IGD-TP

IGD-TP
Implementing Geological Disposal of Radioactive Waste Technology Platform

Strategic Research Agenda 2011

EURATOM

IGD-TP Strategic Research Agenda (SRA)

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Foreword

The Implementing Geological Disposal of Radioactive Waste Technology Platform (IGD-TP) was launched on November 12, 2009. At the same time its Vision Report was published.

The main objectives of the IGD-TP are to initiate and carry out collaborative actions in Europe to facilitate the stepwise implementation of safe, deep geological disposal of spent fuel, high-level waste, and other long-lived radioactive waste by solving the remaining scientific, technological and social challenges, and thereby to support the waste management programmes in the Member States. The platform intends to enhance confidence in the solutions and implementation of geological disposal, to reduce overlapping work, to produce savings in total costs of Research, Development and Demonstration (RD&D), and to make better use of existing competences and research infrastructures.

The IGD-TP's work is driven by ten waste management organisations and one governmental body, that share a common vision that *"by 2025, the first geological disposal facilities for spent fuel, high-level waste, and other long-lived radioactive waste will be operating safely in Europe"* (Vision 2025).

In June 2011, IGD-TP had around 80 participating organisations endorsing the vision and representing stakeholders with a wide range of backgrounds e.g. waste management organisations (WMOs), industry, research institutes, research centres and the academia.

This document, the IGD-TP's Strategic Research Agenda (SRA), is dedicated to identifying the main RD&D issues that need a coordinated effort over the next years in order to reach the Vision 2025. Of particular interest are the issues for which enhanced co-operation within the IGD-TP is considered desirable and practically achievable. The detailed analysis of scientific achievements in the WMOs did not identify a need for cooperative work on Topics such as siting or radioactive waste inventories evaluation, as these areas are advanced in programmes close to implementation. Nonetheless, the need for experienced feedback from such work represents a vital link between the programmes closest to licensing and those which are currently at earlier stages in their repository programmes. Therefore, IGD-TP activities will also contribute to the reflection on these specific topics.

Because the SRA identifies the Key Topics of RD&D that have the greatest potential to support repository implementation through enhanced cooperation in Europe, it also provide valuable input to identifying topics for future calls for proposals issued by the EC framework programme. The SRA is well suited to this role as the Topics within the Key Topics are identified in relation to their priorities, which have been established collectively through discussions among many European waste management organisations and also because benefits are expected to flow to a broad range of participants. In developing the SRA, attention has been focused on increasing cooperation in areas of repository safety and technological development through combined use of resources, which represent the major objectives of the EC framework programme.

The SRA will also be the instrument for creating synergies, co-operation and co-ordination, both internally between the IGD-TP participants and with external activities that take place in other technological platforms such as the SNE-TP and within other international forums.

The SRA is complemented by the Deployment Plan introducing various adapted cooperation tools to implement its actions. They will rely in particular on the Euratom Framework Programmes, which should echo the SRA's priorities.

IGD-TP aims at facilitating the emergence of additional programs originating mainly from academic institutions that would complement the SRA objectives through more fundamental approaches. This should be achieved notably through the contribution of organisations endorsing the Vision 2025 that are representatives of both the different scientific communities and the European countries involved, in order to build a common task force (based on scientific, technological and education&training excellence). This SRA has been produced by a SRA Working Group with representatives from the IGD-TP's member WMOs. The SRA has been consulted with the IGD-TP participants first at a SRA seminar in June 2010 and then later during November 2010 on the preview version of the SRA Key Topics. During January 2011 an open public consultation on the draft SRA document was carried out and the consultations results when applicable to the objectives of the SRA were integrated into the document. Finally the SRA document was discussed at the first open IGD-TP Exchange Forum meeting held on February 8, 2011.

Contents

1 Introduction

1.1 Background to the Implementing Geological Disposal of Radioactive Waste Technology Platform (IGD-TP)

In April 2011 there were 443 nuclear reactors in operation in the world, of which about 150 (34%) were situated in Europe /1-1/. The main source for nuclear waste in Europe is the operation of these nuclear reactors and their eventual decommissioning and dismantling. Under the provisions of the Joint Convention /1-2/, acceded to by nearly all EU Member States, each nation is responsible for managing the radioactive waste produced within its borders. These requirements are repeated in the recent European Commission (EC) proposal for a Council Directive on the Management of Spent Fuel and Radioactive Waste /1-3/.

There is increasing consensus among the experts in nuclear waste management that geological disposal is "an appropriate waste management choice for the most hazardous and long-lived radioactive wastes" /1-4/ i.e. spent fuel, high-level waste, and other long-lived radioactive waste. At the same time, the European citizens have a widespread wish for "a permanent and safe solution for managing radioactive waste"/1-5/. The majority of European Member States with civil nuclear power plants have on-going waste management programmes, but the current status and the main challenges of those programmes vary. Despite the differences between the timing and the challenges in the different programmes, there is a consensus that continued and strengthened co-operation on the scientific, technical, and societal challenges related to deep geological disposal is necessary for the safe and timely implementation of the first geological disposal facilities.

The European Commission has been instrumental since 2002 in the establishing of Technological Platforms (TPs) as forums to improve co-operation within European RTD[1] sectors, especially where a more strategic approach is needed and industry needs to play a greater role in defining the needs and in driving the related RTD activities. A common aspect to all TPs is the development of a common vision and Strategic Research Agenda (SRA) with short- and medium-term objectives, combined with implementation by appropriate Deployment Plans /1-6/. Based on the above-mentioned consensus and also the positive outcome from Euratom projects such as Net.Excel /1-7/ and CARD /1-8/, the vision for a TP on deep geological disposal was established. The "Implementing Geological Disposal of Radioactive Waste Technology Platform" (IGD-TP) Vision Report /1-9/ was prepared by a group of major European waste management organisations and a governmental body in consultation with the wider community. The IGD-TP was formally launched on November 12, 2009. In July 2011, the IGD-TP had around 80 participating organisations endorsing the IGD-TP vision.

The IGD-TP vision statement (Vision 2025) and the commitment of the members are the following:

Our vision *is that by 2025, the first geological disposal facilities for spent fuel, high-level waste, and other long-lived radioactive waste will be operating safely in Europe.*

Our commitment is to:

- *Build confidence in the safety of geological disposal solutions among European citizens and decision-makers.*
- *Encourage the establishment of waste management programmes that integrate geological disposal as the accepted option for the safe long-term management of long-lived and/or high-level waste.*
- *Facilitate access to expertise and technology and maintain competences in the field of geological disposal for the benefit of Member States.*

[1] Research and Technological Development (RTD).

In 2007, the EC presented the European Strategic Energy Technology Plan (SET-Plan) /1-10/ to accelerate the development and implementation of low carbon energy technologies. One of the key technology challenges referenced is to "maintain competitiveness in fission technologies, together with long-term waste management solutions". Hence, the Vision 2025 of IGD-TP is in alignment with the SET-Plan's objective on long-term waste management solutions.

The strategic initiatives prepared by IGD-TP are expected to contribute to the objectives expressed in the Specific Programme implementing the Seventh Framework Programme of the European Atomic Energy Community (Euratom) for Nuclear Research and Training Activities (2007 to 2011) /1-11/, namely *"a sound scientific and technical basis for demonstrating the technologies and safety of disposal of spent fuel and long-lived radioactive wastes in geological formations*", and in addition the IGD-TP should *"underpin the development of a common European view on the main issues related to the management and disposal of waste."* It is also envisaged that the IGD-TP will enhance European co-operation in the areas where work still remains, optimise the solutions and move results from laboratories and pilot-facilities to the industrial scale.

The ambition of the IGD-TP is to bring together stakeholders with various backgrounds (e.g. industry, research institutes, academic community, regulatory bodies, public authorities, the financial world and civil society) who would develop a research and development strategy in areas of research needed to realise the Vision 2025.

The IGD-TP aims to offer benefits to all of its members irrespective of the differences in timescales of waste management programmes in European Member States. For small waste management programmes and programmes in their initial stages, the IGD-TP offers possibilities for knowledge and experience build-up.

The IGD-TP's work and results together with general information about IGD-TP are posted on the website www.igdtp.eu. Generally throughout the SRA Document the terms used follow the definitions in the IAEA "Radioactive Waste Management Glossary" /1-12/.

1.2 International co-operation – background

Geological disposal has been studied since the 1970s as the preferred option for the long-term management of high level and/or long-lived radioactive waste. During this time, waste management organisations and research institutes have collaborated in order to generate improved knowledge aimed at building geological disposal solutions. Research needs are mostly defined by end-user WMOs with major inputs from research institutes and organisations carrying out the research. The quality of the work is checked through peer reviews, regulatory reviews and by cross-referencing programmes and results. One of the drivers for the progress in co-operation has always been the search for commonalities and explanation of differences among waste management programmes.

The continued increase of our knowledge through Research, Development and Demonstration (RD&D) contributes to building confidence in the arguments that demonstrate the safety and feasibility of geological disposal /1-13/. Although the host rocks and designs can differ across the different waste management programmes, there are several areas of RD&D where co-operation is worthwhile and on-going, as discussed below.

International organisations such as the European Commission (EC), the International Atomic Energy Agency (IAEA) and the OECD Nuclear Energy Agency (NEA), and the mechanisms and forums set up by these organisations, already enable important co-operation amongst WMOs and governmental organisations.

The Treaty establishing the European Atomic Energy Community (Euratom) was established to promote the peaceful uses of nuclear energy in Europe, and to regulate the various aspects such as health protection, safeguards, and fuel supply. The Euratom Treaty also includes provisions for European Union (EU) funding of research in nuclear science and technology, related knowledge management and support for infrastructures. Multi-annual Euratom Framework Programmes for research and training activities are

implemented by the European Commission with EU funding, and address the current technical issues and challenges posed by nuclear energy in Europe. This has led to important collaborative research projects in, amongst others, the field of geological disposal, involving different European waste management organizations, research institutes and universities.

There has been an evolution in the focus of this research effort over the years. Early projects included the development of a catalogue of suitable host rocks in the 1970s /1-14/ and the detailed research topics on radioactive waste behaviour in repository conditions, migration of radionuclides in different barriers and thermo-hydro-mechanical behaviour of clay as barrier in the 1980s & 90s. Later from about 2000 and onwards, the co-operation continued through large integrated projects i.e. FUNMIG /1-15/ and NF-PRO /1-16/ and through large-scale demonstration projects such as ESDRED /1-17/.

The IAEA's main focus lies on the development of international guidelines although the Agency also assists its members in scientific and technological aspects (e.g. development of strategies, establishment and transfer of suitable technologies for radioactive waste management). The IAEA's work has set the framework for cooperative efforts to build and strengthen an international safety and security regime. This framework includes advisory international standards, codes and guides; binding international conventions; international peer reviews to evaluate national operations, capabilities and infrastructures; and an international system of emergency preparedness and response.

The Nuclear Energy Agency (NEA) is a specialised agency within the Organisation for Economic Co-operation and Development (OECD). One of the goals of the NEA is to share information among the member countries in the management of radioactive waste and materials, focusing on the development of strategies for the safe, sustainable and broadly acceptable management of all types of radioactive waste, in particular long-lived waste and spent fuel. The main tasks are to exchange information and experience on waste management policies and practices, develop a common understanding of the basic issues involved, and to keep under review the state-of-the-art in the field of radioactive waste and materials management at the technical and scientific levels.

Besides joint research projects there has also for many years been bilateral (often through agreements) and multilateral (often through meetings) co-operation between various waste management organisations to share information and knowledge in science, engineering and methodology-related areas.

The most active and widespread co-operation on RD&D is of course as a result of similarities between waste management programmes having similar host rock and/or disposal concepts (e.g. POSIVA – SKB: KBS-3 concept for the crystalline host rocks; ANDRA – NAGRA – ONDRAF/ NIRAS: clay host rock). Nonetheless, co-operation between organisations with different host rocks exists as well in order to increase the level of knowledge and understanding in the general framework of long-term waste management or to improve knowledge on alternative host rocks. As an example BMWi, who uses salt as the reference host rock type, has been involved in RD&D projects in granite and clay formations for more than two decades in close co-operation with NAGRA, SKB and ANDRA.

1.3 Waste management programme specific RD&D Plans

The EC in its proposal for a Council directive /1-3/ in November 2010 proposes that all Member States shall present national programmes for the management of spent fuel and radioactive waste. Such programmes already exist in many of European Member States, though in different forms owing to national regulations and programme internal needs, and are in some cases revised at regular intervals.

The RD&D plans at waste management programme level might differ significantly as they strongly depend on the national context (like national laws, stage of the programme, see Section 1.4, type of host rock considered, stakeholder interactions, etc). Each WMO focuses on carrying out RD&D that helps to deliver the input, answers and state-of-the-art needed for the next programme stage and beyond, based on the available information and knowledge within the geological disposal community.

In general terms, the development of RD&D plans by the different WMOs is based on similar types of elements as schematically illustrated in Figure 1.3.1.

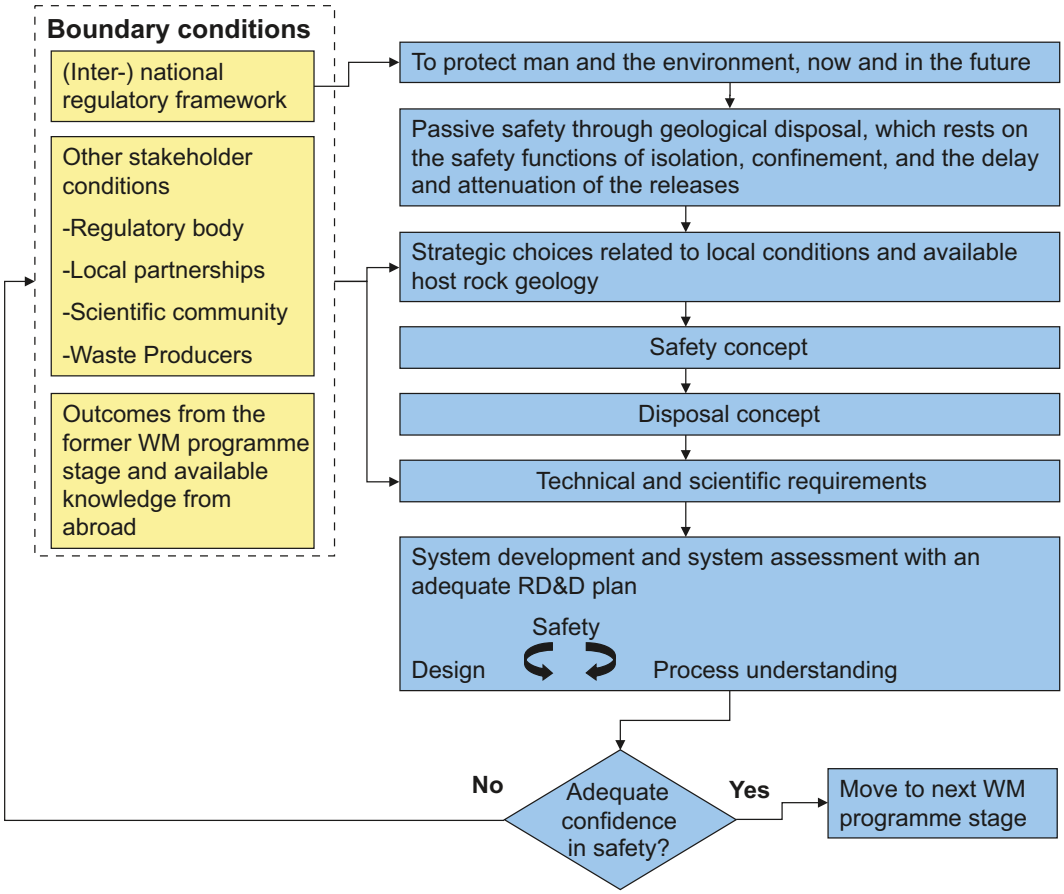

Figure 1.3.1. *Schematic description of elements for developing RD&D plans for a waste management (WM) programme.*

Based on the context (including available host rock geology), this is translated into technical and safety requirements for specific components. Here, other boundary conditions might also be relevant, for example specific questions from the regulator. The resulting evaluation then leads to an RD&D plan that is adequate to perform the system development and assessment needed for the next programme stage. Within this approach for developing RD&D plans and system evaluation, the needed interaction between safety, design and process understanding is considered.

In accordance with (inter-) national guidance the aim of the long-term management of high-level and/or long-lived radioactive waste is to protect *"man and the environment, now and in the future"* /1-18/. At the international level, there is a consensus that the maximum level of passive safety can be obtained through geological disposal /1-19/. The disposal system consists of engineered and natural barriers between the wastes and the surface environment in order to prevent radionuclides and other toxic species reaching the surface in such concentrations that they could present an unacceptable risk. The different components of the disposal system perform a number of functions relevant to long-term safety, called safety functions. In general, the safety functions relied on are "to contain the radionuclides associated with the radioactive waste and to isolate them from the biosphere"/1-19/.

The safety concept describes the conceptual understanding of why the disposal system is safe. The disposal system performs the broad safety functions via a range of features and associated processes that vary in their effectiveness and in the level of scientific and technical understanding that is available. This safety concept is the main starting point to define the technical and scientific requirements for the disposal system and its specific components. However, other boundary conditions might intervene, like for example specific questions from the regulator or other stakeholders (e.g. specific questions on reversibility and retrievability).

The safety concept is built on a limited number of effective and well-understood features that ensure that the disposal system is safe and that safety can be demonstrated, even allowing for the various uncertainties and harmful events and processes that might affect the system´s evolution.

On this basis RD&D plans are developed that address the need for further scientific and technical knowledge that is required to carry out the performance and safety assessments and the integrated safety case before proceeding to the next programme stage. In practice, this involves iteration between design options, demonstrable performance and continued research into process understanding of the [chosen] disposal system. During such iteration, estimates of performance are made and an understanding is developed of which elements of the disposal system actually provide safety under various conditions, thus refining the disposal concept.

The output of this work plan on RD&D leads in principle to an important milestone for the programme, often accompanied by a safety case /1-20, 1-21/. If adequate confidence in safety is obtained, the programme is ready to move to the next stage. This leads to a new iteration in function of the next programme stage whilst taking into consideration changes in boundary conditions (e.g. specific questions addressed by stakeholders). If not, however, a re-iteration through the boundary conditions and safety concept is needed in order to update the RD&D plan as required.

1.4 Background to developing the Strategic Research Agenda of the IGD-TP

Implementing geological disposal will occur through a succession of research, siting and repository development stages as shown in Figure 1.4.1. These stages are broadly consistent across all current repository development programmes, even if the terminology used sometimes differs among the various programmes. A staged decision-making process is typically adopted, in order to provide the required regulatory review and societal inputs to the decisions made at each stage. The required number of the major stages (e.g. site selection, development and design, demonstration and construction, operation and closure) may be subject to a formal licensing process, although this may vary from country to country.

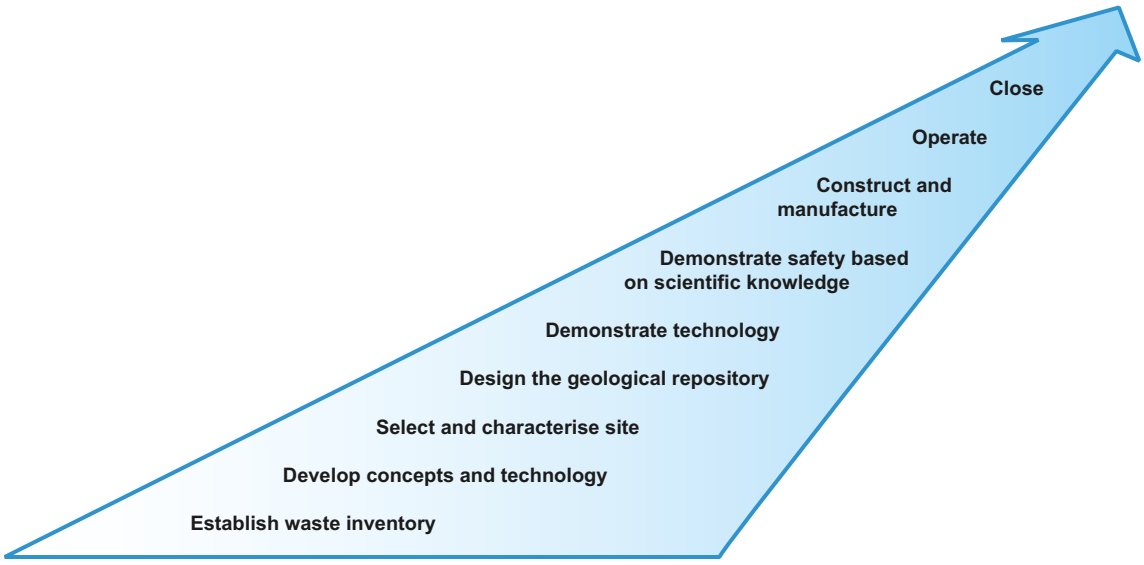

Figure 1.4.1. *Staged implementation of geological disposal. The number of the required stages may be subject to licensing according to the national legislation in question.*

An important element of this staged approach is the determination of the appropriate level of understanding of the relevant research and technology issues needed for each stage. For the development of the SRA, the IGD-TP has emphasised those issues that are material for reaching the vision of having nuclear waste repositories operational by 2025. Nonetheless, even for programmes with later implementation dates, the nature of RD&D activities for any given stage, as well as the sequence of stages, are expected to be similar. Thus the results achieved by the programmes close to licensing will be of benefit to all other programmes. The specific licensing date of these programmes act as drivers for the importance and timing of the results needed.

This document contains the SRA of the IGD-TP and outlines the remaining research, development and demonstration (RD&D) activities needed to reach the above-mentioned Vision 2025. Of particular interest are the activities amenable for joint co-operation and co-ordination. The SRA is a document for communicating the implementation of the oriented research needs and opportunities to stakeholders in the waste management community, and it is also an instrument for creating synergies, co-operation and co-ordination with activities taking place in other technology platforms and within other international co-operation forums.

The IGD-TP adopts a process in which a common vision is established, followed by preparing a SRA needed to achieve the vision. This SRA will therefore be followed by a Deployment Plan (DP) for the activities and joint work to be carried out by the IGD-TP and its members and participants. The development of the IGD-TP´s SRA and DP and the main interactions and involvement of stakeholders can be seen in Figure 1.4.2.

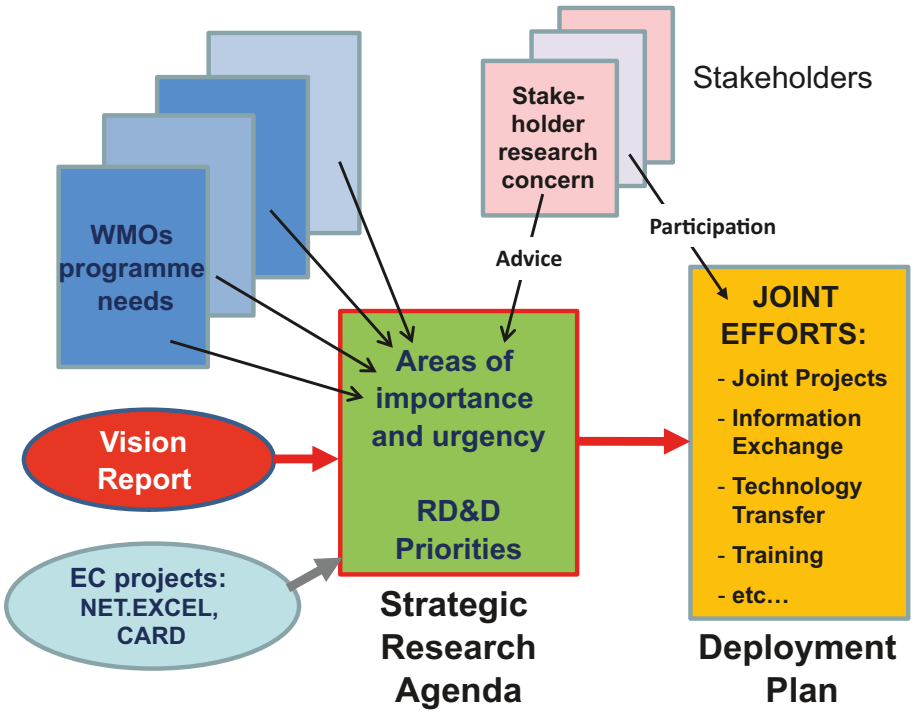

Figure 1.4.2. *The development of the IGD-TP's Strategic Research Agenda (SRA) and the Deployment Plan (DP).*

The IGD-TP's Executive Group (EG), which is the decision-making body of the IGD-TP, set up a working group in January 2010 with the task of preparing a SRA, see Appendix. The principal guidelines provided by the EG for the work were the following:

- To set a logical framework for which the SRA will fill in the areas where implementation-oriented research is still needed.
- To define what co-operation on the topics identified for Strategic Research will develop added value and does not overlap with work carried out in existing forums and provides possibilities for extended international co-operation.
- The SRA should take into account the staged process of repository development:
  - To define as a first priority the needs of WMOs close to reaching the vision and approaching licensing.
  - To define the needs of WMOs in the midst of this development.
  - To define the needs of those WMOs starting this development.
  - To focus on the first two groups above in this document, but to remember that the SRA will be a "living document" and thus has not to be exhaustive.
- To concentrate especially on common issues such as methodology and strategy that can be done together in the IGD-TP in a value added way.
- To concentrate on topics of high urgency in relation to the Vision 2025.
- Not to differentiate the issues according to host rock type.
- To put the emphasis on safety-related research.
- To emphasise construction and operational safety issues.
- To acknowledge the need to involve socio-economic issues in the programme and suggest a way to co-operate with already established groups.

The SRA working group, consisting of representatives from all of the IGD-TP member organisations, started the work with the assistance the SecIGD[2] (Secretariat IGD-TP) project supported by the Euratom 7th Framework Programme. Major input from the IGD-TP participants were solicited at an SRA seminar held in Brussels on June 16, 2010. The SRA draft was finalised for approval by the Executive Group for wider public consultation on the IGD-TP's website in December 2010. The comments from this consultation have already been taken into account where appropriate in this SRA document.

The detailed process and the methodology used in developing this SRA document are explained in Chapter 2.

[2] Secretariat of the Implementing Geological Disposal Technology Platform, Euratom 7th Framework Programme, Support Action launched 04/01/10 http://www.igdtp.eu/secigd/.

2 Framework of the Strategic Research Agenda

The implementation of a geological repository involves interactions with scientific, technologic and social areas. Thus, a full set of competencies is needed to conceive, design, implement and conduct geological disposal. The expertise required and issues addressed extend beyond the realm of pure science and technology. Even if the technical design of the geological disposal programme matches all requirements for implementation, the acceptance by the local public or its representatives might still be difficult to achieve.

Analysing the development and operation of the different European Technology Platforms /2-1/ it becomes clear that there is no standardised procedure for drafting a SRA. However, SRAs by definition must comprise the full range of research topics, and their importance and timing, which play a role in the realisation of the specific vision. Therefore, each technological platform has to decide, which approach is appropriate for creating a vision-oriented SRA, that covers the most essential needs for developing and implementing the required technology.

An operational geological repository for the long-term management of spent fuel, high-level waste, and other long-lived radioactive waste will be the first of its kind. Therefore the rationale of the IGD-TP´s SRA, including its structure, and its contents are of particular interest to stakeholders of geological disposal and the general public. Consequently throughout the development of the SRA, consultation has been held whereby many stakeholders have provided input in order to make clear what is considered necessary for safe geological disposal and what has already been done.

2.1 Rationale for developing the SRA

The Vision 2025 of the IGD-TP can only be achieved through the progress of individual waste management programmes towards the implementation of geological disposal. Waste management programmes are normally based on assessment of what is needed to proceed from the current state-of-the-art of the programme to the practical implementation and operation of the repository. At the moment the Vision 2025 is within reach in a few European Union Member States. In some programmes a longer period is still needed for the preparations, while others are at an early stage of development. Therefore, it is natural that the recognised RD&D needs of the programmes closest to licensing receive particular attention in the content of the SRA as these will be critical for achieving the Vision 2025.

However, to unite all European waste management programmes in joint efforts on the implementation of geologic disposal, the IGD-TP has to offer all participants reasonable incentives for participation, sharing resources and developing competences.

Some of the waste management programmes are either small or have longer time schedules and/or are subject to changes of their political situation (e.g. new European Member States). Developing and implementing of these programmes may require appropriate expertise and infrastructure beside adequate national boundary conditions (e.g. national decision-making frameworks). Basic applied research and education and training may also be of greater importance than in the programmes closer to licensing.

For these reasons, the emphasis in this SRA is on RD&D activities that are critically important for the programmes closest to licensing but which, at the same time, produce results that are useful and of interest to other participating programmes as well.

For the same reasons, some of the RD&D issues that may be of key importance for the achievement of objectives in some individual programmes are of lower common interest to the participating WMOs, if they are specific only to individual programmes. Typically this is the case with site characterisation and the interpretation of its results, and therefore, even if highly important for geologic disposal, this area is discussed only briefly in this SRA. For this reason, the SRA also does not discuss the detailed design and the licensing processes that are individual waste management programme specific issues. However, in some cases host-rock specific RD&D issues are of general importance with a strong added value to other geological disposal options as well.

The appropriate stages for developing geological repositories have been established over the last 30 years. Site selection strategies and site characterisation methodologies and techniques are well advanced. Further development of safe and efficient waste conditioning, handling, and transport is based on the specific needs and day-to-day practise. The testing of disposal techniques and components for geological disposal is part of some national and multi-national RD&D projects. The main focus of on-going research is on the safety strategy and methodology for the development of the safety case for geological repositories (see Figure 2.1.1). All this makes up the state-of-the-art, which provides a well-established scientific and technical basis for the content of the SRA.

The identification of Key Topics for the SRA started with inputs from participating WMOs using individual host-rock specific safety cases and associated RD&D programmes. For those organisations yet to decide on a host rock geology their generic RD&D programmes were used. A first consultation was performed during a SRA seminar with those IGD-TP participants who had endorsed the Vision 2025. Each participant was given the opportunity to provide initial input on the SRA development. The overall process is schematically described in Figure 2.1.2.

Stages of repository development

	Generic studies and concept development	Selection of host rock and site	Technology development and repository design	Technology development and repository construction	Industrial-scale manufacturing and repository operation
Safety strategy and methodology	Development of safety assessment methodology	Application of methodology in safety case and improvement of methods	Application of methodology in safety case and improvement of methods	Application of methodology in safety case	Application of methodology in safety case
Long-term safety: Scientific and technical basis	Broad-based research	Research narrowed to deal with host rock-specific aspects and specific aspects associated with the selected EBS	In situ experiments and improvement of data bases and understanding	Scientific work sharply focused on small number of residual issues, large-scale in situ experiments and component tests	Confirmation studies on components under site conditions incl. monitoring
Facility and component design	Concept variant studies	Repository design concepts adapted to specific rock type	Component design and layout design Operational safety studies	Full-scale prototypes constructed Industrial scheme developed	Full-scale production and operation
Site-related characteristics	Surveys of potential host rocks and their characteristics based on available information	Host rock characterization and site-specific studies	Detailed site characterization Excavation	Construction of main underground facilities Confirmation of rock properties for final design	Construction, confirmation, monitoring

Figure 2.1.1. *Generic stages of repository development as derived from international experience including best practices in technology application. The given RD&D activities reflect today's state-of-the-art in geological disposal (see also Figure 2.2.4).*

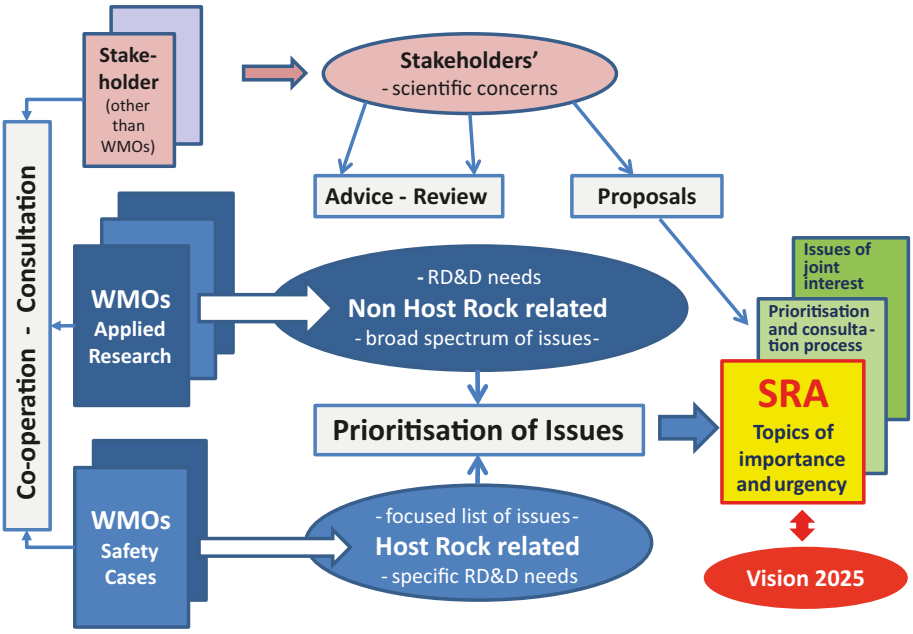

Figure 2.1.2. *Development of SRA in co-operation with and after consultation of stakeholders.*

Following initial consultation with IGD-TP participants, as part of a staged approach, the identified RD&D issues were further discussed and urgent topics for RD&D identified. In consultation with the participants and with interested stakeholders, the first compilation of RD&D needs and concerns was developed. Valuable information was given on specific RD&D aspects during the consultation phases. In the final step, the importance and urgency of RD&D issues has been undertaken, including further consultation with stakeholders (including organisations and individuals not endorsing the Vision 2025). This iterative and interactive process of developing the SRA is described in Section 2.2.

Such a process offers the scientific and technical community, including suppliers, the possibility to comment on the RD&D issues and to contribute to the prioritisation of topics according to their experience and skills. The information and consultation process together with open communication is essential as part of the steps towards and the execution of the SRA. Moreover, it enables the SRA to serve the interest of all stakeholders involved.

The co-operation of programmes, which are at different stages of implementation and follow different time schedules, is an essential part of the IGD-TP. Joint research on a common scientific and technical foundation based on the SRA is benefitial not only to the partners directly engaged but also to the other programmes, and to some extent also to the stakeholders concerned, see Figure 2.1.3. It is acknowledged that co-operation will mean active involvement in specific projects, as well as sharing results and high-quality knowledge between programmes at different stages. The forms of co-operation and technology transfer will be further developed in the IGD-TP's Deployment Plan.

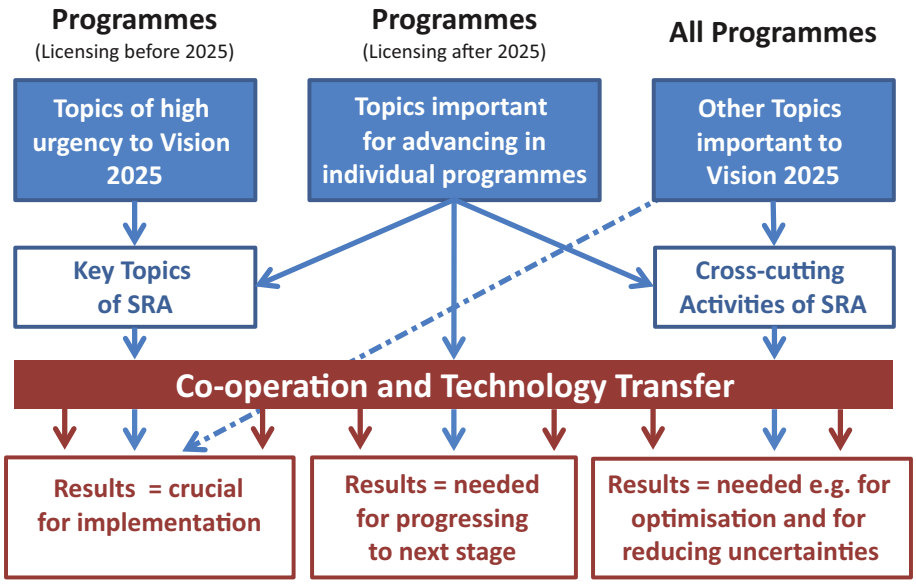

Figure 2.1.3. *An example for co-operation of programmes with different targets dates for licensing.*

2.2 Staged process to identify, characterise and organise issues of the SRA

Starting with the identification and selection of potential issues to be addressed in the SRA, the participating WMOs provided a first view on the kind of products needed, the improvements of present approaches and the importance to the respective waste management programmes in general. The RD&D issues considered by the individual member organisations are, to some extent, dependent on the host rock options pursued and the specific disposal concepts developed.

Due to the mature state of both the understanding of the geological disposal systems as well as the development of emplacement technologies and safety related components the issues generally fall in one of the three main categories:

- Demonstration of long-term safety.
- Development and demonstration of disposal techniques and components.
- Site characterisation and confirmation of site suitability.

These broad issues comprise a wide range of RD&D from those on waste forms and site characteristics to disposal and sealing techniques involving various scientific and engineering disciplines, see Figure 2.2.1

In view of the Vision 2025, intensive site characterisation has been carried out already by those programmes, which are planning for submitting a construction license application and for the construction of the repository by this date. However, it is recognised that for such programmes, activities such as the confirmation of site properties, the development of site-specific repository designs, further characterisation and modelling interpretation will likely be on-going.

Regarding the role of underlying scientific research in the SRA, more than 30 years of such studies have led to a strong scientific basis for geological disposal. Nonetheless, where required such work will continue and, where sufficiency of information exists and no further RD&D is actively pursued, the scientific basis of the safety case will need to be continuously updated. As this underlying scientific research is a broad requirement intrinsic to several of the Key Topics of the SRA, this aspect has not been directly highlighted.

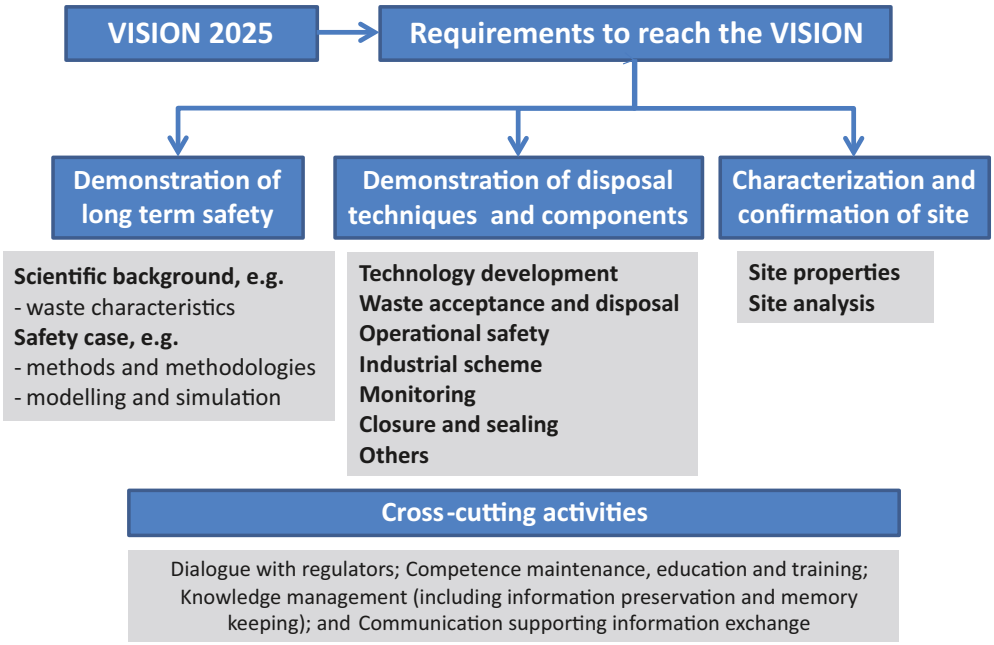

Figure 2.2.1. *Issues to be considered (grey boxes) during the SRA development and how these can be categorised (blue boxes).*

In the course of developing the SRA, the WMOs assessed the latest achievements of their waste management programmes and the results of the EURATOM Framework Programme for Nuclear Research and Training Activities /2-2/.

It has been chosen not to use detailed referencing for all technical matters to keep this SRA report easier to read. The relevant references can be found in the WMO's public RD&D programmes (Andra /2-3/, COVRA /2-4/, BMWi /2-5/, ENRESA /2-6/, Nagra /2-7/, NDA /2-8/, ONDRAF /2-9/, Posiva /2-10/, PURAM /2-11/,RAWRA /2-12/, and SKB /2-13/).

The members of the IGD-TP have adopted a systematic and well-structured strategy for the development of the SRA, which follows a staged process basically made up by five consecutive steps, see Figure 2.2.2.

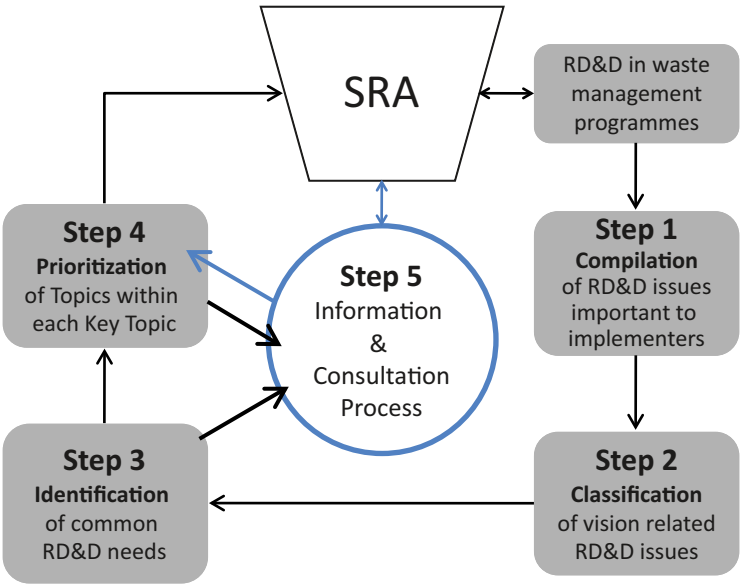

Figure 2.2.2. *Systematic and stepwise approach for developing the SRA.*

Step 1 (Compilation of RD&D issues) is aimed at aggregating/compiling those RD&D issues, which are presently being worked on or which are in process of planning to achieve the Vision 2025 or were considered to be of high importance for each specific WMO programme. For selecting issues the basic criteria are the state-of-the-art, the generally accepted practices established in the different scientific areas and the best appropriate technologies available so far. Those issues which seem not to have reached a mature state for implementation are checked in accordance with the national and international requirements and recommendations by the WMOs for their importance, urgency and RD&D needs.

In **step 2 (Classification of RD&D issues)** selected issues are being put into a closer perspective with the Vision 2025 and its given timeframe and challenges. Resolution of issues that most directly support implementation of the first geological repositories for spent fuel, and high-level waste and other long-lived radioactive waste is most critical for the Vision 2025. According to the challenges outlined in the Vision Report, the issues are classified with regard to a more extensive understanding of the geological disposal systems and their importance for the realisation of the vision.

With regard to licensing, the disposal systems' related safety case with all its different aspects is of highest importance. In this context, the treatment and handling of remaining uncertainties is a task, which still requires RD&D efforts. The outcome also contributes to confidence building in general.

The different nature of uncertainties requires to some extent different strategies in order to reduce the "knowledge gap" and to increase confidence in the data and process models relevant to the total systems' performance analysis. In the course of setting up the safety case for any geological repository remaining uncertainties will be defined and the potential impact on operations and long-term safety need to be assessed, see Figure 2.2.3.

The major technological challenge is to demonstrate that all technologies planned for implementation of construction, operation and closure of deep geological repositories are to a high degree reliable and match all safety requirements. This applies in particular to those technologies, which directly contribute to transport, handling, and emplacement of waste containers and to the sealing of the repositories. Remaining short falls are indicated by the so-called "readiness gap". The outcome of step 2 is the Vision 2025-related classification of RD&D issues. The implementers express their specific needs in these issues and provide detailed information about the significance to their programme.

	Scientific basics	**Technical feasibility**	**Site properties**	**Safety case**
Uncertainties	Borders of knowledge not defined	Engineering standards for limited time frame	- Heterogeneity of geologic formations - Future evolution	Framing of uncertainties and scenarios
Activities in progress	Hypothesis testing Works on models and analogues	Large scale in situ tests and demonstration	Site survey and data compilation Data synthesis and evaluation Site modelling	Sensitivity analysis Performance assessment models
Current status regarding licensing by 2025	Sufficient basis exists for safety case and repository design	Testing in Underground Research Facilities (URFs) in progress	Sufficient knowledge exists for safety case and repository design	Sufficient safety potential and safety margins Further reducing of uncertainties
Vision related aims	**Underpinning the robustness of theories and models**	**Establishing safe disposal technologies on industrial level**	**Increase of confidence in long-term safety**	

Figure 2.2.3. *Overview on the principal areas of RD&D in deep geological disposal and the activities in progress in programmes closest to licensing. Identification and reduction of remaining uncertainties is mainly part of safety case development (see also Figure 2.1.1).*

Step 3 (Identification of common RD&D needs) results in the establishment of the degree of interest the implementers have in the different RD&D issues. As an example Figure 2.2.4 shows in detail the interactions between technology development and repository design and development as identified by the WMOs. In order to form a basis for the strategic prioritization, the WMOs' common RD&D needs are defined as individual **Topics**, grouped according to their subjects into **Key Topics**.

The systematic categorisation of **Key Topics** and **Topics** reflects the main features and safety requirements of geological disposal systems as well as their complexity. For detailed planning of RD&D and importance and urgency of issues it has to be taken into account that several levels of interrelation and interaction exist between many of these issues. This applies not only to scientifically and technically related issues but also to systems' performance and safety studies. The safety case as such is based on all findings and results of a programme and reflects all matters from a safety orientated perspective. In this context the role of "uncertainties" plays a specific role in both the framing of RD&D works and the evaluation of the results to be used for compiling the safety case. Apart from the individual programme, the treatment of uncertainties is of importance to every programme and will be also of interest to those programmes, which are advancing towards the final selection of concept or site.

In some programmes, specific aspects considered are the reversibility of waste disposal and the retrievability of waste. Although, it is mainly technical and operational safety issues which are affected, emphasis also has to be put on the effects such concepts and components might have on the long-term performance of deep repositories. For greater transparency RD&D needs devoted to those questions will be clearly defined and their interrelation with other relevant needs will be outlined.

Step 3 provides a view of the major trends in RD&D and a first picture of the implementers' needs for the realisation of the Vision 2025. It provides not only the basis for the thematic importance of relevant RD&D issues but also information needed for the dialogue with participants and stakeholders of the technology platform.

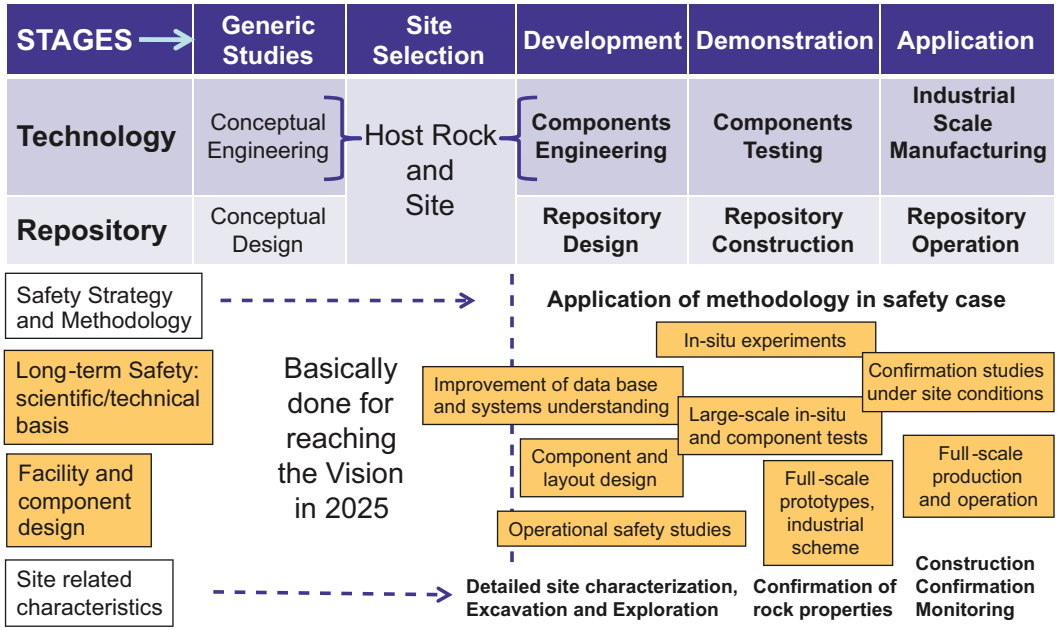

Figure 2.2.4. *An example of RD&D required by programmes, which are striving for licensing before 2025 (see Figure 2.1.1 for overall RD&D agenda).*

The handling of uncertainties in decision-making

All data and arguments supporting the long-term safety of a geological repository have to be checked for their uncertainties. Understanding, evaluation and reduction of the remaining uncertainties require the best scientific knowledge available. In particular, complex scientific issues need an explicit and rigo¬rous treatment. In a decision-making process the following types of uncertainties have to be considered:

- Framing uncertainty.
- Modelling uncertainty.
- Statistical uncertainty.
- Decision-theoretical uncertainty.

Most demanding from the scientific viewpoint is the evaluation of the long-term evolution of geological disposal systems. This requires the definition of relevant scenarios with their consequences for the man and the environment.

By nature, there are two categories of uncertainties to be addressed, the so called epistemic uncertainties, which are essentially knowledge based, and the so called aleatory uncertainties, which are essentially random. Parameter and model uncertainties can be reduced to a great extent by appropriate RD&D. However, scenario uncertainties associated with the development of the disposal system over time are more or less random and basically irreducible. Such uncertainties as well as uncertainties which may challenge programmes need further attention. With respect to this, issues to be addressed by quantitative research could be replenished by qualitative methods and supporting arguments. See /2-14 and 2-15/

Step 4 (Prioritization of Topics within each Key Topic) uses the well-established scheme for organising thematic areas in Research, Development and Demonstration of deep geological disposal, see Figure 2.2.5. Almost all RD&D Topics, which are of concern to the WMOs fit into this scheme. Criteria for the individual Topics within each Key Topic are their importance and urgency for meeting the Vision 2025 as well as the degree of common interest in the individual Topics. The importance of a Topic may depend for instance on the meaning a technical component has for the safety of the disposal system. The urgency of a Topic is directly or indirectly coupled to the date of envisaged licensing. Both metrics are in a way interrelated depending on the nature of the individual Topic. Please note that in the SRA no prioritisation between Key Topics or between their respective Topics has been done. This work is foreseen for the Deployment phase.

Each of the **Key Topics** identified on the basis of the actual state-of-the-art covers a spectrum of **Topics** still to be completed. These Topics are to some extent interrelated and require further RD&D in order to round off the scientific and technical basis needed for licensing. In this respect the importance for licensing and the time when products are needed from the RD&D works are important factors for the prioritisation of Topics in relation to the Vision 2025. A basic element at this point of the rationale is the WMOs' interest in these Topics and the reflections of the stakeholders' concerns. In this way, the first consultation meeting with the IGD-TP participants provided valuable information and input for the framing of potential Topics.

Considering both the WMOs' and stakeholders' views on Topics, importance and timeframes, the Topics within each Key Topic were identified and individually judged, with the outcomes presented in the form of simplified diagrams for further consultation and co-ordination. The entire process led to the compilation of the "Strategic Research Agenda" along with a focused RD&D programme. The execution of this programme is part of the Deployment Plan to be developed and managed by the IGD-TP.

In some cases, the individual Topics identified this way may not be that important or urgent to those members and participants of the IGD-TP who have adopted a longer time schedule for implementation. However, this strategy opens up possibilities for more detailed RD&D on fundamental issues or longer testing and monitoring of specific effects. Such work will be recognised in particular by the scientific and technical community because it contributes to a broader understanding of geological disposal in general and will eventually enhance the knowledge base.

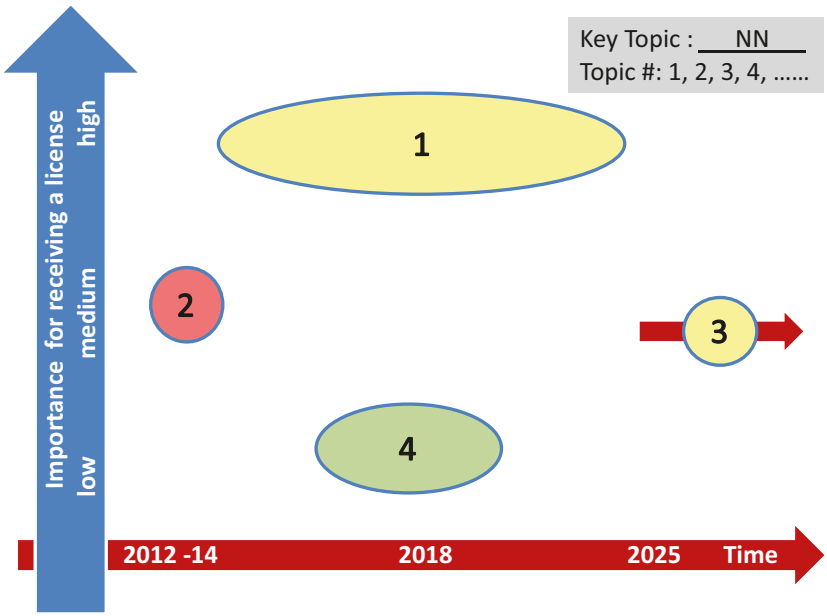

Figure 2.2.5. *An example showing the prioritization of the Topics within a Key Topic in direct comparison. High priority Topics will appear on the upper left of this diagram.*
(Importance: #1 high, #2 medium, #3 medium, #4 low;
Urgency: #1 until operation starts, #2 as soon as possible, #3 after start of operation, #4 before licensing starts).

Step 5 (Information and consultation process) is an essential part of SRA development. The input from the information and consultation processes has provided valuable ideas and shown the level of confirmation and approval from IGD-TP participants and stakeholders. In particular, the selection of Key Topics and to some extent the organisation of the Topics has been done on the basis of the dialogue with IGD-TP participants who have endorsed the Vision 2025 and stakeholders. This is a continuous process, which runs in parallel with the progress of the waste management programmes and accompanies the execution of the SRA.

All information compiled during the SRA development process has its foundation in the scientific and technical arguments and regulatory requirements supporting the importance and timing needs of the individual Topics. In particular, the outcome of the 2nd step with the identification of state-of-the-art and the remaining uncertainties is of great importance for this work.

The stepwise procedure, which included the SRA seminar and input from a large number of reviewers who commented on the draft SRA published on the IGD-TP web site, led to identification of seven main thematic areas that were defined as **Key Topics**:

- Safety case.
- Waste forms and their behaviour.
- Technical feasibility and long-term performance of repository components.
- Development strategy of the repository.
- Safety of construction and operations.
- Monitoring.
- Governance and Stakeholder involvement.

The individual **Topics** classified and prioritised under those **Key Topics** are aimed mainly at scientific and technical aspects. Although many of the Topics are stand-alone, there are quite a number of them, which are in one way or another related to each other. From this point of view the RD&D results achieved will contribute also to a knowledge increase in the other thematic areas or Key Topics. Thus the SRA is expected to have an impact on overarching issues such as confidence building and acceptance of geological disposal among stakeholders.

Cross-cutting Activities, in comparison with Key Topics and Topics, have to be seen from a different view point. They deal primarily not so much with scientific and technical issues of geological disposal as with administrative, management and societal issues.

Accordingly, such activities have to be considered in particular with respect to some overarching needs of geological disposal for fulfilling the vision of the IGD-TP such as licensing and decision-making.

From the various fields of modern technology it has been experienced that well-structured governance and open communication are essential for confidence building with stakeholders. In particular complex and sensitive scientific or technical issues may require special means and methodologies to convey results and decisions to the stakeholders including the general public. In this context important activities supporting the RD&D works are:

- Dialogue with regulators.
- Competence maintenance, education and training.
- Knowledge management (incl. information preservation, memory keeping).
- Communication and other activities supporting information exchange.

The social and political challenges are partially related to information exchange and to the possibilities the stakeholders have to get involved especially in the siting process in waste management programme. So far there are different approaches in different countries, which can help to develop some kind of best practices for stakeholders' dialogue and confidence building.

Procedural issues comprise a separate class of Cross-cutting Activities related to issues such as stakeholder governance, licensing, requirement management, decision-making processes and stakeholder communication practices. In some cases waste transportation and the financing and funding of geological disposal are also issues of the public debate. In what way such issues will be covered by the SRA depends to a great extent on the individual waste management programmes and the stakeholders' involvement in general.

3 Key Topics of the Strategic Research Agenda

3.1 Key Topic 1: Safety case

3.1.1 Definition, scope and rationale

Definition – A safety case demonstrates safety by providing a clear reasoning based on sound scientific and technological principles /3-1/. The safety case should be simple to understand and robust. The safety case is a major set of efforts to achieve the approval of a license application for a specific nuclear waste disposal facility and has to comply with the requirements set up by the national authorities. Attention should also be paid to the recommendations made by international organisations such as the International Atomic Energy Association (IAEA) and the Nuclear Energy Agency by OECD (OECD/NEA).

The safety case must be able to describe the evolution of the repository in a way that can be seen as a reasonable representation of what might happen and that also gives a clear indication of uncertainties in the description.

Safety of construction and operations addressing safety at shorter term is treated in Key Topic 5, see Section 3.5.

Objectives – The objectives are to:

- Develop a broad view on the basis for long-term safety assessments and thereby the scope and contents of safety cases relevant for all participants of the IGD-TP.
- Develop and refine concepts and models for improving long-term safety assessments.
- Improve the treatment of sensitivities and uncertainties.
- Further improve fruitful dialogue with the authorities.

Rationale and benefits – The waste management community and its stakeholders would benefit from having consistent safety cases in the different waste management programmes based on comparable regulatory objectives and assessment time frames. Each safety case should be reviewed by other WMOs to ensure state-of-the-art.

It would be beneficial if the regulatory criteria were defined in advance of the safety case assessments. In practice, the regulatory requirements become progressively more focused as decision-making (throughout the licensing process) proceeds. As a consequence, more focused RD&D in specific areas would be needed. As long as safety assessments are carried out, there is a need for RD&D to update the existing knowledge base. Continuous feedback from the safety assessments to improve and optimise the design and monitoring is also important.

The safety case is based on state-of-the-art RD&D in relevant disciplines. The long-term performance of the repository depends on both the natural geologic environment and the man–made technical barriers. To optimise the long-term performance the man-made barriers should support the geological environment by using relevant engineering techniques and sustainable materials. For some IGD-TP member organisations the safety case is closely linked to the environmental impact assessment and to social perception issues. The safety case reports should be shaped to meet the needs of the regulators as well as other relevant stakeholders.

The link between design, construction and operational practice and long-term safety should be handled in the safety case. The site and host rock properties of a repository define to a large extent the layout of the repository. These properties also define what performance is required from the engineered barriers (often referred to as the engineered barrier system) and disposal system components in order to achieve a safe repository during construction, operation and closure as well as for the long-term performance following closure. An important element in this link is the role of process models, including the investigations that obtain the necessary data, in providing the basis for abstracted safety assessment models and for guiding component performance requirements. A number of international projects are in progress that provide examples of process models and their role in safety assessment and feedback to design, e.g. the EU FP7 FORGE project /3-2/ and the Äspö Hard Rock Laboratory's LASGIT project /3-3/, both of which

deal with gas production and transport in repositories, and the EU FP7 PEBS project /3-4/, which deals with evolution of the engineered barrier system over time. The achievements of these and other related projects that support the scientific and technological basis for the safety case need to be reviewed to determine lessons learned and to define needed new developments, in the context of safety assessment and repository design and operation.

Sensitivity analyses and capturing uncertainties in input data form a part of the regular work within long-term safety assessments. Concepts and computer codes, together with scenario development regarding the impact of slow processes on long-term performance, are being improved continuously.

3.1.2 Importance for licensing, descriptions and timing of work

High importance and urgency Topics

Topic 1. Increase confidence in, and testing and further refinement of the tools (concepts, definition of scenarios and computer codes) used in safety assessments.

Topic 2. Improve safety case communication. This includes safety case communication on:

- Short-term safety of construction and operations.
- The transient phase.
- Long-term safety.

Medium importance and urgency Topics

Topic 3. Increase confidence in and further refinement of methods to make sensitivity and uncertainty analyses.

The urgency and importance of performing further studies of the above mentioned Topics for Key Topic 1 are shown in Figure 3.1.1.

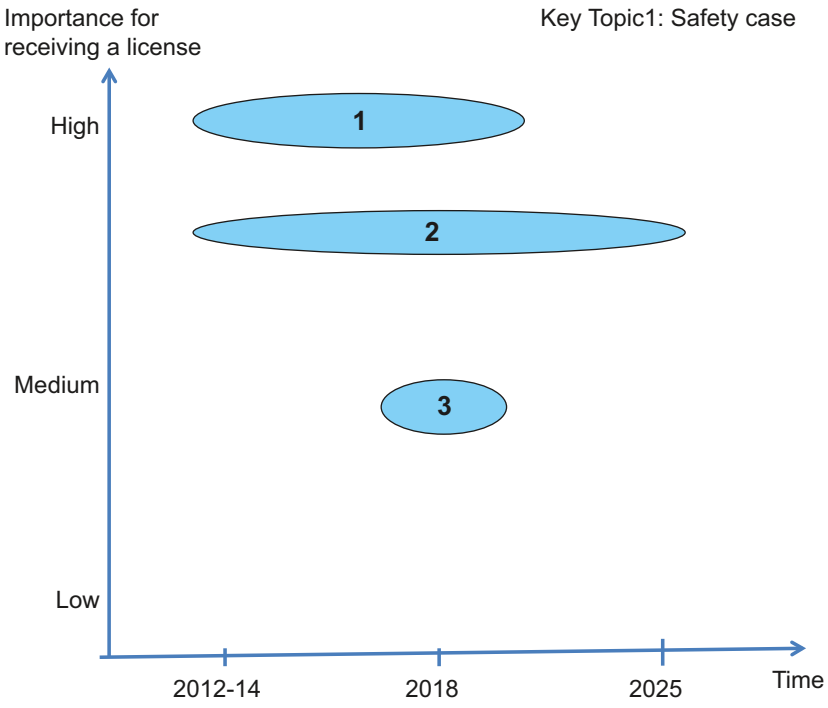

Figure 3.1.1. *Urgency and importance of "Safety case" Topics (Key Topic 1). The numbering of Topics is according to Section 3.1.2.*

3.1.3 On-going work and considerations for the Deployment Plan

Each waste management programme prepares its own safety cases and each regulator reviews it according to their own regulatory framework.

There are existing co-operation and exchange forums, such as the IGSC[3] group within the OECD/NEA that meets regularly to keep up-to-date on recent achievements among the participating programmes. These discussions are held among the safety case experts. Safety case discussions are also often discussed at international co-operation meetings held between various WMOs.

Topic 1.In addition to these on-going activities on Topic 1, one of the practical focus points in the IGD-TP work should be the testing of various material (interaction) models used in performance assessment.

Topic 2. New emphasis is also needed in the area of efficient peer review and related QA processes. Since the normal routes through by which scientific and technical results are assessed and accepted or corrected by the expert community are slow, the review processes can be enhanced by creating new channels and practices for peer review among the participants of the IGD-TP. Effective communication on the RD&D results and directions between the IGD-TP participants and national regulators would also accelerate the review processes. For example, a mirror group consisting of regulators would be an important part in succeeding with the objectives for this Topic.

Topic 3. A broad view should be developed within the IGD-TP on the main principles for analysis of sensitivities and uncertainties. Joint work, e.g. in dedicated working groups, would further improve the understanding and the treatment of these issues in the safety case.

3.2 Key Topic 2: Waste forms and their behaviour

3.2.1 Definition, scope and rationale

Definition – This Key Topic deals in particular with understanding the behaviour of various wastes in geological repositories. The waste types include spent uranium oxide (UO_2) and mixed oxide (MOX) fuels, vitrified high level waste and long-lived intermediate level wastes. The various waste types represent the potential source terms for release of radionuclides after the waste canisters are breached.

Objectives – The purpose of work is to understand safety-relevant processes, in particular the contribution of the waste form to radionuclide retention in the repository. It is important to define the total inventory of various radionuclides and their time-dependent release in mathematical models in order to assess radionuclide release from a repository.

Rationale and benefits – The studies will better quantify the processes controlling radionuclide, chemicals and gas release from waste forms, thus contributing to the quality of models used in safety assessment and adequately defining the types and magnitudes of uncertainties associated with various processes. It is expected that, because experimental facilities and specialised equipment for work with highly radioactive materials are available in only a few countries, benefits for other countries could become available through use of these facilities in such studies under international co-operation arrangements. All knowledge related to each of the waste forms is gathered in specific files for each waste form. WMOs that are at an earlier stage of implementation in their programmes would benefit through participating at the appropriate stage and having access to information from the studies performed.

[3] Integration Group for Safety Case.

3.2.2 Importance for licensing, descriptions and timing of work

High importance and urgency Topics

Topic 1. Improved data for the rapid release fraction for spent uranium oxide fuel and improved understanding of its dissolution behaviour in relation to licensing repositories for operation by 2025. It seems clear that, while significant improvements in understanding of the performance of spent fuel under repository conditions have taken place over the past 10–15 years, the gradual increase in discharge burn-up means that the present spent fuel behaviour database should be extended. Most of the published data on rapid release fractions of various long-lived radionuclides and matrix dissolution relates to fuel with burn-up values below 45 GWd/tU. Over the next 10 years the average burn-up will clearly exceed this value for many reactors, reaching average values of about 60 GWd/tU**.** Because of this, license applications related to disposal of such fuel may be inadequately supported unless further work is performed.

Topic 2. Improved data and understanding of the release of radionuclides and chemical species from various long-lived ILW. This includes detailed characterisation methods, issues related to adequate inventory determination, chemical form, speciation on release, and transport in the near-field and in the far-field. It is clearly of some importance to various waste management programmes to better determine the source terms.

Medium importance and urgency Topics

Topic 3. Improved data and understanding of the behaviour of spent MOX fuel – the rapid release fractions and dissolution behaviour under repository conditions should be further studied to determine how fuel structure influences the dissolution. Quantities of such fuel are presently small and their disposal is likely to be deferred to allow cooling because of their high heat generation.

Topic 4. Further development of burn-up credit methodology and its application for fuels with higher enrichment that allow higher burn-up – a number of studies related to post-emplacement criticality evaluation have been performed, with results showing that, with the application of burn-up credit, canisters of spent fuel in a repository will remain sub-critical provided a moderate burn-up is reached. These studies need to be extended to high burn-up fuel, which has a higher U-235 enrichment. The further development of burn-up credit methodology also seems warranted. This is a broader issue than for high burn-up fuel, as a consistent methodology is needed to evaluate fuel over the entire burn-up range, including MOX fuel.

Low importance and urgency Topics

Topic 5. Improved data and understanding of the performance of vitrified high level waste – although this has been extensively studied and considerable data and information is available, further work is required albeit with a lower importance reflecting its relatively lower importance in safety assessment.

The urgency and importance of performing further studies of the above mentioned Topics for Key Topic 2 are shown in Figure 3.2.1.

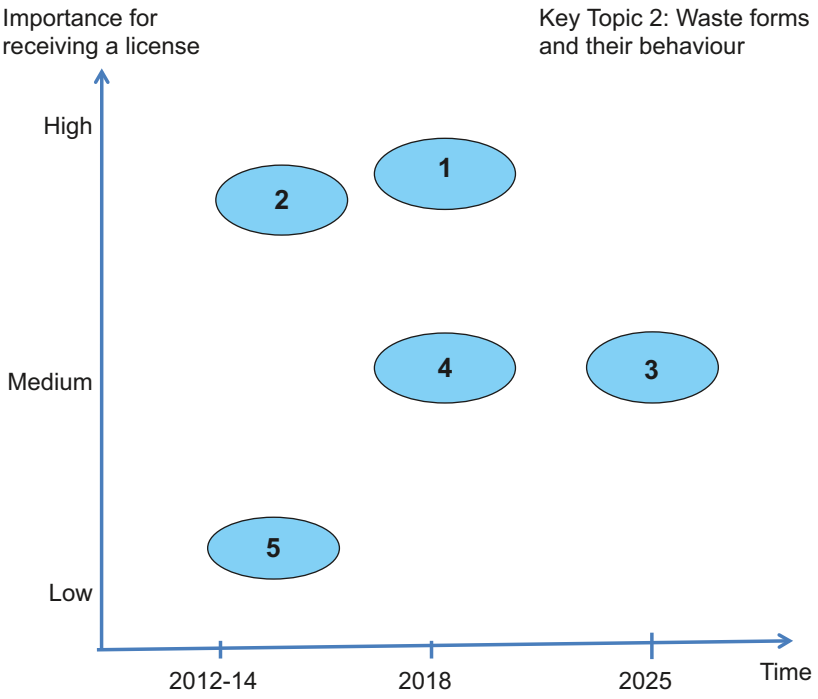

Figure 3.2.1. *Urgency and importance of "Waste forms and their behaviour" Topics (Key Topic 2). The numbering of Topics is according to Section 3.2.2.*

3.2.3 On-going work and considerations for the Deployment Plan

Topics 1–5. Research work is presently proceeding at a number of European laboratories with involvement of WMOs and research institutes. Informal co-operation among some organisations is on-going. Some co-ordinated work has been performed within EU FP projects, (e.g. for spent fuel, most recently in the MICADO project /3-5/). An informal spent fuel workshop takes place every 18 months, which brings together world experts on spent fuel characteristics related to disposal.

Improving our knowledge on waste will need co-ordinated work with the involvement of:

- The WMOs whose role is to identify the gaps and to specify further research areas.
- The waste producers, who have knowledge of the history of the fuel and other wastes and who will have an essential input in generating additional information, including direct characterisation.
- The safety authorities who can provide their technical support, in addition to having their own requirements in order to improve the quality of the information.
- Research institutes whose expected mission will be to better understand the waste characteristics and will help in defining reliable source terms.

Possible avenues for the deployment include separate specialist topical working groups for spent fuel and ILW characterisation and properties, with participation of the respective experts.

3.3 Key Topic 3: Technical feasibility and long-term performance of repository components

3.3.1 Definition, scope and rationale

Definition – This Key Topic involves the RD&D activities for demonstrating and optimising technology and construction[4] of a repository and its components. This includes confirmation of a feasible and safe operational phase, as well as ensuring that the specified safety functions[5] will be provided over the required time frame after repository closure. Included are surface and underground works as well as construction technologies for waste containers (including waste encapsulation or overpacking facilities), buffer, backfill, plugs and seals. Also included is the demonstration of construction and operations of the repository and its components. It is noted that the requirements for the definitions of these materials and their associated properties are in many cases specific to the host rock and repository design concepts. Further this Key Topic addresses the behavioural understanding of the repository components' long-term behaviour and the maintenance of their safety functions.

Objectives – The first objective (a) for Key Topic 3 is to demonstrate, to the level required by national licensing rules, that the technical design requirements based on safety of construction and operations, safety during the post-operational transient phase, and long-term safety after closure can be met in practice by available construction technologies and related working procedures. This includes confirmation of repository components against pre-defined design specifications to determine their state before closure. Further on, this extends to optimising operations and costs over the lifetime of a repository.

The second objective (b) consists in showing that the system demonstrated, according to objective a), will provide all the safety functions needed for the system as a whole to fulfil the long-term safety criteria. This requires that the evolution of the engineered components and materials is sufficiently understood in the actual repository conditions over the specified timeframe. Because of the relationship between technical design requirements and long-term performance requirements these usually must be defined iteratively. In this context, robust design may be necessary to account for uncertainties.

Each component of the repository needs to fulfill the design criteria based on the specified safety functions of the repository and meet the qualifications defined in the regulations.

Rationale and benefits – The work performed for the first objective (a) will contribute to demonstrating that construction technologies are available to meet the performance targets and requirements set for the construction of repositories for spent fuel, high-level waste and other long-lived radioactive waste by 2025. Depending on the national licensing requirements, the construction, manufacturing and installation of essential parts or components and machinery to be used have to be demonstrated to the degree required by the authorities to provide evidence of the safety of geological disposal. The need for the demonstration is also derived from the review comments on on-going RD&D of some regulators.

Dealing with the second objective (b), in support of the requirement to demonstrate long-term performance of the repository and its components, there is a need to adequately understand performance-relevant processes that relate to changes in the properties of the emplaced components and materials over the different time periods defined by the individual regulatory requirements. In general, for the various components and materials, design requirements are established that have to be met at the time of emplacement. The studies should also contribute to better quantifying the long-term performance-relevant processes that may modify properties of the waste containers, buffer, backfill and seals in repositories and help to confirm that licensing requirements will be met.

[4] Construction includes the manufacturing of components and their emplacement.

[5] The post-closure safety functions generally include containment of waste for some required period and limitation of groundwater and solute transport, including retention of radionuclides.

Spent fuel and HLW disposal containers

The selection of waste container material and associated design concepts[6] depend on the disposal environment, required container lifetime and operational handling requirements. For containers for HLW and/or spent fuel, container materials must be sufficiently corrosion resistant to provide complete containment for the required duration (hundreds to several hundreds of thousands of years, depending on disposal system requirements). Sufficient structural strength is also necessary in order to withstand long-term structural loads and handling stresses during encapsulation and repository operations. For repository implementation, it is necessary to demonstrate all aspects of waste container production and waste conditioning (including encapsulation technology) at the industrial scale.

Buffer and backfill materials

The choice of buffer and backfilling materials is partly dependent on the chosen disposal concept. Buffer and backfilling have important safety functions in some disposal concepts and shall therefore fulfill the requirements and specifications set for them. As these depend on the disposal concept under consideration and the geological environment of the site their importance varies between the different waste management programmes.

For example, in fractured crystalline rock strong requirements on the bentonite buffer's safety functions as well as on the backfill are set for the disposal concepts close to implementation. Some of these requirements and regulatory review comments are related to the state directly after emplacement of the buffer and the waste container. Such materials therefore may need to be tested in full-scale with demonstrations at underground research facilities.

This work area also supports concept development activities, such as material selection, if the decisions relating to concept selection and detailed specifications have not yet been taken.

However, there are also requirements for their long-term safety function that must be fulfilled. The processes occurring during repository evolution are similar for many materials and repository environments (e.g. compaction, diagenesis, changes in hydraulic characteristics), which makes comparisons meaningful, even though the impacts on disposal system performance may be significantly different.

Despite on-going studies, the whole supply chain for the buffer and backfilling materials and especially for bentonite buffer materials needs more RD&D work. The development work should encompass the full sourcing process from mining of materials, to processing, manufacturing, storage and logistics until the installation of the buffer and backfill components into a repository. There could also be advantages in defining acceptance levels for the outcomes on European level.

Plugging and sealing

The openings in the repository (tunnels, disposal voids, boreholes, shafts, and access ramp) must be backfilled and sealed during the operational and closure phases. The plugging and sealing might or might not have a safety function, depending on the disposal concept and the host rock. In the case that the plugs and seals have a safety function they are designed to create a mechanical and hydraulic decoupling between the repository and its environment, hence avoiding any preferential flow pathways.

The engineering (design and construction) of plugs and seals shall be based on the safety strategy of the repository while relying on engineering standards and compliance with the existing national legislation.

Different kinds of materials (cement-based, clay-based, salt-based, etc) can be used in the construction of plugs and seals. Interaction (hydraulic, mechanical and chemical) and compatibility with other engineered and geotechnical barriers as well as with the host rock needs to be assessed and ensured so that the safety functions of other components are maintained despite the interaction.

As for other repository components, the design and construction of plugs and seals has to be tested and demonstrated at full-scale at repository depth to confirm feasibility and reliability. Numerical modelling of the long-term performance of plugs and seals is also needed.

[6] Containment may rely on the waste container and/or any surrounding components, for example a disposal liner or an overpack if used.

3.3.2 Importance for licensing, description and timing of work (a) – technical feasibility

High importance and urgency Topics

Topic 1. Demonstrations of full-scale operations of HLW disposal containers – including industrial-scale fabrication, encapsulation, container handling and emplacement are required.

Topic 2. The industrial scale operations for buffer and backfill need to be demonstrated including the entire production and emplacement chain in the repository.

Topic 3. Construction of main underground facilities: Confirmation of rock properties for final detailed design is required.

Topic 4. Repository layout design including operational safety studies, see Key Topic 5, and reversibility/ retrievability are needed.

Topic 5. Pilot demonstrations of repository operations are required.

Topic 6. Full-scale demonstrations of plugging and sealing including construction and installation technologies for plugs and seals such that all the established performance targets and requirements are met and comply with the safety strategy of the disposal concept are required.

Low importance and urgency Topics

Topic 7. Knowledge compilation on non destructive testing (NDT) and related requirements on repository components is required.

Topic 8. Knowledge preservation related to retrievability is required.

3.3.3 Importance for licensing, description and timing of work (b) – long-term performance

High importance and urgency Topics

Topic 9. Improved understanding of the impact of hydrogeochemical evolution on the long-term performance of bentonite buffer in specific disposal concepts developed for crystalline host rocks. This includes laboratory and modelling studies to improved understanding the impacts on the bentonite buffer long-term safety functions.

Topic 10. Description of seals and plugs systems and modelling of their long-term behaviour with assessment of the consequences on long-term safety.

Medium importance and urgency Topics

Topic 11. Understanding of the evolution of cement-based seals is required.

Topic 12. The interaction of cement-based sealing and construction materials with clay-based buffer and seals is also of importance.

Topic 13. Continued development of low pH concretes is needed to allow them to replace conventional cements and concretes in some applications.

Topic 14. Laboratory and modelling work on salt backfill to study its long-term behaviour (consolidation, healing, interaction with the surrounding rock, influence of fluids, permeability and porosity). This Topic is specific to salt host rock environments.

Topic 15. Investigation of the effects of the iron-bentonite interaction and elevated temperatures (above 100°C) on bentonite buffer material evolution.

Low importance and urgency Topics

Topic 16. Sharing of knowledge on container materials behaviour is required.

Topic 17. The emplacement methodology of bentonite directly around waste containers and thereby the influence on thermal effects needs to be optimised.

3.3.4 On-going work and considerations for the Deployment Plan

The discussion here provides some brief details of on-going work that would be important to take account of when developing the Deployment Plan for this Key Topic. Because the technical feasibility aspects of this Key Topic are quite well advanced for waste management programmes closest to implementation, the design and construction aspects refer principally to the status of their work. Considerable co-operation in these areas is already taking place among these waste management programmes on some of these Topics.

Because of the large scope of this Key Topic, it has been included where current work on-going relates to priorities identified in Sections 3.3.2 and 3.3.3.

Demonstration of full-scale operations of HLW and/or spent fuel disposal containers (Topic 1)

The design and development of carbon steel containers for disposal of HLW in clay formations is proceeding in order to meet the license application for clay-based disposal concepts. In particular, design options have been developed and issued that include technical solutions for steel canisters (HLW) and for concrete containers (ILW). These technical solutions are considered as possibilities to be optimised during future detailed studies.

For the copper canister considered for use in fractured crystalline rock, there is a high degree of maturity in the canister design and manufacturing.

The prototype canisters intended to be used in the rock salt have been developed.

Adaptations to meet the requirements of the repository will be made.

Materials evaluation studies and design concept studies for spent fuel and HLW containers are proceeding in several other European Member States, focusing principally on carbon steel and copper, in addition to consideration of other metals.

Demonstration of the full buffer and backfill emplacement process and its supply chain (Topic 2)

Full-scale production of buffer blocks of the required density has been demonstrated, along with their emplacement in boreholes. Production of pelletised buffer for horizontal emplacement has also been demonstrated, along with full-scale demonstration of its emplacement at the required density. Further work will still be needed to manage the emplacement process in different hydrological conditions.

Plugging and sealing (Topic 6)

After having produced technical design specifications of the sealing components, large-scale tests in underground research facilities are envisaged both in crystalline and in clay environments. Individual tests will be performed on the components (construction of bentonite seals, construction of grooves filled with bentonite, performance tests…) prior to build a full demonstration experiment.

In rock salt plugging and sealing tests have been performed at different scales for many years. In particular shaft seals are designed as a multiple layer construction with stabilising and sealing components. Despite the testing of the individual components and their respective materials in the laboratory and *in situ* there is a great need for an integral demonstration experiment under real conditions. The simulation of rock- and water-pressure impact and the determination of the resulting effects on the sealing capabilities are essential not only for long-term performance models but also for licensing.

Demonstration of technical feasibility of the construction of main underground facilities and of operations (Topics 3–5 and Topics 7–8)

Construction related to deep geological disposal has been carried out in underground facilities, according to the requirements of a nuclear facility. Pending work relates to development of rock suitability criteria and their verification practices in different repository areas (tunnels, deposition areas).

Design principles have been developed with respect to repository layout design including operational safety studies, see Key Topic 5, Safety of construction and operations, and retrievability when required. Further work should include the approach to compliance needs in refining these principles, the development of procedures to incorporate operational safety and retrievability requirements further and the testing of these for the detailed design of the repository.

For Topics (7) and (8), networks are already in operation at European and international levels.

Long-term performance (Topics 9–17)

The processes affecting the waste container, the buffer and backfill and the plugging and sealing materials have been extensively studied in various waste management programmes. These are in many cases considered well understood.

The need for further work in the proposed areas discussed above is strongly linked to the specific repository design concept developed for a specific host rock environment, including consideration of the associated future possible evolutions of the buffer (Topic 9), backfilling and sealing (Topic 10) systems. These aspects need to be considered carefully in the development of specific cooperative work. For example, for the identified high importance Topic 9 (improved understanding of the impact of hydrogeochemical evolution on the long-term performance of bentonite buffer), some aspects of work that focus on the extent to which glacial water inflow into an emplacement borehole might cause erosion of the buffer would need to be considered through co-operation whilst also taking account of some system-specific information (e.g. site-specific evolution scenarios).

Similarly as an example the importance of concrete-clay interactions or concrete degradation is strongly influenced by the disposal concept and similar considerations would need to be considered in relation to setting up collaborative projects that can also take account of concept-specific and site-specific issues (Topics 12 and 14).

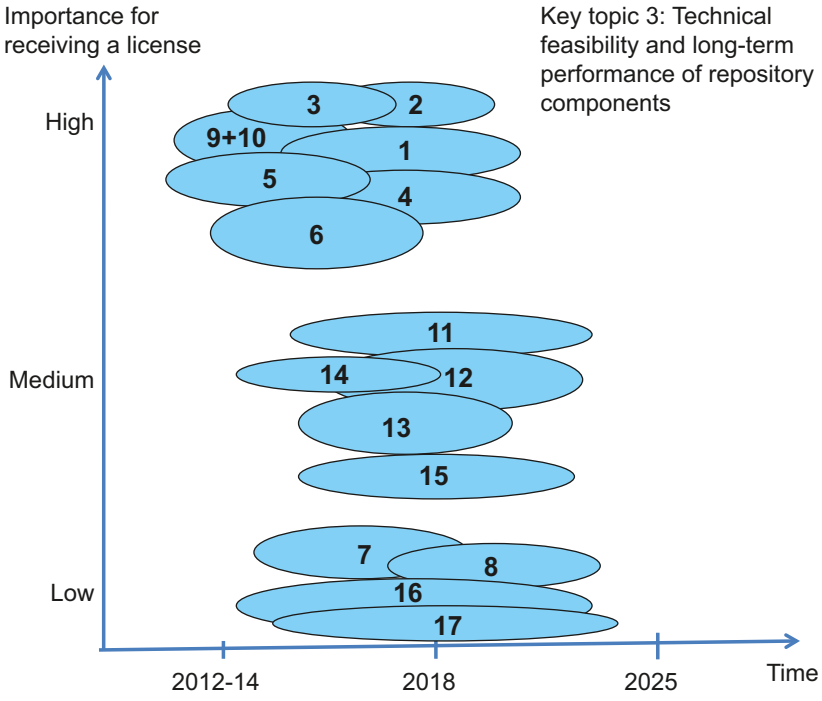

Figure 3.3.1. *Urgency and importance of "Technical feasibility and long-term performance of repository components" Topics (Key Topic 3). The numbering of Topics is according to Sections 3.3.2 and 3.3.3.*

3.4 Key Topic 4: Development strategy of the repository

3.4.1 Definition, scope and rationale

Definition – The future development of reactor, fuel cycle and waste management technologies and policies will inevitably raise needs for changes and adaptations in the design and implementation of geological disposal. Some of the future likely trends are visible already now and may be reflected in flexible designs and implementation schemes. Since the added flexibility may increase costs, the design strategy has to be optimised between the potential but often uncertain benefits of increased flexibility, and the likely cost impacts of such flexibility. This Key Topic deals with the integration of new developments during the lifetime of a geological repository (construction and the operation time up to closure). A license would be issued for constructing and operating a geological repository on the basis of the available information at the time of the application. However, during the operational lifetime of a geological repository from its construction to its closure, new technologies, new scientific findings or improvements are likely to occur and can also be considered for the future closure, as well as for any reversibility and retrievability rationale.

Adaptation is on-going throughout the lifetime of the repository from the reference layout, design, adaptation to the site during construction and also during operation.

Objectives – The Key Topic aims to ensure that a higher level of safety, or at least the same level as that demonstrated for the initial license, is achieved independent of the new developments related to the repository over time.

A geological repository should take account of new developments in order to adapt and to optimise its construction, operation and closure. Improving the industrial conditions is expected to simplify the work and to improve quality and safety and at the same time to reduce the costs.

Rationale and benefits – Development will incorporate adaptation that will consist of adjusting or modifying the design of the repository and thus its construction and operation conditions. Optimisation would include improving the short-term as well as the long-term safety, whilst also improving the industrial conditions of construction and operation.

Improving the safety conditions and its demonstration will be beneficial to gain or to maintain confidence. A benefit from improving the industrial conditions could be a reduction in costs. Specific developments are also likely to occur in the fuel cycle (higher burn-ups, new reactors and fuels, new cycle options), which may call for adaptation of the design, construction and operation conditions. In this case, adaptation might be induced by changes in boundary conditions.

Finally the reversibility and retrievability questions will have to be dealt with, in the framework of the knowledge and situation of the repository at the time any decision is to be taken.

3.4.2 Importance for licensing, description and timing of work

Medium importance and urgency Topics

Topic 1. Improved methodologies for developing strategies and approaches for adaptation and optimisation – in order to proceed to the construction of a geological repository, license applications will need to specify how any adaptation and optimisation in design, construction and operations would be managed during the lifetime of the project. For example, it is important that strategies for considering evolutions are anticipated and clearly acknowledged from the initial licensing stage. In addition, interaction with safety authorities and their Technical Safety Organisations (TSOs) is needed in order to specify the type of requirements at the time of initial license application which will allow further improvements.

It is also useful to generate guidelines on assessing the consequences of any change on the overall disposal system, including those related with reversibility and retrievability. As a matter of priority, a methodology will be discussed for the future integration of adaptations. The focus of such a methodology would be to explore the possibility of defining adaptation trends and intensity as early as the initial operations license to allow further possibilities of improvement and adaptations. The methodology will be based on the following steps:

- Identification of the different types of evolution.
- Indication of changes to expected boundary conditions for each type of evolution.
- Description of design adaptation suited for taking account of the evolutions.
- Preliminary assessment of the consequences of adaptations on the overall safety of the geological repository system, including all relevant sensitivity analyses.

The urgency and importance of performing further studies of the above mentioned Topics for Key Topic 4 are shown in Figure 3.4.1.

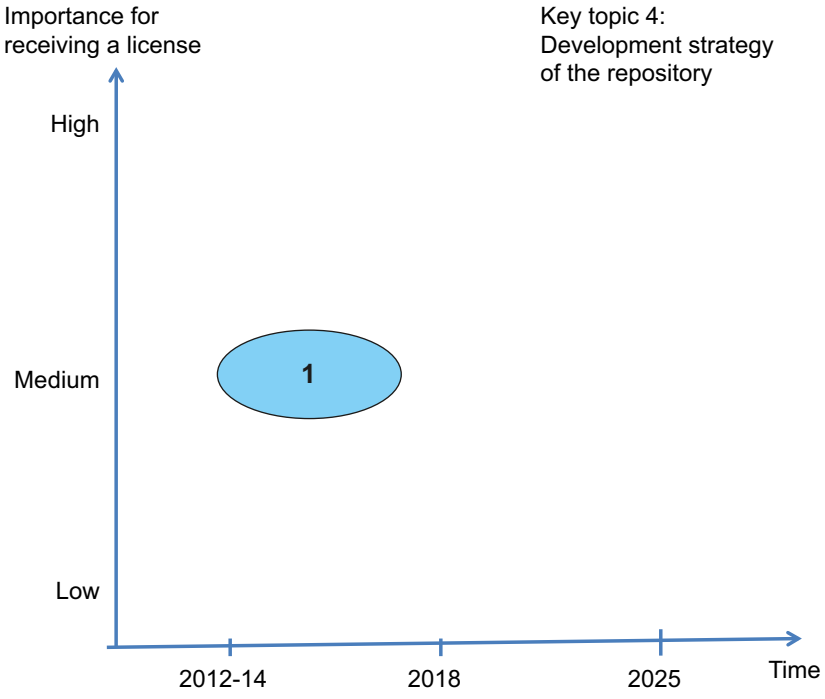

Figure 3.4.1. *Urgency and importance for "Development strategy of the repository" Topics (Key Topic 4). The numbering of Topics is according to Section 3.4.2.*

3.4.3 On-going work and considerations for the Deployment Plan

Topic 1. A development strategy is required at each stage of the repository development starting from the refinement of conceptual designs into site specific designs. When creating such strategies the accumulation of site specific knowledge, boundary conditions and changes in design basis and evolving regulations over time related to deep geological disposal as well as after the start of the repository operations should be taken into consideration. A topical working group's first task could be to identify those components of the repository system that through adaptation and optimisation would potentially reduce over-conservatism, improving quality and simplifying the design, construction and operations. A general programme of work needed would be the first deliverable from which further work would be developed.

3.5 Key Topic 5: Safety of construction and operations

3.5.1 Definition, scope and rationale

Definition – This Key Topic deals with the protection of operators and members of the public that might possibly be affected by construction and operations (like construction, normal emplacement and other operating modes, closure, monitoring and active control) in or at geological disposal facilities.

Objectives – The purpose of this Key Topic on Safety of construction and operations is to achieve consistency among the WMOs in areas such as methodological approaches, strategies, procedures, and reference values.

Rationale and benefits – Even though geological repository development is founded on the implementation of safety culture, the practical issues of industrial safety will first be confronted at the construction stage and the issues of radiation safety later at the operational stage. As such in relation to licensing repositories for operation by 2025, preliminary and final safety assessment reports will be needed.

Adaptations in view of operational safety might affect the design of the repository system and should be evaluated with respect to long-term safety. It should be mentioned that geological disposal installations are quite unique installations, where one needs to combine (amongst others):

- Nuclear engineering practice and radiation protection.
- Classical industrial safety aspects.
- Geotechnical and rock engineering in underground works (including practical mining experience when applicable).

Although regulations for each of the safety aspects exist (or might exist as these can be dependent on national circumstance), there are not always clear integrated regulations available. Between the different aspects conflicting requirements might even exist.

Although, design and concepts differ from one waste management programme to another, it is clear that some operations and challenges of safety of construction and operations have similarities.

3.5.2 Importance for licensing, descriptions and timing of work

High importance and urgency Topics

Topic 1. Improved methodology, approaches and documentation on safety of construction and operations. Building on studies undertaken in the past decades, which has been particularly focused on the long-term safety issues, the work should include:

- Improved methodologies for the way to assess the risk with respect to safe working conditions.
- The approach used for management of the risks during the construction and operational phase.
- Further development of the documentation to be used to report on safety of construction and operations.

The timing to set up a first set of guidelines is approximately the next 5 years.

Examples of additional development and demonstration:

- Concrete support for disposal drifts in clay environment: besides the design of concrete supports there is a need to proceed to demonstration of excavating large drifts and installing the supports. The long-term behaviour of the concrete in such an environment, and especially its consequences on the long-term safety should be assessed.
- Ventilation in an underground construction is always challenging. It becomes more challenging when ventilation according to the nuclear facility requirements is required. Strategies for ventilation (single or dual) and their demonstration need to be developed for all types of geological repositories.

Medium importance and urgency Topics

Topic 2. Strategies to evaluate the impacts of construction and operational issues on the disposal system – developing strategies and evaluating the impact on long-term safety, design, complexity and cost of geological repositories for specific operational issues. For example, strategies to evaluate operational issues such as emergency plans, volatile radionuclides and their impacts on workers and the environment during the operational phase. Explosive gases, air dust, ventilation and fire fighting strategies are certainly of interest to various WMOs.

The timing of the work is the next 10 years.

The urgency and importance of performing further studies of the above mentioned Topics for Key Topic 5 are shown in Figure 3.5.1.

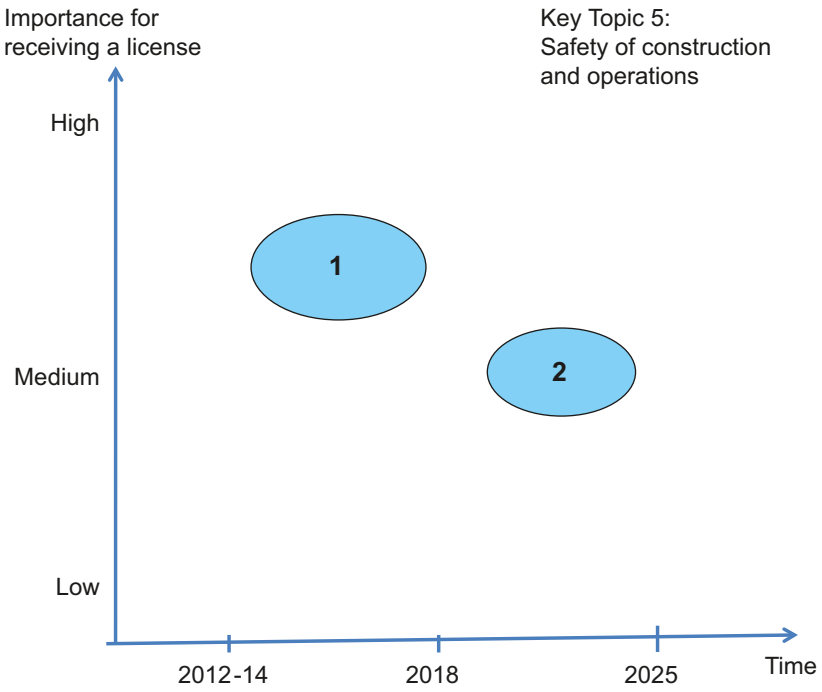

Figure 3.5.1. *Urgency and importance for "Safety of construction and operations" Topics (Key Topic 5). The numbering of Topics is according to Section 3.5.2.*

3.5.3 On-going work and considerations for the Deployment Plan

Safety of construction and operations is considered by all waste management programmes and has already been considered in the current safety assessment reports for respective programmes. However further development is still required.

To improve our knowledge to achieve the objectives of this Key Topic it is proposed to:

Topic 1. To start with checking the available information from existing facilities in operation or under construction (e.g. in WIPP, Konrad, ONKALO, and in all underground research facilities). Then to evaluate where exchange of experiences with other industries might be possible (for example with the mining industry and with the more recent work of the sequestration industries, noting that mining and tunnelling requirements might be very different); and to develop common databases and/or information exchange forums (for example for initiating events, accessing standard procedures, and for reporting and sharing data relating to deviations such as frequency of failure of various types of equipments).

Practical work can include initiation of full-scale demonstration of construction and emplacement of concrete supports in clay drifts. Another area where practical work can be done is design and modelling of ventilation systems and related demonstration.

Topic 2. Possible avenues for the deployment include the development of a technical working group to define the framework for guidelines and establish a work plan for Topics identified on safety of construction and operations. Moreover, with respect to the development of operational safety databases, it might be worthwhile to investigate the possibility of setting up a clearinghouse (a central institution or agency for the collection, maintenance, and distribution of materials, information, etc) for operational events.

3.6 Key Topic 6: Monitoring

3.6.1 Definition, scope and rationale

Definition – Strategic, methodological and technical aspects of continuous or periodic observations and measurements of environmental, engineering, or radiological parameters to help evaluate the behaviour of components of the waste disposal system, or of the impacts of the waste disposal system and its operation on the public and the environment until the end of institutional control /3-6/.

Objectives – The scope of this Key Topic covers the development of:

- Practical monitoring strategies including techniques for implementation. This includes monitoring strategies for site characterisation, facility construction and operation.
- Monitoring strategies for current and future requirements for steps leading to closure of the facilities in an operational disposal system. It would also consider requirements for post closure monitoring of this geological disposal system and monitoring of progress in relevant scientific and technological areas.

Rationale and benefits – The siting and environmental approvals included in a license application for construction, operation and/or closure of a geological disposal facility need data that partly originate from continuous or periodic observations and measurements.

Results of monitoring need to be used to strengthen the safety cases (including the update of site models), and information needs of the safety case need to be used to continuously improve monitoring programmes.

Monitoring would be carried out during each step of the development and operation of the geological disposal facilities. The purposes of the monitoring programme include providing baseline information for subsequent safety assessments, assurance of operational safety and operability of the facility, and confirmation that conditions are consistent with post-closure safety.

3.6.2 Importance for licensing, descriptions and timing of work

High importance and urgency Topics

Topic 1. Monitoring strategies and programmes for performance confirmation of the repository. It is acknowledged that many European Member States have included explicit or implicit repository monitoring requirements in their regulatory and guidance framework. Among these, performance confirmation monitoring stands out as a Topic requiring further developments within the waste management community. It should be noted that in those cases, a license application is not received favorably, if it does not include a monitoring programme. Included in the strategies and programmes are also any development of tools in support of decision-making from the recorded monitoring data.

Topic 2. Availability of monitoring technologies and techniques. The role of monitoring in assisting the stepwise decision-making from the beginning of the construction phase to the closure of the facility is increasingly recognised as a significant aspect of managing implementation of a repository. As part of this it is important and of high priority that the strategy for monitoring the first construction stage of the repository is defined. State-of-the-art methodologies, technologies and potential techniques that can be used in expected repository conditions should be available early enough for license application to be able to define the strategy and prepare all equipments for early disposals around 2020 to 2025.

Topic 3. Monitoring of the environmental reference state. The pre-operational stage of repository development includes, among other activities, environmental assessment activities, which would make use of monitoring. Environmental impact assessment and the licensing-related safety case are highly important parts of each licensing documentation pack. At such time, definition of the reference state of the environment of the site, with an exhaustive evaluation of bio and physical markers would be made. In preparation for such time, development of guidelines for defining the reference state would be beneficial. Guidelines would help develop consistent levels of characterisation between projects in various waste management programmes and would ideally be available for use for the beginning of the construction phase i.e. before 2017, for disposal programmes closest to implementation.

To support the development of future monitoring programmes for the post-construction phases, guidelines should include aspects relating to identification of the relevant and discriminant parameters at the pre-operational stage. In particular monitoring could be used to provide data for input to an appropriately established environmental database related to the initial reference state of the environment on the repository site and its surroundings that may be of use to future decision makers.

Medium importance and urgency Topics

Topic 4. Monitoring of engineered barrier systems (EBS) during operations – determination of parameters for monitoring the EBS and the development of appropriate monitoring techniques and sensors.

Topic 5. Post-closure monitoring – determination of conditions at closure and the possible parameters for monitoring during the post-closure stage until the end of institutional control including the development of appropriate monitoring techniques (e.g. wireless transmission, large energy autonomy technologies).

The urgency and importance of performing further studies of the above mentioned Topics for Key Topic 6 are shown in Figure 3.6.1.

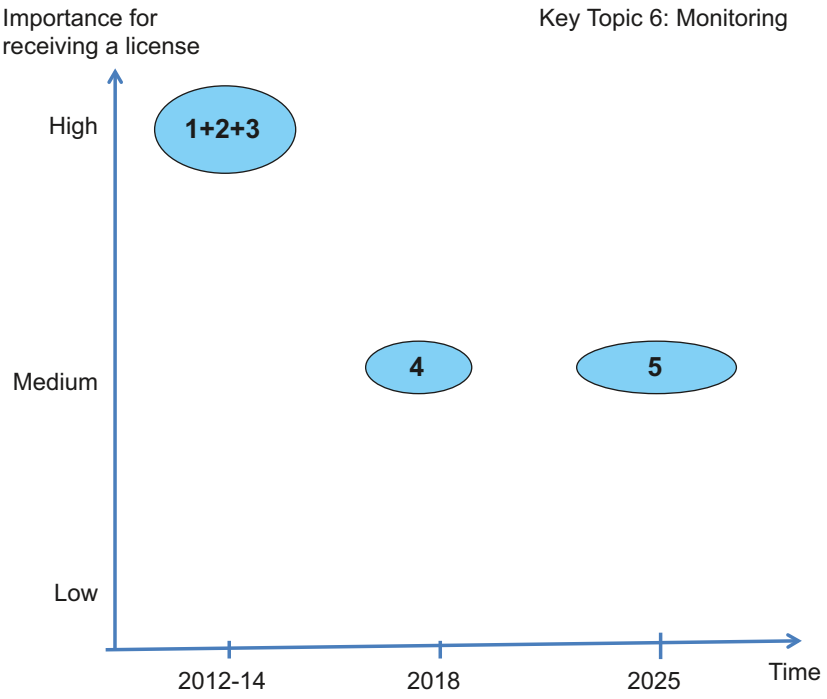

Figure 3.6.1. *Urgency and importance for "Monitoring" Topics (Key Topic 6). The numbering of Topics is according to Section 3.6.2.*

3.6.3 On-going work and considerations for the Deployment Plan

Topic 1. Several information exchange forums and collaborative groups have considered topics on monitoring. Such groups include work completed and reported by the IAEA /3-7/, the OECD NEA /3-8/ and the European Commission /3-9/.

Topic 2. Of particular relevance to this Key Topic is the on-going EU FP7 MoDeRn project /3-10/, which intends to lay the basis for a monitoring strategy and which looks at several European monitoring programmes that are in operation for the environmental monitoring for existing disposal sites. In addition to the work of the MoDeRn project, further work in relation to monitoring for geological repository projects, can be identified. Such work includes regular synthesis and update of the information about the state-of-the-art on monitoring methodology and monitoring techniques (including the results from the MoDeRn project).

Topics 3–5. In addition, within the framework of IGD-TP, there would be the potential to work on topics to develop further information on:

- Identification of the practical goals and possibilities of monitoring in each stage of the geological repository development programme.
- What the different kinds of monitoring activities are that could be applied in each stage.
- How a monitoring programme can remain flexible during the time scale of siting, construction, operating and closing the repository.
- How the feedback and lessons learned from earlier stages of development can be integrated to the next stages of the repository development.
- The maintenance of data continuity and comparability during the very long-term (e.g. for a century or more) and how the information arising from monitoring programmes will be preserved and transferred to users.

The way forward should build upon existing and expected results on repository monitoring. Products from MoDeRn will drive further RD&D projects.

3.7 Key Topic 7: Governance and Stakeholder involvement

3.7.1 Definition, scope and rationale

Definition – This Key Topic deals with the mechanisms and processes through which stakeholder involvement in waste management programmes RD&D activities take place and provides an opportunity for feedback on how these processes are governed (the rules of the decision-making processes). This Key Topic refers to ways of dialogue and review on research results that are important to support successful, effective and sustained engagement with all relevant stakeholders throughout siting, design, licensing, construction, and operation and closure of a repository. It focuses in particular on methods for communicating with those involved in key decisions relating to the implementation of geological disposal.

Objectives – The purpose of this Key Topic is to develop guidance for communicating to decision makers and stakeholders the results of research that underpin the development of safety cases and environmental assessments. It considers tools and approaches for communicating current information relating to geological disposal.

Rationale and benefits – It is essential that effective approaches to dialogue and reviews are established to build stakeholder support, confidence and trust in the concept of safe geological disposal of radioactive waste and in meeting the Vision of an operating geological disposal facility by 2025. Communicating RD&D results in a way that can best support decision makers and stakeholders involved with geological disposal programmes is important for all those working towards this Vision. Doing this effectively means engaging the various stakeholders in the review process in a way that best meets their interests and aspirations. This is an on-going iterative approach where learning experiences from one example can feed back to the design of further engagement activities, both in that country and in other countries where more progress is needed.

Such work includes how peer review is carried out, which can provide stakeholders with an assurance of the quality of communicated RD&D. This is particularly beneficial when promoting stakeholder understanding and confidence of scientific and technical RD&D issues, as it provides a degree of assurance from the wider scientific and expert community that such information can be trusted (for example it provides an "expert seal of approval").

It is important that RD&D results are communicated through dialogue with stakeholders in a clear, transparent and integrated way in order to make them as accessible and understandable as possible. Integration includes demonstrating the validity and quality of information that is available from various sources, including appropriate engagement and interaction between various organisations such as the implementers, research institutes, regulators and academia. Methods, tools and guidance that integrate and facilitate dialogue of RD&D from these sources to meet this objective help to maintain and build stakeholder relations, advise decision makers effectively and provide a route for preserving this information over long time periods. Through application of these methods, tools and guidance, successful commonalities can be identified to aid and benefit the communication cultures and strategies used on a national basis, which are often inevitably different between European cultures owing to the nature of societal issues.

3.7.2 Importance for licensing, descriptions and timing of work

High importance and urgency Topics

Topic 1. Governance of decision-making processes – experience in geological disposal siting programmes world-wide has shown that where the public and other stakeholders have been involved in the decision-making process, decisions with high levels of political acceptance have been achieved, which therefore have an increased likelihood of being implemented. In order to communicate clearly with decision makers it is necessary to develop improved methods for the integration of technical, social and economic information in an open and transparent decision-making framework.

Medium importance and urgency Topics

Topic 2. Use of RD&D results to have open and transparent dialogue with stakeholders and how such results can be reviewed – improved methods, tools and guidance so that the relevant scientific, technical and engineering RD&D results are communicated effectively are required.

Topic 3. Involvement of stakeholders – Development of a repository will be an active presence in a local community during the license application period and even more so when construction and operations commence. The way in which local communities and other stakeholders are able to be involved and influence the work of the researchers. developers and the decision makers is and will continue to be important. Understanding how decisions are reached that recognise that suitable agreement has been achieved will be needed if the processes are to be open and transparent.

The urgency and importance of performing further studies of the above mentioned Topics for Key Topic 7 are shown in Figure 3.7.1.

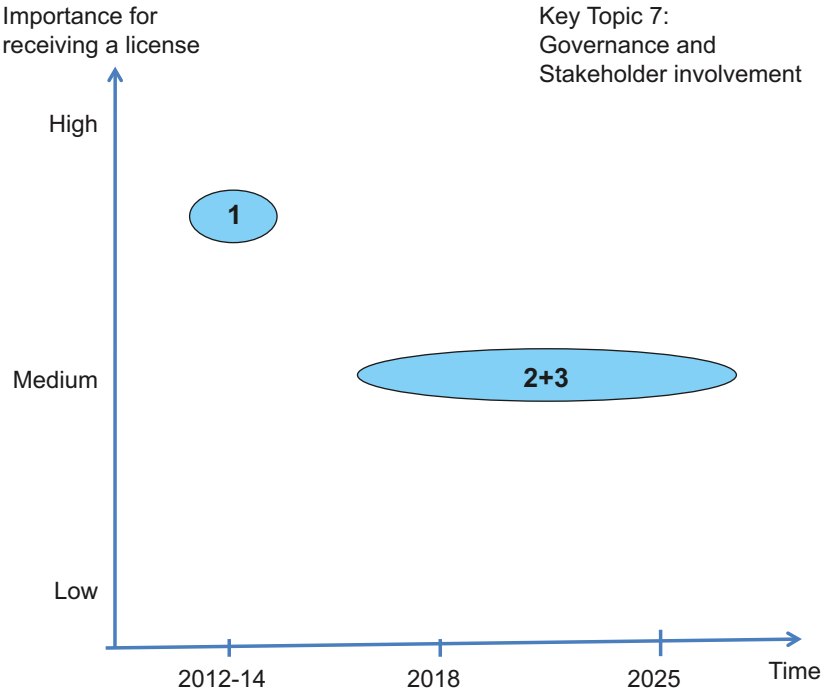

Figure 3.7.1. *Urgency and importance for "Governance and Stakeholder involvement" Topics (Key Topic 7). The numbering of Topics is according to Section 3.7.2.*

3.7.3 On-going work and considerations for the Deployment Plan

Topics 1–3. The IAEA has looked at achieving public and political acceptance of geological disposal and produced a publication in 2008. There is the Forum for Stakeholder Confidence (FSC) organised by the OECD/NEA, which has undertaken research into stakeholder involvement and governance. In addition, WMOs that have undergone the siting process have undertaken significant social science research programmes.

There have been a range of active international research projects dealing with engagement of researchers, local communities and potential operators such as COWAM /3-11/, CARL /3-12/ and ARGONA /3-13/. These international projects help WMOs to share experiences and also facilitate interactions between local stakeholders in different European Member States. There are also several projects conducted in the Euratom 7th Framework Programme on stakeholder involvement and governance considering the socio-technical challenges for implementing geological disposal /3-14–15/.

Improving our knowledge on stakeholder involvement and governance of decision processes will need co-ordinated work with the involvement of:

- The WMOs whose role is to implement geological disposal and obtain and maintain sufficient public confidence to proceed.
- The local siting communities, who will eventually host the geological disposal facility and have to live with the consequences throughout its lifetime.
- Ultimate decision-making authorities, such as governments, regulators and safety authorities who will decide on the geological disposal facility project based on a range of inputs.
- The general public at large (often the silent majority), whose short-term interest and governance over geological disposal may be limited, but who need sufficient confidence to allow the project to develop based on basic understanding and awareness on the matter.

Possible avenues for the deployment include working groups of respective specialists for developing cost effective engagement processes.

4 Cross-cutting and waste management programme specific activities

During the process of identification of RD&D Topics for inclusion in the Strategic Research Agenda, several Cross-cutting Activities have been identified that are a component of each of the Key Topics. Such activities include:

- Dialogue with the regulators.
- Competence maintenance, education and training.
- Knowledge management.
- Communication and use of RD&D results.

In addition, several activities have also been identified that are required for meeting the Vision 2025, but which are considered highly dependent on the specifics related to each geological disposal programme. Most of these issues have been omitted from the Strategic Research Agenda due to their programme specificity. Nonetheless, these activities continue within each waste management programme and identification of commonalities between the various programmes should be made and where beneficial, collaborative work for developing common approaches should be pursued. Such activities include:

- Site characterisation issues.
- Transportation.
- Requirement management systems.
- Waste acceptance (quality assurance and safeguard issues).
- Industrial scheme.
- Economics of funding and planning.

4.1 Cross-cutting Activities

4.1.1 Dialogue with the regulators

Dialogue with the regulators is performed in varied ways in the different waste management programmes in Europe, but generally the dialogue is held through both formal and informal contact. The primary contact is the one where the regulator executes its very formal role to oversee and assess the compliance of the work of the implementer to the regulations. The responsibility for this largely resides with each country's national regulatory bodies, usually defined by national law and statutes and hence varying from country to country.

The second type of contact between the implementer and the regulator is sharing general information on on-going work and recent achievements. Such contacts are common in many European Member States and are often held in an informal way.

Through such dialogue, waste management programmes among their other activities have developed safety cases that meet the requirements for safety set out by the regulators applicable to the respective stages of implementation. For example, at present several safety cases are in development across Europe in preparation for the repository construction license applications. To support common approaches to such documentation where possible, and because of the international dimension of this activity through the peer review process, it is desirable to continue in Europe and internationally to develop a common basis for nuclear safety regulation with respect to the development of safety cases for geological disposal.

On-going work and considerations for the Deployment Plan

Although it is recognised that the effective independence of regulators is an essential element of nuclear safety and there is on-going work within the IAEA to facilitated co-ordination among national regulators, it is proposed that dialogue between the regulators and the waste management programmes could be enhanced by establishing a regulators' mirror group(s) within the framework of the IGD-TP. In particular, this activity would be aimed at improved safety case development and stakeholder confidence through dialogue on common regulatory objectives and assessment time frames, and the enhanced communication of:

- RD&D issues' importance for licensing and urgency.
- RD&D results.
- Scientific reviews.

4.1.2 Competence maintenance, education and training

A broad range of different types of qualifications, competence and expertise is needed for every stage of a repository development programme as defined for example in international guidelines (e.g. IAEA's safety requirements WS-R-4 /4-1/and safety guide for geological disposal of radioactive waste GS-G-3.4 /4-2/ and in national regulations.

In terms of suitably qualified and competent personnel, the geological disposal community is fairly small. Many waste management programmes may be faced with a future skills shortage owing to an aging workforce where many senior workers and executives are approaching retirement. There is a lack of mechanisms with few national exceptions for formal education specialised in geological disposal that could be recognised directly in the different European Member States. A solid basic education in one of the related technical or natural science disciplines is also seen as more relevant for the professionals in the field starting their career. The geological disposal specifics are generally learned on-the-job. The lack of formalisation and mutual recognition applies in a greater extent to training courses and other competence development activities undertaken by the professionals in the field. There are also few formalised strategies for transmitting knowledge and insights from senior workers to those with less experience and knowledge in geological disposal. Actions related to the recognition of learning outcomes and for the quality assurance of existing and new training schemes and competence development activities are currently lacking in Europe and the IGD-TP can here play a supporting role.

On-going work and considerations for the Deployment Plan

Some recent action has been taken to improve the development and co-ordination of education and training in the field of geological disposal, although the major European-wide actions consist of the FP7 European Fission Training Schemes (EFTS). In addition, co-ordinated efforts have been made both at the national and international level to improve the education and training with a specific focus on geological disposal. The cross-European initiatives to improve education and training include European Fission Training Schemes funded by Euratom FP7 Framework Programme, and the training elements that have been integrated into the FP6 and FP7 collaborative projects like in the ESDRED project /4-3/. The Petrus II project, one of the EFTSs, focuses especially in geological disposal through mobilising resources from a strong partnership between academic and non-academic institutions, is building suitable frameworks for implementing and delivering sustainable training programmes /4-4/.

The European-wide network of universities forming the ENEN[7] association have also developed courses both on national and European level with a European Master's supplement, which have been accredited according to mutually agreed quality assurance principles of the association. These courses are available at several universities across Europe /4-5/.

[7] European Nuclear Education Network.

For recognising competence and other competence-developing activities including work experience across Europe, tools such as the Europass /4-6/ require wider outreach also in the geological disposal community. Within the Nordic countries, the entry of the suppliers working in the nuclear sites is facilitated by a training certificate recognised in all Nordic countries. Such instruments reduce the need for overlapping training and the Europass scheme aims at having a similar instrument in all European Member States.

In addition, co-ordinated efforts have been initiated also on an international level including:

- IAEA URF network of excellence – a training programme in demonstration of technologies for waste disposal in underground research facilities /4-7/.
- ITC-School Training Association – that provides both theoretical and practical training and research in all aspects of science, engineering, decision-making and communication concerned with underground waste management and related environmental issues /4-8/.

It is recognised that a more co-ordinated and more formal approach to education and training in the field of radioactive waste management and disposal would be of benefit to various programmes, both at the national level, and the international level to complement the existing efforts.

Updating and improving knowledge on radioactive waste disposal is a common interest of the IGD-TP and can be applied to all activities that will be undertaken to address identified RD&D Key Topics. The IGD-TP can co-operate with the existing education and training activities in:

- Co-operating in assuring development of the up-to-date and sustainable education and training programmes in Europe through mutual recognition and accreditation of programmes, which meet the quality level required by the IGD-TP.
- Defining the requirements related to the development of a framework for the mutual recognition and accreditation of the training programmes of all level of trainees.
- Further contributing to the identification of needs, the inventory of available resources including research infrastructures and the conception of the training programmes by taking into account both training providers and end-users point of view.
- Supporting existing and future European Fission Training schemes and other education and training initiatives to development the delivery of courses integrated to these schemes and enhance the participation of their personnel in these schemes.

One area between education and training and knowledge management includes also training activities aimed at stakeholders involved with the waste management programmes, but not working for or with their direct implementation.

4.1.3 Knowledge management

Knowledge, in general, is both documented information (explicit, using a variety of recording media) and undocumented personal insight (tacit), experience and skills (both implicit and explicit). Nuclear knowledge is all knowledge specific or relevant to nuclear related activities, including, but not limited to, scientific and technical engineering knowledge.

Nuclear knowledge management (NKM) is an integrated and systematic approach for identifying, acquiring, transforming, developing, disseminating, using, and preserving the nuclear knowledge that is critical to an individual or organisation in achieving specified objectives /4-9/.

Long-term projects, as the waste management programmes, always involve the risk of knowledge loss, in part or in full, which should be taken into account in implementing a geological disposal programme.

Knowledge can easily lose its usefulness for the future generation, if contextual information (metadata) is not retained i.e. not attached in a way that allows reproducibility, transparency, and traceability.

Therefore, managing nuclear knowledge in implementing a disposal programme includes many challenges, see Figure 4.1.1.:

- Collecting and managing nuclear knowledge: over very long timescales.
- Managing issues that arise from the limited experience in building, operating and closing deep geological disposal repositories.
- Creating knowledge from different information sources.
- Managing knowledge transfer and sharing.
- Integration of NKM into an organisation's culture, management strategy, and operational structures.
- Managing information technology.
- Managing stakeholder relationships.
- Managing education and training issues.
- Managing knowledge management tools and techniques for use in radioactive waste management.

Design, engineering, construction, operation and the safety case involve many complex, multi-disciplinary issues and these must be summarised in a comprehensive and concise manner, with links to all supporting information.

The management of increased knowledge in repository development is one of the major challenges over the lifetime of a waste management programme. It covers all data and information and in particular the basis of the decisions made. This is a major requirement for the creation and preservation of the developed knowledge related to openness, traceability and transparency.

Information must be preserved in such a way that the future stakeholders have sufficient trust in its authenticity and veracity to be able to use it with confidence.

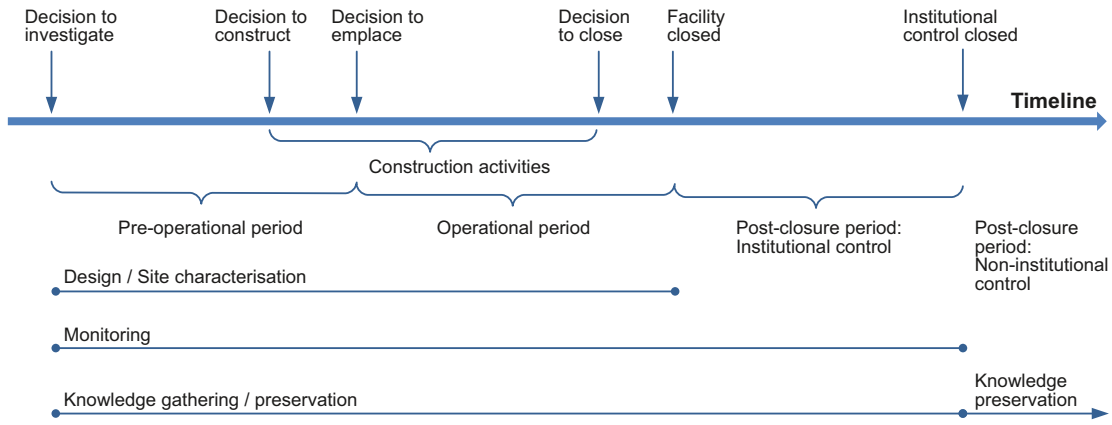

Figure 4.1.1. *Timeline to illustrate how new knowledge related to geological disposal continuously increases during a repository development programme spanning over several decades.*

On-going work and considerations for the Deployment Plan

Current standards and practices encourage the capture of information to meet present day needs. The IAEA has published a number of documents on Nuclear knowledge management for guidance, applications, lessons learned and terminology. Starting in 2006, the IAEA developed a guidance publication on "Knowledge management for radioactive waste management organisations" /4-9/. This guidance covered salient aspects of managing tacit and explicit knowledge, both in document (records) form and as skills and experiences in human beings. It addressed information management, human resources, technical competence management, primary and continuing education, stakeholder involvement, management systems and approaches, and knowledge analysis and integration.

However, the geological repository development programmes, the consecutive licensing applications and the needs of the safe management of radioactive waste require for equipping the participants of these processes and the stakeholders of future generations with the necessary knowledge to demonstrate and to judge the safety of waste disposal facility over the longer term, in many cases beyond the institutional control period.

On the basis of both an internal vision document /4-10/ on radioactive waste knowledge consolidation and transfer which has been published in 2009 and the survey on long-term preservation and memory for geological disposal of radioactive waste /4-11/ in OECD countries, OECD/NEA/RWMC proposed a broad initiative in that area in 2010A four year long (2010–2013) project in the area of geological disposal /4-12/ is currently on-going.

NKM guidance needs to be developed for future IGD-TP's projects about the methodologies to identify information to be preserved, to determine metadata which are necessary for the keeping of long-term usefulness of this information during the life-cycle of a repository, and to ensure the reproducibility, transparency and traceability of the preserved information. The proposals of this guidance need to be integrated into the working plan of each major IGD-TP joint activity.

The concept of a contextual information network /4-13/, proposed by IAEA in 2006, can be applied at organisational as well as national and international scales. It would be an appropriate starting point to establish IGD-TP member waste management programme networks, which would then provide links to other IGD-TP and national information networks thus "creating" a European IGD-TP network.

Possible avenues for the deployment include working groups of respective specialists for developing of both NKM guidance for IGD-TP's projects and the IGD-TP's contextual information network as well.

4.1.4 Communication

It is essential that effective approaches to communication and dialogue are established. Gaining confidence and trust through exchange of information, effective communication and dialogue has different aspects and is the responsibility of all those organisations working towards the Vision 2025. WMOs together with the wider scientific community have to be confident that their work is communicated in such a way that it meets established criteria, and the regulators have to be confident in the work being communicated and carried out by such organisations. It is also important that all those that take an interest in these works (local, national and international groups) are confident that research organisations, implementers and regulators are doing their work appropriately.

All relevant information needs to be communicated in a way that makes it as accessible and as understandable as possible to enable people to engage with issues at the level they feel comfortable. This also means ensuring commitment to a communication and involvement approach that ensures that issues raised by relevant stakeholder groups are fed into the appropriate RD&D Topics and are properly addressed. This is an essential part of communicating the technical information underpinning the safety case effectively so that it is comprehensible to the regulators, political decision makers, and other interested groups (including local public groups).

On-going work and considerations for the Deployment Plan

Communication activities need to be organised according to, and driven by the individual waste management programme needs to take into consideration national and local circumstances. Communication needs to be both proactive and reactive, and needs to change over time to address different issues and different groups of stakeholders, and also will change to reflect the changing stage of implementation for each waste management programme.

The IGD-TP can support such communication activities by:

- Facilitating and encouraging exchange of practices among participants.
- Ensuring that work and progress made with Key Topic 7 is regularly disseminated and used within the work of other Key Topics and other identified activities for example in education and training.

4.2 Waste management programme specific activities

The main tasks of a waste management programme are to design, construct and operate disposal facilities in a safe way. The role and responsibility of WMOs is to define the programmes and specify the requirements for the development of a repository and related facilities. Most of the RD&D programme issues for the repository design have already been covered or have been taken into account through the Key Topics of the SRA, the aim being to demonstrate that construction of the repository is feasible and safety can be achieved. All information related to this is compiled and integrated in the license applications, which include a safety case.

Considering the specificity of disposing of radioactive waste, a few key activities are being undertaken directly by the WMOs. This is needed especially in order to control the required high level of safety, quality and reliability, which cannot be delegated and which will ensure the safety of the disposal facilities.

4.2.1 Site characterisation issues

Site characterisation is (or in some cases have been) a central activity in the different waste management programmes. For the programmes close to licensing stage this issue no longer constitutes a technical challenge and does not require further RD&D work since relevant methodologies, techniques and equipment are already available, although their application in confirming rock properties. This means that site characterisation is not considered a Key Topic or Topic in this SRA to fulfill the Vision 2025.

However, site characterisation and at a later stage site selection remain sensitive issues combining both the political and scientific fields. IGD-TP's Deployment Plan will consider developing a common approach or methodology, which can be shared by those WMOs close to the licensing stage and by those WMOs that are in the very beginning of their siting process.

4.2.2 Transportation

Transportation of radioactive materials is an integral part of the nuclear fuel management and has to be performed in such a way that the protection of "the man and the environment" can be ensured. This is independent of the radioactive material transported.

The IAEA has published advisory regulations for the safe transport of such materials that are recognised throughout the world as the basis for both national and international transport safety requirements. The IAEA regulations have been adopted in about 60 countries, as well as by the International Civil Aviation Organisation (ICAO), the International Maritime Organisation (IMO) and regional transport organisations. On the basis of these regulations, transportation is safely done by road, by rail and sea (and in specific cases also by air), and is carried out by fulfilling the national requirements and legal boundary conditions.

A combination of regulatory standards and requirements, engineering design, quality controlled fabrication and inspection and validated performance of scale models provides a high confidence in the safety and security of the technologies used. Specific examples are the transport packages (containers and casks), the respective means of transport like trucks or purpose-built ships and the documented reliability of the specialised transport companies.

The implementation and adaptation of the standards is the responsibility of each country or of the responsible organisation. The procedures to handle the technical and legal requirements of transportation are well co-ordinated and considered state-of-the-art. The adaptation to legal requirements or technological improvements will always be considered. However, social aspects relating to transportation are less well established such as e.g. the implications for regional and local infrastructures (traffic volume, environmental aspects, and economy) or for security measures (monitoring and surveillance of shipments).

4.2.3 Requirement management systems (RMS)

Designing, constructing and operating a geological repository or a disposal facility system is a complex project that has to take into account the many requirements that the disposal system has to fulfill. A requirement management process helps to formalize the repository design process, and to ensure that the design takes adequate account of the various requirements and constraints on the disposal system, and helps to achieve the important goals of clear communication and traceable, justified decision-making.

As such, the requirement management process aims to raise the quality of the process of decision-making and support the decision-making and the design process itself. Requirement management provides measures to meet the various requirements from the stakeholders involved and aids in confidence building. Furthermore, as the waste management programme continues over a period of 100 years or more and the constraints and premises are likely to change within this timeframe, the requirement management should be a continuous process with a clear long-term frame.

Requirement management is seen as an integral part of waste management programmes, becoming increasingly more valuable throughout the stages of implementation. Several programmes close to licensing have their own requirement management systems (RMS), whilst other programmes are in the process of developing and or adopting such systems. Several informal contacts between waste management organisations have taken place already in order to exchange information on this activity and it has been discussed also on international forums /4-14/. Nonetheless, owing to its complexity, RMS advancements are possible and further co-ordination on this issue would be beneficial.

4.2.4 Waste acceptance

A repository is designed, constructed and operated to accommodate a given type or types of radioactive waste. The establishment of waste acceptance criteria is an essential step in radioactive waste interim storage and disposal. This typically requires that a number of criteria be established, including:

- Activity limits.
- Characteristics of the waste form and waste packages (e.g. waste constituents and quantities. packaging materials, dimensions).
- Methodology for acceptance.
- Method for dealing with non-conformities.

The basic principles are outlined in the IAEA documents /4-15/, while the specific detailed requirements are developed by the organisation accepting the waste for disposal. The waste acceptance approach takes also into account the provisions outlined by the relevant regulator.

Waste acceptance criteria give clear guidance to waste producers regarding documentation and practices. An important element of developing waste acceptance criteria for WMOs is the assessment of disposability of a given waste, which will depend on the repository design and disposal concept.

Significant work has already been done at both the national level in many countries and through the IAEA on waste acceptance criteria /4-16/.

An area of possible future co-operation for WMOs, however out of the scope of this SRA, is the potential for pretreatment of some intermediate level long-lived wastes that contain organic materials in order to address some issues arising in waste acceptance.

4.2.5 Industrial scheme

The disposal of radioactive waste calls on different types of expertise and different levels of competence. The safety requirements and the very long time scales require a high level of understanding and control of the disposal facilities. WMOs are responsible for ensuring this understanding and control over time.

During the lifetime of such facilities, the WMOs must undertake activities that are either relatively short in duration of the activity or that require qualifications that are often better possessed by specialised companies. The question of contracting/subcontracting for some types of activities is therefore often raised. The setting up of the adequate solution and of the control mechanisms by the WMO for contracted activities is necessary to attain the high quality of operations and safety objectives.

The industrial scheme determination activity is WMO specific but needs to be addressed in order to answer several questions:

- Among the activities accomplished or planned for radioactive waste management, which can be contracted and which need to be company internal?
- What are the motivations for the contracting strategy (e.g. culture, circumstances, financial issues, organisational issues, competence maintenance, national regulatory requirements)?
- Do the WMOs have to invest additionally to monitor and control the work performed by contractors due to the very high quality standard that is required?

In addition, the WMO's need to develop supplier networks for the novel processes, equipment and components needed at their facilities and these need to be maintained over the lifetime of the facilities.

The question regarding development of industrial schemes need to be addressed early in the waste management programmes with geological repositories to be commissioned by 2025. It can take place in existing exchange schemes between WMOs or within a dedicated IGD-TP working group if seen beneficial.

4.2.6 Economics of funding and planning

The economics of funding and planning of geological disposal must be undertaken in order to ensure the financing of a waste management programme and to inform decision makers and those responsible for the financing needs and availability. The costs of a disposal programme is affected by many factors including the type of wastes to be disposed (e.g. the waste inventory), the timing of the waste production, the need for interim storage arrangements, and the timing and duration of the different stages in the implementation of a repository (from site characterisation to the start of the operations until closure).

Such funding and financial planning work includes many uncertainties and up to date several methodologies and models have been developed to support such activities. These take into account of fixed costs and variable costs built around a set of assumptions, generally becoming progressively more refined as more RD&D, design, construction and operations information becomes available as the waste management programme moves through various stages in the implementation of their programme.

At the present time, benchmarking of cost estimates for implementing geological disposal is on-going in a study organised under the framework of EDRAM (International Association for Environmentally Safe Disposal of Radioactive Materials) /4-17/. Several WMOs are participating in the study and are comparing cost assessment methodologies of the cost estimates of geological repositories with the objectives of establishing a common list of cost items for disposal projects and of funding and planning the related accounting and financing mechanisms. The on-going work is focussed on the methodology rather than on actual costs of each waste management programme.

4.2.7 Consideration of WMO specific activities by the Deployment Plan

Consideration should be given to existing forums for collaboration and co-operation for the above mentioned activities where they exist. Where co-operation is less well established, and/or improvements in co-operation would be beneficial, the necessary co-operation can be initiated by the IGD-TP. It is recommended that relevant working groups shall be established within the IGD-TP among WMOs to consider the respective activities and develop plans for the deployment of these Key Topics if this is seen beneficial.

5 Way forward

5.1 Introduction to joint activity development

The production of the IGD-TP's SRA is the most significant step of the IGD-TP's work in pointing out the future strategic directions of the practical work to be carried out by the Technology Platform. The start of the deployment of the SRA is an important milestone for the IGD-TP, because it connects the RD&D work to be carried out for addressing the remaining RD&D challenges that stand between the present situation and the Vision 2025. The deployment of the SRA is important not only for producing the direct RD&D results and derived benefits, but also in enhancing the innovations related to geological disposal.

The SRA's Key Topics identified in Chapter 3 are all in demand. The implementation oriented RD&D Topics identified under Key Topic 3 "Technical feasibility and long-term performance of repository components", though, provide most opportunities to work on a practical basis and on operations related activities. As stated earlier, the joint work potential is one of the driving forces for the IGD-TP. The combination of practices from nuclear engineering, common industrial practices, and underground works for various purposes requires the production of innovative artefacts and processes for deep geological disposal. Also the broad combination of practices provides an opportunity for the emergence of a wider supplier network of companies, and in this way the new RD&D results can be turned into industrial-scale innovations that would benefit the whole geological disposal community.

In the IGD-TP development process and in the EU FP7 SecIGD Project's work plan /5-1/ it was foreseen that guidelines for the joint activities need to be agreed in advance before embarking the joint activities. There are several reasons behind the requirement of these enablers.

The members and participants wish to start joint activities and projects quickly now that the Key Topics have been agreed and the Topics identified. For speeding up the start up process, generic contract models including immaterial rights, access right to results, and the funding models need to be agreed in advance. Project management models for smooth decision-making and fund management need to be in place. Among others, joint procurement principles for the projects need to be developed and agreed. Several implementing organisations are public bodies subject to the public procurement procedures when the contracts reach the threshold values of public procurement. Other implementing organisations are private companies, which are not bound by the same regulations. In these types of questions common approaches need to be agreed and they are intended to be addressed first in the form of a background study and a small joint effort by a Work Package of the SecIGD Project.

5.2 Maintaining a living Strategic Research Agenda

The SRA presented in this report is developed with the Vision 2025 in mind and is based on the state-of-the-art in RD&D prevailing at the time of writing. Unlike the vision report of the IGD-TP, the SRA is intended to be an agenda that is updated as the RD&D activities evolve towards repository implementation. It is the first in line of SRAs and is further influenced, beyond the Vision 2025 and the priorities of the different waste management programmes, by the fact that the IGD-TP itself is in its second year of operation. The SRA is likely to evolve also as the membership and participation in the IGD-TP increases.

As the timeline from the beginning of the start of a repository development to the implementation and operation of the disposal facility is several decades, many changes are expected to take place. The status of a single waste management programme in relation to decision-making and timing of stages in development compared with the other European waste management programmes changes or can change over time. Joint activities on prioritised RD&D needs produce results that contribute to the implementation of the Vision 2025 and new RD&D needs become the focus of future joint activities. Also the individual waste management programmes important milestones e.g. in licensing and other RD&D breakthroughs can result in changed priorities and in changed joint interests.

Such events and several other reasons influencing the underlying data and assumptions used in formulating the first SRA require the IGD-TP to initiate again the staged process defined in Section 2.2 for updating the SRA when necessary. Likewise, the consultation processes and the dialogue initiated will continue as part of the iterative process of updating the SRA for the life time of the IGD-TP.

The task of the IGD-TP's Executive Group (EG) is to review the SRA on a regular basis and set up a new working group to update the IGD-TP's SRA when needed. The need arises for example when the EG review points out to significant changes in the basis on which the previous SRA was founded, or RD&D related to the Key Topics have been addressed at a sufficient level through joint or individual activities, or new Topics have emerged as the repository programmes have advanced to the next stages of the repository development.

5.3 Deployment Plan: Next step in the IGD-TP's development process

After the first SRA is finalised, a Deployment Plan (DP) is produced outlining how the Key Topic work and other Cross-cutting Activities are foreseen to be organised, funded and carried out by the Technology Platform and its members. A draft of the IGD-TP's DP is aimed to be published in 2011.

SecIGD's Work Package *"Planning for Forms of Cooperation, Deployment and Principles of Deployment",* which is lead by ANDRA, will provide the background studies needed for the development of the DP. The work focuses on looking at the different ways and models of working together in the IGD-TP, and how the DP is based on and connected with the SRA. The methods to be used for dealing with the SRA Topics need to achieve a high level of efficiency to speed the deployment.

Experience from multinational activities, EC Framework Programmes and bilateral co-operation will be used for developing the methods to ensure effective resource utilisation in the deployment. In addition, experience from the EG members' joint efforts has been gathered. This forms the basis for the activities related to proposing guidelines and models of co-operation which were scheduled to start after the SRA was submitted for broader consultation in the beginning of 2011. For testing the preliminary guidelines, a small joint effort derived from the SRA of the IGD-TP will be initiated in 2011.

The use of already gained experience and how to deal with intellectual property rights as a part of the input to the DP will be addressed. These first guidelines and models for co-operation will be disseminated along with the DP for the IGD-TP participants.

5.4 Forms of co-operation in dealing with Key Topic deployment

The implementation of the joint activities among the platform members and participants focuses on the Topics identified for the SRA and which are not yet addressed on any existing forums as pointed out at the end of each Key Topic description in Chapter 3. It should also be noted that not all Topics will be of interest to all IGD-TP members or participants.

Some activities on Topics may wait for the outcome of on-going work, before further joint activities are initiated. This type of review will be an important part of the regular review of the SRA document by the Executive Group.

The joint activities may be based on project specific agreements or on framework agreements. In addition, in the future joint ventures, joint industrial initiatives or even joint companies may also be feasible. Parts of the work may be carried out on a commercial service basis. The joint activities already now take place in various forms like multilateral projects including at least three parties, within a Euratom Framework project consortium, or in bilateral projects.

The combinations of members' and numbers of members in the different project consortiums may vary. Consortiums can be formed by partners with equal input or from a group of lead partners contracting work jointly (or individually) either from the IGD-TP participants or from research institutes, consultants or other suppliers outside the IGD-TP. Not all future joint activities require to be lead by implementing organisation (i.e. EG member), but to be IGD-TP related work, the work needs to address the Key Topics and Topics identified in the SRA.

Further forms of co-operation can also be generated around the Cross-cutting Activities, which are more exchange and infrastructure creation oriented than directly suited for joint RD&D activities like the Key Topics. The Cross-cutting Activities are needed by the IGD-TP to ensure and sustain infrastructures to achieve the Vision 2025. For example, the lack of competent professionals could jeopardize the deployment of the SRA.

The deployment itself will ultimately depend on the commitment of the members of the IGD-TP to resource these deployment activities. Also the EC Framework Programme can potentially promote the co-operation further by issuing calls on strategic research considered important for Europe.

5.5 The connection of the SRA to the Euratom Framework Programmes

The IGD-TP SRA and DP will constitute a strategic and an action plan for the IGD-TP participants and especially for the Executive Group members. At the same time, the Euratom Framework Programmes (FP) are European Union instruments, which support the RTD and Innovation in the European Member States.

Therefore, depending on the precise content and scope of future FPs, a significant part of future FP calls for proposals can be based on the importance and planning of the IGD-TP SRA and DP. As part of the overall promotions of strategic RD&D carried out collectively within IGD-TP, the IGD-TP's Executive Group shall be prepared, if requested, to assist the EC in identifying relevant topics for possible inclusion in future FP calls.

The EC officials will not take part in the discussions where the IGD-TP EG discusses potential joint initiatives, to be submitted as proposals in response to FP calls that conform to the Vision 2025, the SRA/DP and the needs of end-users.

Other applicants to the EC FP calls, who are not IGD-TP EG members, wishing to submit proposals in response to FP calls may request from IGD-TP EG a check of the conformity of their projects with the SRA and DP. The EG may thus provide an 'approval' or 'label' indicating that the project in question addresses the Vision 2025 and conforms with the SRA/DP and the needs of end users. This 'approval' is not mandatory, though it may be taken into consideration by the EC's independent experts during the evaluation. For each such 'labelled' project, when and if funded, the IGD-TP's EG shall mandate a representative who has to report on the progress of the project to the EG. Final reports from such projects shall be assessed by the IGD-TP's EG to take stock of the results, and if necessary to initiate an update of the SRA and DP.

5.6 Other forums and stakeholders needed for the deployment of the SRA

The IGD-TP's first annual Exchange Forum (EF) was held early February 2011. One aim of the EF was to solicit advice for the deployment of the SRA and to engage the participants of the EF in the deployment process of the IGD-TP. Another aim was that the participants of the EF could find Key Topics and Topics that are of interest to their organisations. Through their engagement in the specific joint activities of the IGD-TP they can contribute in achieving the Vision 2025. The contributions can take place in several forms as discussed above.

The development of suppliers for all stages of the repository development is both an opportunity and a challenge for the geological disposal community. This is especially the case during the operation period after the Vision 2025 has been achieved. Such a network or networks capable of industrial-scale operations and quality assurance within the repository context is needed. Also the identified Cross-cutting Activities can assist in the creation of innovation supportive infrastructures also for the geological disposal community.

The IGD-TP's SRA should be seen as an encouragement for the IGD-TP participants and other stakeholders to look at opportunities to get involved, to maintain and further enhance their competences and to exchange information, and to create new innovations and business opportunities in the process of the SRA deployment.

6 Conclusions

The co-operation between the waste management programmes being at different stages and following different time schedules is an essential part of the IGD-TP. The joint work among the WMOs and the active participation by interested IGD-TP participants and other stakeholders in bringing this SRA together, show that the setting up and the cooperative work of the IGD-TP already have proven to be beneficial for the participants. The detailed discussions have increased understanding on strategies in different waste management programmes and the meetings and consultation rounds with all IGD-TP participants has improved the content of the SRA. One joint project, LUCOEX, has already been started within the EU FP7 framework during the time this SRA was developed and new joint activities have been planned.

As outcome of the stepwise SRA development procedure with several cross-checks in the form of seminars and consultation meetings, the seven main thematic areas have been defined as **Key Topics** emphasising what is needed to proceed from the current status to the practical implementation of the Vision 2025. These are:

- Safety case.
- Waste forms and their behaviour.
- Technical feasibility and long-term performance of repository components.
- Development strategy of the repository.
- Safety of construction and operations.
- Monitoring.
- Governance and Stakeholder involvement.

While many waste management programmes are still at an early stage of development and therefore, it is natural that the recognised RD&D needs of the programmes closest to licensing received a particular attention in the development of the SRA. However, all European waste management programmes are foreseen to use similar stages in their programme development and therefore the IGD-TP offers all participants reasonable incentives for participation and sharing of resources.

Individual **Topics** have been classified and prioritised under each **Key Topics** and are aimed mainly at addressing scientific and technical aspects. Although, many of the Topics stand on their own there are quite a number of them, which are related to each other. Prioritisation between Topics belonging to different Key Topics has not been part of the SRA development and is foreseen to be discussed during the deployment phase of the IGD-TP.

The upcoming deployment phase of the IGD-TP's SRA is foreseen to be helpful in:

- Keeping up a technical and scientific activities, which should support the different stages of the implementation of the repositories.
- Reducing of overlapping work.
- Better use of existing competence and research infrastructures.
- Identification and use of synergies and possibilities for cost sharing.
- Allowing and facilitating the interactions between waste management programmes of different maturity.
- Competence building.
- Knowledge transfer to programmes at earlier stages of development.
- Allowing a better insertion of the management of radioactive waste in the European Research Area.
- Defining and setting up of different types of specific joint activities and networks to reach the Vision 2025.

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Appendix

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