring to the potential siting environments in Japan, recommends that NUMO should also look to repository concepts different from H-12. In some potential siting environments the H-12 concept could even be greatly simplified because of benign host rock conditions. Narrowing down to the most appropriate concept could be assisted by use of a requirements management system (see further discussion on alternative concepts at 5.6).

3.6 NUMO points out that measures planned for operational safety have to be assessed vis-a-vis their potential impact on long-term safety. However, the issue is broader: all construction and operation practices (including any specific requirement to maintain retrievability) may have implications for long-term safety and, therefore, require an assessment before adopting them.

3.7 An area of fundamental importance is evidence for the existence and maintenance of a sound scientific and technical basis for the GD programme. This was emphasised in the H-12 report, but NUMO was able to provide only limited information about how this important aspect will be addressed. As discussed below, safety assessment provides the means to assess the consequences of scientific and technical uncertainties and to identify what further R&D may be required. Identification of appropriate R&D and ability to specify and direct national R&D priorities is a key matter for NUMO.

3.8 A central aspect of NUMO's development is to ensure that it is informed of and makes best use of the intensive development work on GD that is taking place in other countries. NUMO has been able to do this by involving scientists and programme managers from other national GD projects as advisers and in R&D work, as well as taking an active part itself in international programmes. The review Panel believes that this is an area where NUMO should continue to be active and maintain a high profile, taking advantage of involvement in large scale demonstration and testing projects in the advanced European programmes that expect to be implementing GD by 2025. In so doing, it would be helpful if NUMO could identify topics where its approach may differ from, or be in the lead of approaches used in other countries (e.g. few other countries have to deal with tectonic activity of the same scale as does NUMO, which has led them to the development of pioneering methodologies). To facilitate information exchange and make co-operation more efficient, the Panel suggests that it would be helpful if NUMO were to publish more of its documentation in English.

4 NUMO's Safety Strategy

4.1 NUMO is following the internationally accepted approach to establishing the safe disposal of radioactive wastes through a hierarchical approach to safety. The **safety concept** that underpins GD is essentially based on the use of a multi-barrier system, where a combination of engineered and natural barriers provides isolation of the wastes from the surface environment and containment of the radionuclides associated with the wastes. A long-term **safety case** is developed for the concept or concepts under consideration, to provide a key input to decision-making in the stepwise implementation of the programme. The safety case comprises a number of elements:

- **safety functions** of the various components of the multi-barrier system for a specific safety concept and how they are met;
- **safety assessment**, analysing the performance of the overall system, quantifying radiological dose or risk resulting from disposal system evolution and providing feedback on what is important and what not;

- multiple lines of arguments; e.g. natural analogues;
- quality of arguments, data and analyses; management of uncertainty; evaluation of confidence;

A different level of detail will be associated with each of these elements according to the different stages of the implementation programme and the varying requirements of different audiences for the safety case.

The **safety strategy** brings all of this together by managing the supply and integration of information from site characterisation, engineering design and research and development; iteration to identify further information needs; and matching repository concept and design to the conditions at a potential site.

This overall approach to safety is considered in more detail in the remainder of Section 4.

4.2 The Safety Strategy developed by NUMO represents, in principle, a state of the art approach that utilises concepts from other national programmes, has a firm basis in the internationally accepted methodologies described at 4.1 (arising from the IAEA and NEA[2]) and is adapted to the particular requirements of the evolving Japanese regulatory system. Although the Panel has some specific issues to raise concerning the use of terminology, we consequently consider the basic framework to be sound and ready for application at this stage of the GD programme, although we consider that benefits could be gained from trialling some aspects of the approach in the immediate future (see 6.7).

4.3 It is clear that the search for increasingly higher levels of safety assurance is the driving force in the step-wise approach chosen by NUMO. There will be a number of checkpoints at which the real progress in this direction will be assessed before moving to the next stage. The whole repository development programme has been considered, up until final closure. The detailed roadmaps show that NUMO has a good understanding of the activities needed in the future. We comment further on the roadmaps at 5.1.

4.4 Japanese policy is to “confirm” long-term safety. Whilst this may be a nuance of translation, the Panel feels that there is scope for misunderstanding about what ‘confirmation’ might imply. The emphasis needs to be placed on choosing a good site, within the constraints of the site selection process, and matching it with a good repository design, for which there is a sound scientific and technical basis. At the early stages of implementation in particular, the main objective for NUMO is to show that it has the knowledge and capability to propose a disposal system that has the prospect of being safe, subject to gaining an adequate understanding of site conditions and being able to analyse the evolution of the system under those conditions. Thus, in discussions with communities and other stakeholders, NUMO can make it clear that it intends actively to ***create*** safety by selecting a good site and a design adapted to the wastes disposed of and the site selected.

4.5 The foundation of NUMO’s approach to safety is three ‘policies’ that are designed to reach the goal of ensuring safe disposal. For the Panel, these are clearly a component of NUMO’s approach to producing, managing and presenting information in its safety strategy. It would be useful for NUMO in communicating its safety strategy to describe the process that led to it defining these policies, why they were chosen and how it will ensure that the overall goal (safe disposal) is met.

4.6 In most national programmes (e.g. Belgium, Finland, France, Switzerland, UK) the safety case and the supporting safety assessments are central to decision making from the outset of the programme, including the site selection process. Initially provisional

---

[2] *Geological Disposal of Radioactive Waste, Safety Requirements.* Jointly Sponsored by the IAEA and the NEA, IAEA: Safety Standards Series No. WS-R-4, International Atomic Energy Agency, Vienna.

Post-closure Safety Case for Geological Repositories: Nature and Purpose. NEA Report Number 3679. OECD/NEA Nuclear Energy Agency, 2004, Paris, France.

cases/assessments are an input to all the important decisions and help to identify unresolved, relevant issues. A regularly updated safety case will also be used for guiding the R&D work. This central role of the safety case does not have great prominence in the documentation provided to the Panel, nor do the 'anchor points' or 'guiding lights' of safety functions. It appears that safety functions will only be defined after some analysis of a disposal concept that has been tailored to site conditions. It would inspire much greater confidence if the safety functions were to be defined initially, since NUMO, R&D organisations and other stakeholders will then be able to understand what is considered to provide safety and what must therefore be tested.

4.7 Bringing all of this together in safety assessments appears clearly in the different steps of the safety roadmap, but the outcomes of the iterative development of the safety case and the completion of the safety assessments seem not to drive the decision making and the approach chosen. This seems a critical matter to the Panel and we make a specific suggestion on how NUMO might strengthen its capacity in this area at 6.7.

4.8 The Panel notes that safety assessment has two overall goals: to evaluate the expected level of safety (including the meaning of remaining uncertainties) and to provide feedback for system development (e.g., matching repository design to the site). Safety assessment should thus be presented as a tool for integrating the information that has been acquired up to a given point from site investigations, engineering design and R&D, and for analysing the consequences of the uncertainties associated with that information in order to prioritise further information-gathering. Currently, the interdependence of repository concepts, the safety concept and safety functions, does not emerge with the necessary clarity. It may be useful for NUMO to explain the use of safety assessment within a strategy of "adaptive staging", in which the importance of feedback and guidance for site selection, guiding RD&D, etc is more clearly visible. A planned, adaptive staging strategy also allows NUMO to make use of a flexible approach to all aspects of its programme. Experience with other national programmes is that the need for, and benefits of, flexibility need to be explained early on in a programme, to avoid misunderstandings about 'changes of direction', which can be harmful to the GD programme.

4.9 In developing its strategy, NUMO is thinking far ahead. The timescales to the DIA stage are already long and to the point of construction and operation are one, possibly two, generations into the future. Consequently, we can expect that the details of the strategy will change to accommodate developments in the siting programme. The important thing for NUMO is to have the elements of a workable plan, and we believe that this is well demonstrated in the documentation provided. The critical part of the plan clearly concerns the next 5 to 10 years and we comment further on this at 5.1.

4.10 Some national programmes are required to use the BAT (best available technology) approach to interfacing design with safety. The Panel suggests that this may not be the most appropriate conceptual basis for NUMO, as it is open to subjective interpretation, can introduce adaptations with nugatory benefits for large resource commitments and may thus constrain optimisation, unless implemented as 'BATNEEC' (BAT not entailing excessive cost).

4.11 There are areas of work where we consider NUMO needs to be proactive in the short-term (i.e. next five years) and also to take the leading role:

- The development and analysis of scenarios and the application of probabilistic methodologies to assess the likelihood of lower probability scenarios. We consider that NUMO could provide valuable information here to inform the development of appropriate regulatory standards by, for example, scoping the risks associated with low probability events.
- Related to this, NUMO should extend its consideration of the very long-term (beyond 100,000 years) to answer questions about the ultimate 'fate of the repository'. In some national programmes, eventual exposure of the repository by uplift and erosion is having to be addressed, even though it is only a possibility in the very distant future (millions of years) and this has regulatory implications.

- Scoping out the safety case implications of significant design alternatives for (a) different geological/geographical environments, (b) different approaches to managing the waste in terms of storage and retrieval, and (c) different inventories and different scenarios of development of the Japanese nuclear power programme.

5 NUMO's Project Plan

5.1 The impressive series of roadmaps that contain NUMO's Project Plan reveal the depth of thinking that NUMO has put into planning. They appear to contain all major aspects that need to be considered. In the Panel's view, the challenge to NUMO will be in interfacing the requirements that the roadmaps place on the organisation with its actual work programme. The project plan has addressed the many important steps in the total programme, but many of these are far into the future. One area that could be more clearly represented in NUMO's plans is the immediate steps and activities that NUMO will need to activate as soon as potential host communities emerge from the volunteer process. It would be valuable for NUMO to be able to state exactly, step by step, how it will initiate and carry out, for example, the first year of its programme as it enters the literature review, as this will be where the strategy will be most obviously and publicly tested.

5.2 Thus, an important impression of the Panel is that NUMO has identified and understands the issues to be addressed very well, has a structured project plan represented by the detailed roadmaps, but will need to put much effort into mapping its issue resolution activities (R&D and other work) onto those roadmaps. The management framework within which to make the decisions on crucial points such as site selection and/or the exclusion of sites, defining the site characterisation programme, selection of the disposal concept and optimisation of the design is not so clearly presented, and the involvement of stakeholders and research organisations in these decisions is currently not clear.

5.3 The Panel suggests that NUMO takes care to differentiate between the selection of a potential *host rock* at a site and choosing a *location* for the repository within the host rock. It would be helpful if NUMO were to explain the challenges that will be faced when a volunteer area enters the process, in terms of the possible choices between rock types.

5.4 The Panel felt that NUMO may be overemphasising the significance of the information that can be derived from monitoring in the R&D and safety strategy. While this is an important topic to have a strategy on and to be able to discuss with the public, it should not be allowed to become confused with other design and management issues that will really affect safety and viability.

5.5 In this respect, NUMO's documentation dwells rather more on far-field (natural barrier) retardation performance (i.e., on radionuclide mobility and transport) than on the containment provided by the engineered barriers and the Panel considers that the latter should be given more prominence in the way that NUMO presents the GD concept. At present, safety assessment is largely presented as a tool for conducting radionuclide transport calculations. Particularly at the early stages of site selection, a much more important role will be to present the developing understanding of the containment potential of all components of the multi-barrier system under the likely site conditions and the extent to which this matches up to their defined safety functions.

5.6 Topics where NUMO might wish to consider placing increased programmatic emphasis include the following:

- Deeper investigation of repository concepts that are alternatives to the emplacement methodologies used in H-12. The Panel considers that it would be useful for NUMO to carry out simple, scoping evaluations of the benefits and drawbacks of different designs in different situations and waste management scenarios, so that it can gain a clear picture of whether (and in

what circumstances) it would be beneficial to give serious consideration to other repository concepts;

- Clarifying how exactly it will link the functionality of Site Descriptive Models to the rest of the programme. NUMO is unclear on what level of information it expects that it will have collected by the end of each stage of the site selection process, referring rather to types of investigation methods. Care needs to be taken about the assumptions on the level of detail of information that can be available at early stages as an input to repository design. The assumed characteristics of each successive site descriptive model need to be communicated more clearly to build confidence (or otherwise, to test) that the information required will be available;
- Safety aspects of transporting waste to the repository site: even though this is carried out as a routine operation worldwide and is subject to rigorous and universally accepted IAEA regulations, it is a topic that is always of interest and concern to the public – both from the radiological and the environmental perspectives (and the latter also affect other transport activities around the repository area);
- Being prepared to respond to questions about which rock properties are important in its safety case, how they contribute to safety and what type of THMC conditions would be favourable for a host rock. Whilst there is an understandable reticence within an entirely volunteer process to be in any way prescriptive, a qualitative or semi-quantitative discussion of how certain properties contribute to safety would be valuable in answering the inevitable public question of 'what are you looking for?'

6 Suggestions for NUMO's Forward Planning

6.1 In this Section, we make additional suggestions that may assist NUMO in presenting and implementing its forward plan. *We note that some of our suggestions go beyond NUMO's own immediate responsibilities in that other organisations would need to consider them.* We consider that it would be valuable to the Japanese GD programme for NUMO to enter a dialogue with the relevant government and other agencies on some of these matters.

6.2 If the volunteer siting process leads to a decisions for co-disposal of HLW and TRU wastes then this will have significant effects on the nature and content of NUMO's technical work programme. At present, it is thus difficult for NUMO to focus the R&D and site evaluation programme but the Panel suggests that NUMO needs to consider both possibilities (separate or co-disposal) in all aspects of its planning and activities. This will have important resource implications for NUMO.

6.3 A similar issue is the option/possibility of having to abandon a site during the siting process. Experience from other national programmes is that technical surprises will almost certainly arise in the siting process, which might require an adaptation of the concept, and it cannot be *a priori* excluded that a site has to be abandoned. It will thus be useful for NUMO to share with volunteer communities its thinking about the possibility of surprises, the likelihood of adaptation and the consequent need for flexibility (especially in the early PI period). Taking this a step further, it would also be useful for NUMO to explain to communities how it will choose between two clearly suitable sites and the point in the programme up to which communities can withdraw from the siting process.

6.4 It is widely recognised internationally that gaining public approval is essential for GD projects. Although NUMO has an active outreach programme to the public, the Panel gained the impression that the public may not be sufficiently involved in an active and equal fashion – something that has been found essential in other national programmes. Having a programme that is able to 'listen and adapt' seems to be a prerequisite to success in most countries and simple explanation of a programme is not enough.

Consequently, the Panel suggests that it may also be useful for NUMO to interact with specialists in communicating to and interacting with different audiences about scientific and risk issues. There are ethical and societal considerations in discussing hazards and the provision of safety over very long time periods that require more than just a natural sciences input. The underlying necessity of having clear social and ethical standards and positions is recognised by NUMO but may be an area that could be further developed with expert assistance and more prominently advanced in communicating with potential host communities.

6.5 We believe that it would assist the overall Japanese nuclear power programme if the different wastes destined for GD were placed into a broader national context of how the nuclear fuel cycle may develop. There are clearly many issues of optimising just the disposal aspects that also affect optimisation of the fuel cycle, and vice versa. NUMO could take a prominent role in explaining the alternatives pathways and options within its overall management strategy and how these could beneficially affect national decisions on nuclear power production. Examples of alternatives, some of which have already been mentioned, include: length of storage time for HLW; co-disposal with TRU and, possibly, other wastes; combining protracted, high-security storage underground with eventual disposal; the possibility that some types of fuel will not be reprocessed in future and may require direct disposal etc.

6.6 Several Japanese organisations are carrying out fundamental research into long-term safety issues. Some of this research is currently outside the realm of NUMO, but the implementation of the safety strategy described in the report requires that NUMO has means to guide the ongoing and future research programmes in the direction that corresponds to its information needs. For example, in Finland, Posiva (as the 'end-user') is responsible for the whole of the R&D programme that generates the information that it needs. The same situation exists in Sweden and also in Switzerland. In the UK, the NDA has a published R&D strategy and commissions R&D to meet these strategic requirements, for example, sponsoring R&D in universities and maintaining close contacts with the national research councils. It is important for the success of the Japanese GD programme as a whole that mechanisms are in place so that NUMO, the end-user of this information, can take this guiding and commanding role.

6.7 It is 12 years since H-12 and the exercise carried out recently for TRU did not involve NUMO, which was not at that time responsible for TRU disposal. A major challenge for NUMO will be to integrate the efforts of the different teams that will be involved in safety assessment, design and site evaluation, especially when much of the practical work will be carried out by the wide range of organisations mentioned above. It is evident to the Panel that a range of site and safety assessment techniques have been developed in a non-centralised way and that making them interlock to make a fully integrated safety assessment (for example) will be challenging. Because it will be some time before site-specific information comes along so that NUMO can conduct a first, fully focussed, safety assessment, there is a potential window of opportunity in which this could be done. The Panel therefore suggest that NUMO might consider running a mock assessment exercise, with its own staff acting as the project directors and the objective of carrying out a comprehensive assessment at an example location, bringing together its work on site descriptive models, repository concepts, scenario development, tectonic hazard analysis and safety assessment methodologies. The end result itself will be unimportant, quantitatively – the aim is rather to test the mechanisms for managing interactions between groups and organisations and the success of these interactions. This approach has proved invaluable as a team-building and understanding-building tool in a number of organisations in other national programmes (for example, the Site-94 project in Sweden). NUMO would need to decide whether it is practical to run such an exercise in parallel with initiating literature surveys on any volunteer sites that may arise in the coming year or two.

6.8 The regulatory basis for GD in terms of specific dose and risk guidelines, and other requirements on NUMO as an implementer, is under development and, we understand, may take some years before it crystallises completely. Establishing standards needs to be done within both a clear scientific framework and a context of identifying and

meeting societal expectations. It is clear that NUMO has carried out work on issues that would be influential in establishing national standards and that NUMO consequently should have a strong voice in such discussions. The Panel encourages NUMO to set out its own ideas on appropriate approaches and to help foster open discussions with other government agencies and with the public.

6.9 The Panel understands that retrievability is a requirement on the Japanese GD programme. Provision of specific capabilities to facilitate retrieval could have impacts on the long-term safety case and operational safety. As with other national programmes, NUMO will have to ensure that any such provisions that it may be required to make do not unduly affect the pre- or post-closure safety of the repository.

7 Concluding Remarks

7.1 NUMO's primary intention in developing the '2010 Report' has been to show that they have the knowledge, tools and strategy to be ready to continue their carefully planned site selection process with literature surveys and preliminary site investigations, as soon as candidate sites become available.

7.2 The impressive series of roadmaps that contain NUMO's Project Plan reveal the depth of thinking that NUMO has put into planning to meet this objective. They appear to contain all major aspects that need to be considered. NUMO has identified and understands the issues to be addressed very well, has a structured project plan represented by the detailed roadmaps, but will need to put much effort into mapping its activities onto those roadmaps.

7.3 The Safety Strategy developed by NUMO represents, in principle, a state of the art approach that utilises concepts from other national programmes, has a firm basis in the internationally accepted methodologies and is adapted to the particular requirements of the evolving Japanese regulatory system.

7.4 The Panel considers that it would be useful for NUMO to carry out simple, scoping evaluations of the benefits and drawbacks of different repository concepts and designs in different situations and waste management/inventory scenarios, so that it can gain a clear picture of whether (and in what circumstances) it would be beneficial to give serious consideration to other concepts.

7.5 In these early stages of implementation the Panel considers that the highest level objective for NUMO is to show that, for a potentially wide range of siting environments, it has the knowledge and capability to propose a disposal system that has the prospect of being safe, subject to gaining an adequate understanding of site conditions and being able to analyse the evolution of the system under those conditions. NUMO also needs to know when it has to exclude a site. In the Review Panel's opinion, the information received from NUMO and the outcomes of the discussions held with them fulfil this objective: it is clear that NUMO knows how to continue the geological disposal programme and what the challenges are for the future. However, the Panel believes that NUMO could be much clearer about the step-by-step activities included in these immediate steps into the LS and PI stage in order to be absolutely convincing. The Panel believes that this may simply be a matter of assembling and presenting the relevant material in a more prescriptive way.

8 The Review Panel

Neil Chapman (Chairman): is Professor of Environmental Geology in the University of Sheffield, UK, in the Department of Engineering Materials (part time), Chairman of the ITC School of Underground Waste Storage and Disposal (Switzerland) and an independent consultant in radioactive waste management with more than 30 years experience as an adviser to national and international programmes. He is the author of eight books and over 150 papers on radioactive waste management and was awarded the 2010 James Watt Medal of the Institution of Civil Engineers for published work in this area.

Joonhong Ahn: is Professor of Nuclear Engineering at the University of California, Berkeley, USA, where he specialises in research into multi-barrier geological repository systems, with particular emphasis on performance and safety assessment. He is a member of the Nuclear and Radiation Studies Board, US National Academies.

Alan Hooper: is visiting Professor of Repository Science and Engineering at Imperial College, London, UK and acting Chief Scientific Adviser to the Radioactive Waste Management Directorate of the UK Nuclear Decommissioning Authority (NDA). He has more than 30 years experience of managing the scientific and technical activities in support of nuclear decommissioning and radioactive waste management programmes for the UK electricity supply industry and national waste management organisation.

Juhani Vira: is Vice-President for Research at Posiva Oy, Finland and responsible for the overall management of site characterisation and research into long-term safety of the planned repository for spent fuel at Olkiluoto. He has been working in the area of nuclear fuel cycle and waste management since 1975, first as a researcher, later as a research manager. Currently he is actively involved in the licensing process of the planned repository.

Piet Zuidema: is the member of the Executive Team that manages Nagra, the Swiss national radioactive waste implementing organisation, where he is responsible for the overall coordination and management of the Science & Technology programme. He has more than 25 years of experience. He was in charge of several major repository projects within the Swiss deep geological repository programme and is also responsible for Nagra's RD+D programme. He is also member of several international committees (e.g. NEA / OECD) and has participated in several expert advisory groups in other waste management organisations abroad.