# Main findings

## *1. Licensing regimes*

***Licensing regimes vary from country to country. When the license regime involves several regulators and several licenses, this may lead to complex situations. Identifying a leading organisation in charge of overall coordination including preparation of the licensing decision is a useful practice. Also, if a stepwise licensing process is implemented, it is important to fix in legislation decisions and/or time points and to identify the relevant actors.***

It was recognized during the workshop that the number and level of licences to be granted vary among countries. Depending on the national legislation, a licensing process implies to deal with one license combined with several regulatory permissions to a number of licenses, all of them taken at the highest level. It may be granted by different regulators and require the production of a large number of supporting documents. In particular it was stressed that mining regulations are often not applicable and specific regulations for underground activities involving nuclear operations may have to be elaborated.

The licensing process may be quite complex. A typical example was given by Sweden where the license application is addressed by two different legislative acts: the Environmental Code and the Nuclear Activities Act. The license application is thus being reviewed in parallel by two regulators: the Environmental Court and the Swedish Radiation and Safety Authority (SSM). Municipalities are involved as well since they have right of veto and should give statements to the Government on the project. At the same time both regulators will define conditions associated to the permits. On the basis of these statements and statements by the regulators, the final licensing authority, i.e. the Government, will make a decision. A similar kind of licensing process is foreseen in the United Kingdom.

In Finland and France, the Parliament is strongly involved in the licensing process. In Finland, a Decision in Principle had to be rendered by Parliament in 2000 before the construction of Onkalo. The construction license of the repository facility will be granted by the Government. The actual construction will be regulated by STUK, the nuclear regulator. It will include several reviews and approval steps, holdpoints and viewpoints. In France, the submission by ANDRA of the license application for construction will be followed by a review led by the nuclear regulator, ASN. On this basis, the Government will present a bill in Parliament in order to define the conditions of reversibility for the repository. The creation decree will be signed by the Government. It will include licensing conditions defined by ASN.

Lessons learned, with respect to licensing regimes, from the discussions at the round tables include:

(i) when several regulators are involved in assessing an application, there is a need that the law or a governmental decree designates a lead regulator. In many cases, it was noticed that the nuclear regulator is the leading regulator. An example was given by the United Kingdom where ONR will be the licensing body even though the Environmental Agency will play a major role in reviewing the assessment of post-closure safety.

(ii) when preparing for a licence application it is important that the licensee identifies all the necessary permits early in the process. Overlapping and/or conflicting requirements and relationships as specified in different permits must be clarified. In this respect it is important that one organization be in charge of overall coordination including preparation of the licensing decision. Many programmes have agreed that the final decision on licensing conditions lies with the leading regulator who should make sure that there are no conflicting or irreconcilable regimes. Possibly due to time constraints this difficulty was not highlighted in presentations during the workshop.

(iii) in countries that have adopted a stepwise process for implementing geological repositories, it is agreed that decision and timeframe to progress to the next step shall be indicated in the legislation. If time takes precedence over everything else, this may have implication on the quality of the project. Conversely, if there are no deadlines and/or stated requirements for the decision cannot be met in a reasonable period, local communities and the stakeholders may lose confidence and knowledge, both may have detrimental effects on the project.

It was made clear, during the workshop, that depending on whether the licensing authority is the main regulator or the government/parliament, the situation can be very different. When the licensing authority is also the main regulator (USA, Canada, UK) the project is less sensitive to the political situation (the fate of the Yucca Mountain Project is an exception in this respect). However there can still be possible conflict between the regulator and local government, which could imply judicial actions as it was the case for WIPP in the USA. Complex situations may also arise in the case of multiple licensing authorities, and they have risen in the past in the UK. When the Government is the final licensing authority, which is the case in most European countries (Sweden, Finland, France, Germany), the Government has responsibility in coordinating the procedure for granting the necessary permits.

The different roles devoted to the regulator(s) consist of:

- defining technical regulation, developing guidance,
- reviewing the license application,
- sending statements to the Government and setting up the licensing conditions and hold points,
- inspecting and reviewing construction, operation and closure,
- making decisions at the different hold points and, in some cases, submitting those too to government,
- providing information to political authorities and the public.

### *2. Challenges for construction (implementer)*

***There is considerable experience in civil and mining engineering that can be applied when constructing a deep geological disposal facility. Specific challenges are, however, the minimization of disturbances to the host rock and the understanding of its long-term behavior. Construction activities may affect the geohydraulic and geochemical properties of the various system components which are important safety features of the repository system. Clearly defined technical specifications and an effective quality management plan are important in ensuring successful repository implementation which is consistent with safety requirements. Monitoring plan should also be defined in advance.***

There is a general agreement that, in the license application for constructing a repository, the implementer should demonstrate the industrial feasibility of construction. The safety case presented by the implementer before the construction of the facility should show that all subsequent activities that may be carried out, will not compromise safety.

It was recognized that there is significant experience in the construction of railway and motorway tunnels. Much experience, more than one hundred years, in the construction of large underground cavities also exists as well as experience in building underground laboratories for RD&D research in waste disposal. The implementer should utilize and apply the relevant information to the construction of deep geological repositories (DGRs). Specific challenges for DGRs are the minimization of disturbances to the host rock and the behavior in the long term.

During the workshop the conditions for preparing the application for the construction phase were discussed. It was acknowledged that before construction begins the implementer should substantiate an adequate level of site characterization and make sure that construction plans take the findings of site characterization into account. On this basis, the implementer adapts the conceptual design to the site properties, specifies and substantiates the reference design of the disposal facility, sets out detailed techniques for excavation and construction.

Site characterization may be performed in several ways. It may be performed in an independent underground laboratory in the same host rock formation as the one planned for the disposal facility but in a different location (e.g. Bure underground laboratory in France) or a characterization facility constructed after the access to the final disposal facility is excavated (e.g. a specific URL such as the Onkalo facility in Finland). In the later case the construction work of the access pathway to the facility should comply with nuclear and environmental regulations.

There was consensus among participants that the safety case, to support the implementer's application to construct the facility, should cover all subsequent activities, including later operation, closure and post-closure of the facility. The implementer also selects the main options for the operational phase and develops technical proposals for the closure of the facility. The demonstration of feasibility implies that a credible solution should exist in principle for all steps in the project even if this initial solution is not the final one. This means that sufficient flexibility should be maintained when granting a license to accommodate possible future developments and needs.

Identification of construction factors that may disturb safety functions and compromise long term safety is of major importance. It was recognized that construction affects site characteristics and that the implementer has to set requirements on construction work. In general, the most important features for safety that could be either created or influenced by construction activities are related to geohydraulic or geochemical disturbances. The focus of monitoring should be placed on these features. Geohydraulic changes are brought about by the inflow of groundwater to the open tunnels and shafts, and especially so in crystalline rock; boreholes drilled from the facility or in its neighborhood could add to these effects. The effect of main stress directions in hard rock is important to consider. The hydraulic changes could entail geochemical effects, but further geochemical effects could also be caused by the man-made materials used in the construction, e.g., grouting or tunnel lining, and investigations activities. There should be limitation on materials that might induce unwanted chemical interactions. A special type of disturbance to the host rock is the excavation damage zone (EDZ) created around the tunnels and shafts.

These constraints should lead the implementer to demonstrate that they are able to ensure that the engineered components will be built according to nuclear specifications at an industrial level and in a way that the characteristics of the host rock important for long-term safety will not be compromised by construction activities. It is therefore important to establish criteria and specifications – e.g., through safety function indicators – and define QA rules so that it can be judged if the «product» meets the requirements.

### *3. Challenges for construction (regulator)*

***The regulatory organization should prepare itself to the licensing review before construction by allocating sufficient resources. It should increase its competence, e.g., by interacting early with the implementer and through its own R&D. This will allow the regulator to define appropriate technical conditions associated to the construction license and to elaborate a relevant inspection plan of the construction work.***

It was agreed in the workshop that regulators should increase their experience through dialogue with implementers, particularly early in the process but avoiding co-conception. Examples were given from France and Sweden. In France a stepwise approach was set up by the 1991 Act. The application decrees leading to the construction of the Bure underground laboratory and the subsequent 2006 Act defined the steps toward the application for construction in 2015. This shows a good example of a stepwise process. Another example is the review of the RD&D programs of SKB by the regulator every third year in Sweden. R&D requirements to the implementer should be substantiated by experience from regulatory R&D.

The regulatory organization should prepare itself for the licensing review. This point was detailed by the USNRC when describing the organization for reviewing the Yucca Mountain Project. It was pointed that the review was planned to last three years, including hearings, examination of 3 million pages and 299 contentions. It needed the elaboration of a detailed project plan and allocation of adequate resources, including the creation of a safety integration review team with work break-down structure and experienced staff who are familiar with legal terminology.

It was also agreed that as part of the authorization process, regulators should impose conditions and requirements on the implementers to ensure regulatory compliance during the construction phase. These conditions may specify:

- hold points in the construction for regulatory involvement or interaction,
- requirements for documentation and substantiation to be provided to the regulator before authorization to operate the facility,
- if not already established in the regulatory framework, definition, in discussion with stakeholders, the detailed procedures and expected conditions for delivering the authorization for closure of the disposal.

As detailed in the Finnish presentations, the regulator requires from the implementer : the description of constructing organization, staff competences, the regulations, codes and standards to be used in the construction, the management system (especially safety and quality management), design data, drawings, construction documentation, in-service inspection plan, etc.

Regulators should also outline their expectations. The long-term safety related rules and instructions on the design and construction should be put in place before construction begins. This requires all systems, structures, components and activities to be clearly classified, based on their safety functions, and the implementation of a quality management system for resource controls.

Regulators' inspection activities shall cover all areas of the regulator's responsibilities. Inspections shall be carried out to ensure that the implementers' full compliance with regulations, and conditions as stated in all approvals granted by the regulator. In Finland, during the construction of Onkalo, inspection activities have been divided into three areas:

- Construction Inspection Program (CIP) on management system, on main operations and concerning functions and activities ;
- Inspections concerning the readiness to begin excavation and other work phases ; and

- Inspection concerning construction works on site (once every two weeks).

### 4. *Challenges for operation (implementer and regulator)*

***After construction, obtaining the operational license is the most important and crucial step. Main challenges include (a) establishing sufficient confidence so that the methods for closing the individual disposal units comply with the safety objectives and (b) addressing the issue of ageing of materials during a 50-100 years operational period. This latter challenge is amplified when reversibility/retrievability is required. Managing concomitant construction of new galleries with continuing operation and/or closure in the existing galleries remains as another challenge.***

*General context*

The implementer will typically submit an application for licensing the operation of the underground and surface facilities under the nuclear safety regime, after construction of the surface facilities, excavation of ramp and/or sinking of shafts to access the repository level and the excavation, construction and equipping the first fraction of disposal modules. Since entering the nuclear regime is not easily reversible, the workshop identified the operational license as the most important and crucial step in a project and both the implementer and the regulator should make adequate preparations for it ahead of time. Subject to regulatory approval, construction of extensions to the disposal facility may continue after the operational licence has been granted.

The regulatory process shall lead to the commissioning of the disposal facility, so that waste emplacement in the facility can begin, and shall include a formal review of the updated safety case. At this stage the safety case should be at its broadest and should demonstrate that there is a high degree of confidence in the feasibility of the project and that the facility, once constructed and operated in accordance with the approved plans, will meet the safety requirements during both the operational period and the period after closure.

The workshop suggested that the major technical challenge to be faced by the implementer in advance of the operational licensing process is to create sufficient confidence in the technical feasibility of the methods for closing the individual disposal units and in their compliance with the safety objectives. Demonstrations tests will be needed to that effect. Another challenge is the ageing of materials during a 50-100 years operational period. This challenge is amplified when reservability/retrievability requirements have to be taken into account. Another important issue that the implementer and the regulator are to address in the safety case and in the license conditions is the concomitant operation of the underground facility and construction of new parts, the periodic re-certification and permit renewal, and the mechanisms to allow for changes in the design and in the operating procedures.

*Preparation for the operational license*

The implementer prepares early for the operational licence and interacts with the regulator on this subject. This is usually done through elaborating generic/interim operational safety reports starting before construction. The initial assessment of operational safety is useful with respect to identification of key accident scenarios, and therefore leading to design optimization or update of guidance if needed.

The Swedish regulator (SSM) stressed that an important component for the preparation before the operational licence is the elaboration of norms for underground nuclear activities. For conventional non-nuclear facilities, the corresponding norms and standards are applicable. They include requirements relative to rock excavation, mining, concrete structures, worker safety, fire safety, ventilation, electrical installations etc. For any nuclear facility additional requirements apply with regards to operational nuclear safety and radiation protection. Those additional requirements can be described as imposing restriction on conventional non-nuclear facilities, i.e. the same type of activity that is performed in a conventional non-nuclear facility may be subject to stricter control and less flexibility when performed in a nuclear facility.

For a spent fuel and/or high level waste repository designed to provide both pre- and post-closure containment and isolation, additional restrictions apply due to the risk for potential negative impacts on post-closure safety. These additional requirements impose even stricter restrictions on the construction and operations of a repository compared to conventional nuclear facilities.

In France, in view of the license application, ANDRA identified in Dossier 2009 challenging issues during both operational and post-closure phases such as: containment systems, fire, co-activity and explosion risks, improvement in the understanding of the rock damage around the major underground structures and sealing of the repository. As an illustration, some requirements on fire risk were identified in order to take into account the combined constraints of “conventional” underground facilities (tunnel, mine) and nuclear facilities. After the review in 2010 by IRSN and the Standing Group of Experts on waste management (GPD) it was concluded that ANDRA had to introduce specific safety provisions on handling fire risk for the underground nuclear facility, as no current such guidance exists for this type of facility.

To ensure operational safety, undesirable events have to be prevented or the likelihood of their occurrence shall be kept sufficiently small. The consequences (e.g. release of radionuclides to the environment) have to be limited if such events ever occur. This implies provisions shall be provided through (i) design, e.g., the design of handling devices/transport containers and shielding, (ii) organizational/administrative procedures, e.g. appropriate operating schemes and emergency preparedness, and (iii) waste acceptance criteria in order to ensure the robustness of the waste packages (nuclide inventory, properties of waste matrix, properties of waste package, etc.).

*Contents of operational license application*

The discussion in the round tables addressed the content of the safety case to be prepared for the licence application. The updating of the preliminary safety case developed for the construction licence will be based on the description of the facility « as built », on more detailed information gained during construction, on a possible updated design and on demonstration tests of appropriate duration. The safety case will provide assurance that design and safety principles developed in previous phases have been followed and that safety requirements are met. The implementer should address all the subsequent phases of geological disposal and, as a minimum, present the overall approach for operation, partial closure of the disposal units and final closure of the disposal facility (updated as appropriate based on construction experience). A detailed description and substantiation of the suitability for safe operation of the operational facilities and structures, systems and components, in the context of planned operations and the proposed management system should be defined.

Waste acceptance criteria should be finalized and procedures in case of lack of compliance should be defined. All the activities associated with waste emplacement will need to be appropriately covered in the operational aspects of the safety case. They include receipt of the waste packages on site, handling and storage of the packages on the surface, transport of the packages underground and to the locations where they will be emplaced, as well as emplacement itself.

A safety operation envelope should be defined. As part of the operating rules a number of provisions should exist including those for worker protection against both radiological and non-radiological hazards, description of the procedures and rules for proper response to an accident or emergency during waste emplacement operations, procedures for site security and safeguards controls, procedures for the monitoring and surveillance of the facility and its surrounding surface environment.

The "operational phase" encompasses activities being carried out in parallel, i.e. characterization, excavation, construction, disposal, as well as partial backfilling and closure of disposal tunnels occurs simultaneously in different parts of the disposal facility. Thus, construction and closure are on-going, same time activities within a repository over a period of roughly of 50-100 years. A specific challenge is thus to make sure that excavation/construction/disposal/backfilling activities are carried out such as not to jeopardise the anticipated initial state for the passive post-closure development ("operation") of a sealed and closed repository.

The position of individual countries on retrievability is very diverse. When retrievabilily is imposed by law or regulation, specific studies (France, Germany) show that it may be implemented without compromising long term safety. However, it was suggested in the round tables that it is more difficult to demonstrate that retrievability will be possible with respect to operational safety.

*Monitoring*

During the operational phase, the implementer should put in place a monitoring programme to monitor the evolution of the components important for safety. The monitoring programme should be brought up to date based on experience from site characterization and from construction. The implementer should provide a description of the monitoring programme for the operational phase including the continued monitoring of host rock evolution due to construction and operation, confirmation of barrier system performance (type of parameters to be measured and how they are related to the performance of components that provide the safety functions) as well as radiation monitoring for operational safety. A description of the environmental monitoring programme should also be presented. There is a necessity to perform early planning of monitoring. The monitoring plan should be reviewed by the regulator. The issue of independent monitoring by the regulator was raised. It was concluded that this is best accomplished through inspection.

## 5. *Optimisation*

***There is a need, during the project, to address targets very different in nature and which may potentially compete with each other. Alternative solutions are typically compared and evaluated with a view to lower potential impacts and risks to workers, people and the environment in the short and the long term to as low as reasonably practicable. This is often called "radiological optimisation". In repository development, the set of target functions can be much broader, blurring the meaning of "optimisation". The visibility and importance to optimisation for licensing varies from country to country, and it may take different names.***

There is no single straightforward definition of optimisation, and not all regulatory guidelines use this term. The regulatory documents that provide guidance on what and how to optimise define constraints that must be considered in the optimisation process. Typical factors to be considered in optimisation include nuclear safety and security; radiation protection (operational phase with normal operation and incidents/accidents; post-closure safety with expected/unlikely evolution); worker health and safety; technological issues including "robustness"; environmental aspects during construction, operation and post-closure phase; cost; societal expectations; etc.

The variety of the remarks and views on this subject reflected the diversity of optimisation goals that may be pursued in the framework of a geological disposal programme. While optimisation of protection, as defined by ICRP, is regarded as a process to keep the magnitude of individual doses, the number of people exposed, and the likelihood of potential exposure as low as reasonably achievable with economic and social factors being taken into account, optimisation can also be seen as a way of increasing the technical quality and robustness of the whole waste management process. An “optimal solution” in a wider sense may also mean addressing safety requirements whilst balancing other factors such as the need to use resources efficiently, political and acceptance issues and any other boundary conditions imposed by society. It was noted that optimisation variables are often not well defined and could be quite programme-specific.

Examples of optimisation issues addressed during the workshop included site selection (Germany), location of disposal facility in a selected zone (France), design of the engineered barrier system (Sweden, Finland). Optimisation is a forward-looking activity and continues as well during the operational phase, e.g. in the framework of re-licensing, and it may concern working procedures, installations, equipment (USA, WIPP).

There was general agreement on a series of statements on the subject. Namely: the endpoint of optimisation should represent a balance between the different factors considered in the optimisation process while respecting the constraints. Optimisation is normally forward oriented rather than directed on re-examining past decisions (except for situations that require remedial action) and should focus on those issues where (residual) flexibility is available. Optimisation should be taken at several levels, from the overall waste management system (including waste treatment, interim storage, final disposal, etc.) down to individual elements of the repository system. Optimisation also has to find a balance on how long to keep options open and when to take decisions and narrow down the number of options; optimisation, however, should not be used as an excuse to take no decisions and not to move forward. For optimisation, not only the endpoint counts; equally important is the process of optimisation that should be conducted in a transparent manner and relies on a structured interaction between regulator and implementer. In this respect regulators need to be clear about their requirements and these requirements become constraints on the optimisation process, together with any societal constraints that may be applied in certain programmes. Once the safety objectives (dose/risk targets and other constraints) have been met, further optimisation should be aimed at moving the project forward as efficiently as possible, and this could largely be described as “cost optimisation”.

## Conclusions

The workshop was considered a success as there was a vast amount of interest in the topics covered with active participation of both regulators and implementers. Informative programme overviews and project details were delivered in the given presentations by many participants.

It was acknowledged, during the workshop, that many repository projects are at different developmental levels and therefore different concerns were noted among countries and/or waste management programmes. Due to this reason, the experience in dealing with the preparation or review of a license application is diverse.

Despite the various developmental levels, commonalities among the waste management programmes or countries can be drawn. The most apparent consensus was on the role of the stepwise process which, in many countries, is inscribed in their legislation. In this context, early interaction with a competent regulator is considered important in order to communicate effectively on issues related to the construction and operational licence. It is recognized that the early identification of challenges associated with construction, with long term safety, and with risk management related to repository operation are also crucial in development. In this respect, and at specific steps before the license application, the implementer often produces generic/interim reports that are reviewed by the regulator.

Many commonalities are also found to be necessary information in the safety case. The European Pilot Study[1] had identified the need to describe, in the license application, all subsequent activities leading to a given decision, including later operation, closure and post-closure. This implies that feasibility of a technical solution shall exist in principle for all phases of the repository although this technical option may not be used in the final design. It is inevitable that techniques will evolve; hence, implementers shall be allowed to have some level of flexibility in the license for their repository implementation. This, nevertheless, remains to be a challenge for the regulator when stipulating licensing conditions.

Many advanced programmes recognize the importance of a quality management system including the planning of required resources. Competent and experienced implementers and the regulators are also keys in advancing repository development. This is especially important when the implementer has to be prepared for the industrial phase and supervise large contracting companies. In this respect a monitoring plan and proper documentation to monitor and record construction and operational progresses are very important. The quality management process shall be reviewed by regulators and an inspection programme put in place.

Main differences between countries are observed in the licensing regimes or in the licensing process. The need of developing specific regulations is noted as well. In some countries, a license or a license application may be regulated or assessed by more than one regulating body. Such situation can be complex as different regulating authorities may stipulate different license conditions. In such situation, it is often the government who has the responsibility to deliver the final decisions on the license conditions. Another difficult situation faced by the implementers is to account for potential political changes in the planning of the essential resources for the industrial phase.

Finally, the workshop concluded that many others areas of this subject: “Challenges faced by implementers and regulators in the industrial phase of repository development” need to be further explored in the future. Aspects such as (i) the need to introduce enough flexibility in the project within the limits set by the licensing conditions, (ii) the need to comply with competing targets in the framework of an optimisation process and the obligation to address a series of operational issues including the constraints associated with concomitant operation and construction, (iii) aging of disposal system components, (iv) the application of retrievability constraints, if required, (iv) the different roles of monitoring in the different phases of the project, and (v) the identification of events / scenarios to be considered when assessing operational safety. These and other issues will be taken up in the programme of work of the RWMC’s RF and the IGSC in the future.

[1]. Report on the European Pilot Study on the Regulatory Review of a Safety Case for Geological Disposal of Radioactive Waste *Version for consultation @ 26.11.2010 distributed to IGSC members on 13.07.2011*