1.3.3 "International Cooperation"

Use the knowledge, technology and experience gained internationally and co-develop RD&D where possible to improve and consolidate confidence in the scientific and technical data base, to help reduce risks to successful programme implementation and to avoid unnecessary costs.

Domain Insight

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Overview

International cooperation is an important part of implementing geological disposal. While the character and inventory of nuclear waste and spent fuel as well as geological conditions vary between different states, the basic principles and technologies for long-term safe geological disposal of nuclear waste and spent nuclear fuel are the same. Sharing experiences and learning from other programmes is thus a key means for any nuclear waste programme on how to practically achieve long-term safe disposal. Such sharing and learning includes, but is not limited to, methods for establishing the inventory and characteristics of the waste streams produced through use of nuclear technology, different waste container and other engineered barrier designs, properties of different potential host rocks, approaches and methods for safety assessment and safety case production, practical approaches to siting and site investigations and how to conduct effective stakeholder interactions during the long duration and different stages of a waste management programme. Most issues of concern in a given national programme can be understood by, or explained to, key experts in other programmes. Interacting with other programmes provide insights to all participants. Examples of international cooperation include the services and actions offered by the international organisations like the International Atomic Energy Agency (IAEA), Organisation for Economic Co-operation and Development (OECD) or the European Union, but also occur through multinational advisory and review groups, cooperation between sister organisations, secondments, joint research in order to share and reduce costs or in order to share facilities including generic underground research facilities, technology transfer, training courses or purchase of consultancy services or management solutions. In addition to the collaborative generation and transfer of knowledge, these actions also help to develop capability and understanding and generate “Communities of Practice” (CoP) regarding how to implement geological disposal, to the mutual benefit of all parties involved.

Keywords

Knowledge, technology, international experience, international organisations, advisory groups, , secondments, collaborative research, generic underground research facilities, technology transfer, competence maintenance, training courses, multinational repositories, consultancy services

Key Acronyms

IAEA	International Atomic Energy Agency
OECD/NEA	OECD Nuclear Energy Agency
WMO	Waste Management Organisations
TSO	Technical Support Organisations
RD&D	Research, Development and Demonstration
RE	Research Entities

1. Typical overall goals and activities in the domain of International Cooperation

Essentially all states with advanced nuclear programmes have plans for geological disposal. Deep geological disposal is internationally recognised as the best long-term solution for dealing with higher-activity radioactive waste with some of these countries (currently Finland, Sweden and France) are well on the way to construction.

International cooperation is an important part of implementing geological disposal. This includes the activities of international organisations as well as working closely with sister organisations, e.g. different Waste Management Organisations (WMOs), different regulators, different Technical Support Organisations (TSOs) or different Research Entities (REs) with their associated local communities in different states. International cooperation involves sharing existing knowledge, experience and understanding, participation in joint research with the objective to collaboratively develop the scientific base or investigate common issues and to undertake technology transfer exercises with other disposal programmes to benefit from latest advancements, specifically relevant technology that could be utilised in the national programme.

As specified in the EURAD Roadmap “Programme Management” Theme Overview (see EURAD 2021) the domain goal of International Cooperation in to *use the knowledge, technology and experience gained internationally and co-develop RD&D where possible to improve and consolidate confidence in the scientific and technical data base, to help reduce risks to successful programme implementation and to avoid unnecessary costs*. International cooperation with these aims involves activities in all different roadmap phases, see **Table 1**.

Table 1 Goal of International Cooperation and key Activities at different roadmap phases (from the “Programme Management” Theme Overview)

Domain Goal	
1.3.3 Use the knowledge, technology and experience gained internationally and co-develop RD&D where possible to improve and consolidate confidence in the scientific and technical data base, to help reduce risks to successful programme implementation and to avoid unnecessary costs (International Cooperation)	
Domain Activities	
Phase 1: Programme Initiation	Establish international contacts, both through the international organisations and bilaterally with organisation judged to have relevant experiences in building and managing a radioactive waste management (RWM) programme. Assess availability of relevant scientific, engineering experiences and policy framework in existing disposal programmes and establish means for collaboration or procurement. Initiate transfer of knowledge and research activities in order to identify, evaluate and close relevant gaps.
Phase 2: DGR Site Identification	All organisations: maintain and expand international contacts. WMO to seek collaboration with organisations having experience in the siting process, site investigations or in developing repository concepts similar to what is envisaged in the programme.

Phase 3: DGR Site Characterisation	Training and collaboration activities will continue in all organisations.
Phase 4: DGR Construction	Make a dedicated effort to maintain the core competence of the safety case, geoscience and waste properties, since these competences may otherwise be lost when the programme transforms to an industrial project, and to increase competences in other scientific and technological domains relevant to construction and operating, including future optimisation. Share experiences on construction and operation with sister organisations.
Phase 5: DGR Operation and Closure	Both regulator and WMO to continue with the dedicated efforts to maintain the core competence of the safety case, geoscience and waste properties – this is likely to become increasingly demanding over a multi-decade operational period. Sharing of operational experience among international counterpart organisations with DGRs should focus on means of maintaining the competencies mentioned above.

2. Contribution to generic safety functions and implementation goals

While the character and inventory of nuclear waste and spent fuel as well as geological conditions vary between different states, the basic principles and technologies for long-term safe geological disposal of nuclear waste and spent nuclear fuel are the same. Sharing experiences and learning from other programmes is thus a key means for any nuclear waste programme on how to practically achieve long-term safe disposal. Such sharing and learning include, but is not limited to, methods for assessing the inventory and characteristics of the waste stream produced in the nuclear programmes, different waste container and other engineered barrier designs, properties of different potential host rocks, approaches and methods for safety assessment and safety case production, practical approaches to siting and site investigations or how to handle stakeholder interactions throughout the long course and different stages of a waste management programme.

Possibly, three stages of international cooperation can be identified. First, a broad cooperation allowing to establish the most fundamental tenets for passive long-term safety. Second, the cooperation between more advanced programmes to translate these fundamental safety functions into more detailed science and technology developments based on understanding how natural and engineered components evolve and interact. Third, international cooperation as the opportunity to transfer knowledge from mature programmes to emerging programmes.

International cooperation is a very important tool for programmes and organisations to share knowledge and skills. Therefore it strongly contributes to the understanding and eventual selection of the waste management/disposal concepts/solutions. The strategy adopted at present to achieve this fundamental safety objective in respect of the disposal of radioactive waste is to contain the waste and to isolate it from the accessible biosphere, to the extent that this is necessary (IAEA, SSR-5).

Over the past half century, a range of long-term safe disposal concepts developed for a relatively wide range of different geological environments have been designed and assessed in an iterative manner in different waste management programmes worldwide. The means that there is a widespread knowledge on how to ensure the basic safety goals listed in Domain 7.1.1 "Safety Requirements" even if this knowledge usually cannot be directly copied between programmes. For example:

1. To ensure *isolation* of waste from people and the accessible biosphere it is well recognised that this involves siting and designing the DGR in a sufficiently stable environment at a sufficient protection from the disruptive effects of geomorphological processes as well as from future human activities. However, the need for such stability will be different for different wastes and DGR designs and the processes of concern will be different for different geological and geographical settings.
2. Various examples on how to provide sufficient *containment* have been developed and assessed, e.g. by EBS solutions with a tight waste container surrounded by a buffer. There is a wide understanding e.g. on how different waste container and buffer materials evolve over time being subject to different loads. However, the time needed for complete containment within a specific barrier component, as well as the importance of different processes that could disrupt the containment, can differ substantially between different wastes and for different host rock environments.
3. All DGR concepts *build on containment of contaminants within the total disposal system* (i.e. waste package, engineered barriers and natural barriers) by *retention or retardation*. The fundamental retention processes, e.g. solution/dissolution, advection (groundwater flow), dispersion, diffusion, sorption and other chemical interactions are the same in any medium. However, the importance of this retention differs between wastes and host rocks and also to what extent the DGR concept can offer complete containment.
4. To ensure *long-term stability with respect to external events and environmental evolution* the DGR is sited such that disposal system performance is not significantly affected by external disturbances, e.g.: evolution of geological and surface environment due to tectonics and climate change. However, the time needed for such stability varies between concepts and the evolutionary processes of concern vary for different geological settings.
5. To *ensure long-term stability with respect to internal evolution* the DGR is designed and implemented such that disposal system performance is not significantly affected by internal disturbances. While many of these potential disturbances are similar in most DGR concepts the key processes of concern vary between wastes, EBS designs and host rock environments.

In conclusion, international experiences are extremely valuable both for selecting and assessing long-term safety of DGR concepts and most issues of concern in a national programme can be understood by, or explained to, key experts in other programmes even if they do not have exactly the same type of waste or exactly the same type of geological environments. However, also understanding and being able to explain any differences between the different national programmes is essential to demonstrate sufficient understanding and to retain the confidence of key stakeholder groups, e.g. national regulators, community representatives and the wider public. Direct copy of concepts or means of assessment may not always work.

2.1 Role of international cooperation in achieving feasible implementation of geological disposal

International cooperation is also judged to be of key importance for achieving feasible implementation and contributes to all different implementation goals listed Domain 7.1.1 "Safety Requirements". Most issues of concern in a national programme can be understood by, or explained to, key experts in other programmes.

Technical practicability including selection of designs for ease of underground operations and package handling, will be enhanced by learning from experiences by other programmes, e.g. from peer review, technology transfer or participating in joint international tests of equipment or approaches as set up in international underground research facilities (URFs) (see further Section 3). The extent to which these international experiences need to be adapted to the conditions of the national programme and to what extent additional development and tests would be needed, of course depend on how similar or different the national programme is to the international experiences.

Especially at later phases of a DGR programme, it becomes essential to *ensure that design confirms to technical design requirements that would lead to fulfilment of safety functions*. The level of detail in how to specify safety functions as well as design requirements will develop during the different roadmap phases. At early stages, rather general safety functions and requirements are acceptable, but closer to implementation the design requirements become an essential part of the safety case. Practical experience on how to develop practical design requirements that both are relevant for post-closure safety and are practical to implement and verify is now acquired in mature programmes. While the specific technical design requirements may only apply to specific wastes, EBS designs and geological conditions, see e.g. [Posiva and SKB 2017] the basic approach adapted is considered to be transferrable to any programme – also at quite early phases of the roadmap. Considering the variation in e.g. varying rates of waste disposal, types of waste or waste packaging, or uncertainty in inventory seen in different national programmes, and how the programmes adapt to manage these differences, could help in preparing the own national programme to *allow operational flexibility.* Furthermore, many specific solutions, especially regarding transport containers, packaging and handling are commercially available through a few companies acting on multinational markets.

Means to ensure *Nuclear Security and Safeguards* are fundamental aspects of international cooperation. The IAEA Department of Nuclear Safety and Security aims at providing a strong, sustainable and visible global nuclear safety and security framework. Through a set of technical measures, or safeguards, the IAEA, through its Department of Safeguards, verifies that states are honouring their international legal obligations to use nuclear material and technology only for peaceful purposes. Sharing experiences between programmes and with the IAEA on how to implement the needed practical measures is fundamental for meeting these aims and obligations.

Sharing experiences on issues related to operational safety, considering both radiological and non-radiological risks, will help programmes to satisfy *Operational Safety*. In addition, sharing experiences on underground excavation work, which can imply a great potential non-radiological risk to workers, is often handled by the supply chain that also can involve multinational contractors. Programmes can exchange experiences in how to make use of the experiences of these contractors, but also on how to deal with these and how to setup contracts.

Sharing experiences on what aspects of DGR construction and operation that could affect the environment, e.g. use of scarce materials, energy requirements, impacts on groundwater levels and composition, handling of rock spoils, noise or disturbance from traffic, will help programmes to keep these *environmental impacts* sufficiently low. However, the local conditions, as well as the concerns of local stakeholders are fundamental aspects to include in such assessments.

Finally, international cooperation will provide programme with key insights on how to allow optimisation of disposal system design and operation. Comparisons with other programmes could provide insights into what aspects of a DGR programme that could be trimmed to result in an efficient use of resources and would also provide insights into when such optimisation efforts should be made. Too early focus on costs may lead to non-optimal solutions, but if these issues are considered at a very late phase of the DGR roadmap it may no longer be practical to make any changes. However, actual solutions and findings are usually quite programme, concept and site specific.

3. Examples of International Cooperation

3.1 Use of publicly available knowledge

Much of the information and knowledge attained by the different waste management programmes are in the public domain and can be accessed from webpages or peer-reviewed journals. However, the degree to which organisations publish their findings vary between programmes and has also changed over time. For example, the licensing process may steer programmes to primarily publish in the national language and other information may not be published for commercial or security reasons. Furthermore, it may not always be easy to understand the documents without additional insights regarding the basis or other aspects of the published study. In conclusion, while published information is essential for fostering international cooperation it cannot solely be relied upon. A large and detailed international knowledgebase exists, but the application, interpretation and expansion of this international knowledge to national boundary conditions (policy, inventory, geological setting and paired disposal concept) remains the role of the national implementer.

3.2 International organisations

There are essentially three major international organisations that foster international cooperation on radioactive waste and spent fuel management, IAEA, OECD/NEA and the European Union (through the Euratom treaty). In addition to the requirements, guides, recommendations and other documents produced by these organisations and the direct funding of joint research and development (R&D) by EU, these organisations provide platforms for interaction with peers from sister organisations and also allow interaction with regulators from other countries. Over the years, these interactions have strongly advanced the understanding on how to conduct a repository development programme and how to carry out safety assessments. A key contribution to international cooperation offered by the international organisations is the "*community of practice* (CoP)" resulting from these actions.

3.2.1 IAEA

The IAEA (www.iaea.org) within the United Nations family, is the international centre for cooperation in the nuclear field. The agency works with its member states and multiple partners worldwide to promote the safe, secure and peaceful use of nuclear technologies. Radioactive waste and spent fuel management is a key topic within all IAEA departments including Technical Cooperation, Nuclear Energy, Nuclear Safety and Security, Nuclear Sciences and Applications and Safeguards.

The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (www.iaea.org/topics/nuclear-safety-conventions/joint-convention-safety-spent-fuel-management-and-safety-radioactive-waste), adopted in September 1997 and entered into force in June 2001, is a key advance of the agency's work in this area. The Joint Convention is the first legal instrument to address the issue of spent fuel and RWM safety on a global scale, by establishing fundamental safety principles and creating a similar "peer review" process to the Convention on Nuclear Safety. Participating states are committed to achieve and maintain a consistently high level of safety and national reports and peer-review meetings are held every 3rd year.

The agency publishes the safety standards series comprises three levels of documents: Safety Fundamentals, Safety Requirements and Safety Guides, see e.g. IAEA SF-1, IAEA SSR-5, IAEA-SSG-14 and IAEA SSG-23. In addition, a multitude of technical support documents covering topics throughout all aspects of radioactive waste and spent fuel management in the form of safety reports, technical reports and TECDOCs. All publications are available on IAEA website.

Interaction between experts throughout the world is established by various means. Various conferences and meetings are organised on a yearly basis. Production of IAEA documents are usually achieved by groups of international experts, assembled by the agency and later reviewed and disseminated though technical meetings with representatives from the member states. The agency also performs international peer reviews of RWM programmes or aspects such programmes (see further section 3.4).

Technical cooperation is the agency's primary mechanism for transferring nuclear technology to member states. This is e.g. achieved by assessing the state of the RWM programme, by organising workshops. The TC programme is funded by the Technical Cooperation Fund (TCF), extrabudgetary contributions, government cost-sharing (funding where the donor is the recipient) and in-kind contributions. All member states are eligible for support through technical cooperation projects, although in practice these tend to focus on the needs and priorities of less developed countries.

Guidelines, other documents and data bases are in the public domain and are accessible free of charge from the IAEA web page. Participation conferences, working groups etc. is free of charge. The cost of developing documents etc. is handled by defined cost-sharing, where most organisations participate at their own cost, but financial support for travel and consultancy can be provided to individuals by the IAEA.

3.2.2 OECD NEA

The OECD Nuclear Energy Agency (NEA), www.oecd-nea.org, is an intergovernmental agency that facilitates cooperation among countries with advanced nuclear technology infrastructures to seek excellence in nuclear safety, technology, science, environment and law. The NEA operates within the framework of the OECD. Management of radioactive waste and spent fuel is handled through the NEA Radioactive Waste Management Committee (RWMC), which consists of senior representatives from regulatory authorities, RWM and decommissioning organisations, policymaking bodies and research-and-development institutions from the NEA countries. The RWMC supports members in the development of safe and economically efficient management of all types of radioactive waste including spent fuel considered as radioactive waste based on the latest scientific and technological knowledge. It provides a neutral forum where policymakers, regulators and implementing organisations can discuss issues of common interest and develop best practices and feasible solutions that meet the diverse needs of its participants.

To support discussion of safety provision between members, the Integration Group for the Safety Case (IGSC) was established in 2000 by the RWMC. The IGSC is the main technical advisory body to the RWMC on deep geological disposal, especially for long-lived and high-level radioactive waste. A safety case is a collection of safety claims, arguments and underpinning evidence that demonstrate the safety of a management process or a facility throughout its lifetime. The expertise, approach and strategies required for the development of assessment scenarios, the management of uncertainties and the associated risk evaluations in compiling and presenting safety cases for different disposal facilities share some commonalities. The IGSC has three subgroups – Clay Club, Salt Club and Crystalline Club – to discuss the safety cases for each of these 'international big three' broad geologic formations. In addition, the Expert Group on Operational Safety (EGOS) was established to discuss and share best practice on the safety cases during the operational phase of a disposal facility.

Both the RWMC and the IGSC organise workshops, symposia and other activities fostering cooperation between programmes and individual experts working in these programmes. International peer reviews of RWM programmes or aspects such programmes are also carried out (see further section 3.4).

Documents and databases are in the public domain and are accessible free of charge from the NEA webpage. Participation conferences, working groups etc. is free of charge. The cost of developing documents etc. is handled by defined cost-sharing, where organisations participate at their own cost. Cost for consultants, if needed, are also shared between participating organisations on a voluntary basis.

3.2.3 European Union and Euratom

The European Atomic Energy Community (EAEC or Euratom) is an international organisation established by the Euratom treaty on 25 March 1957.Over the years its scope has been considerably increased to cover a large variety of areas associated with nuclear power and ionizing radiation. It is legally distinct from the European Union (EU) although it has the same membership and is governed by many of the EU's institutions.

The EU's Radioactive Waste and Spent Fuel Management Directive (2011/70/Euratom) requires that all EU countries have a national policy for spent fuel and RWM and that they draw up and implement national programmes for the management of these materials. The programmes should cover all types of spent fuel and radioactive waste under EU countries' jurisdiction and all stages of spent fuel and RWM from generation to disposal. Every three years since August 2015, EU countries submit national reports on the implementation of the directive to the commission. Based on those, the commission drafts a report on the overall implementation of the directive and an inventory of radioactive waste and spent fuel present in the community's territory and the future prospects.

Through the Euratom treaty the EU has since long supported joint European research on RWM and spent fuel. Since 2019, this work has further deepened into a European Joint Programme on Radioactive Waste Management (EURAD, https://www.ejp-eurad.eu/). EURAD supports the implementation of the

Waste Directive (Council Directive 2011/70) in EU member states, taking into account the various stages of advancement of national programmes.

EURAD gathers WMOs having the ultimate responsibility for the implementation of geological disposal, TSOs carrying out activities aimed at providing the technical and scientific basis for supporting the work and decisions made by a national regulatory body and nationally funded REs working to different degrees on the challenges of RWM including disposal (and sometimes in direct support to implementers (WMOs or TSOs), under the responsibility of member states. In addition, the WMOs in some countries outside the EU (Australia, Canada, Japan; Switzerland and UK) are also associated to EURAD.

Guidelines, other documents and databases are in the public domain and are accessible free of charge. Participation in conferences, working groups etc. is free of charge. EURAD also directly fund R&D projects, although participating organisations usually also co-fund the work, e.g. by “in-kind" contributions. Costs for consultants, etc. are fully covered by EURAD.

Beyond RD&D and Strategic Studies, ambitious activities of EURAD are to consolidate efforts across member states on knowledge management. This includes access to existing knowledge (State-of-Knowledge), guiding the planning and implementation of a RD&D plan of national RWM programme, and developing/delivering training/mobility in-line with core competencies.

While EURAD is currently a main benefactor of EU-funding there are other projects funded. For example, PREDIS, pre-disposal management of radioactive waste, targeting the development and implementation of activities for pre-disposal treatment of radioactive waste streams other than nuclear fuel and high-level radioactive waste is also funded by the EU.

3.3 Other international bodies

There is a range of other international bodies funded by their actual members. Especially the ICRP has a very prominent standing. In the following, some of these organisations are described, but there may be others of equal importance not mentioned here.

3.3.1 ICRP

The International Commission on Radiological Protection (ICRP; www.icrp.org) is an independent, international organisation that advances for the public benefit the science of radiological protection, in particular by providing recommendations and guidance on all aspects of protection against ionizing radiation. While the ICRP is not associated to any other international organisation, it has a fundamental impact on national radiation protection regulations.

3.3.2 EDRAM

The “International Association for Environmentally Safe Disposal of Radioactive Materials”, or in short EDRAM group (https://www.edram.info/), is an association of well-established organisations with responsibility for management of radioactive wastes in their respective countries. Twelve waste management organisations from eleven countries (Belgium, Germany, Finland, France, the United Kingdom, Japan, Canada, Sweden, Switzerland, Spain and the USA) founded EDRAM in 1998. Two meetings are held every year to discuss the progress of work worldwide and the most recent developments in the different member countries.

3.3.3 IGD-TP

The Implementing Geological Disposal of radioactive waste Technology Platform (IGD-TP; https://igdtp.eu/) is dedicated to initiating and carrying out European strategic initiatives to facilitate the stepwise implementation of safe, deep geological disposal of spent fuel, high-level waste and other long-lived radioactive waste. It aims to address the remaining scientific, technological and social challenges, and support European waste management programmes.

The IGD-TP was launched on 12. November 2009, initiated by the European Commission and waste management organisations. Now solely funded by the WMOs, the group welcomes all interested parties endorsing the IGD-TP Vision and willing to contribute positively and constructively to the group's goals, such as establishing and implementing the Strategic Research Agenda and participating in information exchange and knowledge transfer. The platform stays behind the EURAD project.

3.3.4 SITEX

SITEX (https://www.sitex.network/) was established as a French non-profit association on January 9, 2018. The SITEX network is open to any institution or individual party having interest in independent regulatory assessment of RWM activities and willing to join. Members belong to one out of three colleges (Technical Expertise Function, Regulatory Function, Civil Society Function), according to their specific function. SITEX is the base for the EURAD project.

3.3.5 EURADSCIENCE

EURADSCIENCE is an international network of research entities established to unite the work of national research organisations on RWM from cradle to grave, and to drive scientific excellence in the field over the next decades to come. The EURADSCIENCE network links research-oriented organisations to EURAD.

3.4 Programme or project reviews by international bodies

Both the IAEA and the OECD/NEA carry out international reviews of various aspects of radioactive waste and spent fuel management in member states. These reviews provide independent expert opinion and advice, drawn from an international team of specialists.

- ARTEMIS (https://www.iaea.org/services/review-missions/integrated-review-service-for-radioactive-waste-and-spent-fuel-management-decommissioning-and-remediation-artemis) is an integrated IAEA expert peer review service for radioactive waste and spent fuel management, decommissioning and remediation programmes. This service is intended for facility operators and organisations responsible for RWM, as well as for regulators, national policy and other decision-makers. The IAEA also perform Integrated Regulatory Review Service (IRRS) to help host states to strengthen and enhance the effectiveness of their regulatory infrastructure. Reviews are based on the IAEA safety standards, technical guidance and international good practices. The scope of reviews varies according to the needs of the requesting organisation or facility, spanning national frameworks, regulatory systems and specific aspects of national programmes. Reviews may involve detailed assessments and technical advice on the implementation of specific programmes and project activities, with an emphasis on technology, on safety, or both. Review missions are comprised of meetings, interviews, site visits and document reviews, as necessary. Observations, preliminary findings and recommendations are provided to the Member state in a draft review report for clarifications and fact-checking before a final approved report is delivered. The recipient entity remains fully responsible for all ensuing decisions and actions. The final review report, unless otherwise requested by the member state, is made public three months after delivery. ARTEMIS reviews are conducted by an independent expert peer review team, assembled, trained and funded by IAEA. Views communicated are of the team, not the IAEA.
- OECD/NEA carry out international peer reviews of national RWM programmes, or of specific aspects of them, under the aegis of the RWMC. International peer review as a working method is closely associated with OECD practice, where it is facilitated by the homogeneous membership and the high degree of trust shared by the member countries. This document lays down the guidelines that the requesting country, the secretariat and the international review team ought to have in mind when an international peer review is requested, organised or carried out.

These review missions are judged to be critically important for disseminating good practices between programmes in different member states, For example, to date the majority of the radioactive waste and spent fuel management programmes, or aspects thereof, being part of EURAD have been subject to such reviews. These reviews help the requesting country to ensure its RWM programme is delivered to a suitable international standard, but also provides critical insight to the members of the international teams of specialists on commonalities and challenges in managing radioactive waste and spent fuel in a wide variety of political, legal, technical and geoscientific contexts.

The member state being subject to the review need to cover all costs for the international review team. Regarding the IAEA reviews, member states that pay into the technical cooperation fund can use money from that fund to cover such reviews, but this is relatively unusual.

3.5 Bilateral agreements between sister organisations

Direct cooperation between sister organisations (e.g. different WMOs, different regulators, different TSOs or different REs) allows for sharing resources and ensuring that the expertise involved reaches critical mass. Such cooperation includes but is not limited to:

- information exchange (each on its own cost)
- joint projects and support (cost covered according to agreement)
- specific work (contract for product)
- secondment (see section 3.6)
- advisory committees (see section 3.7)

There are numerous examples of such cooperations through different bilateral agreements. It is especially strong between programmes with similar waste streams and with similar geological conditions. For example, there is, and has been, a substantial cooperation on site characterisation methods, EBS development and safety assessment modelling, between the WMOs in Sweden and Finland, both considering direct disposal of spent nuclear fuel in the crystalline Fennoscandian Shield. There is also a deep cooperation between Nagra and Andra, both considering disposal in hard argillaceous clay rocks. Also some regulators, such as in Sweden and Finland, share information bilaterally. Bilateral cooperation is common in most programmes although its scope and importance vary from relatively general information exchange to executing joint R&D projects.

3.6 Secondments

A special aspect of cooperation between sister organisations is to second one or a few employees to work with the other organisation for a limited period, e.g. between a few months to several years. For example, such secondments are, or have been, practiced by the Canadian, Finnish, French, Japanese, Swedish, Swiss, UK or US programmes. Apart from the learning aspects, this also creates personal contacts that often develop into deepened international cooperation at later stages. Traditionally, the seconded persons have been in an early stage of their career, but it could be argued that organisations should also consider seconding more mid- to senior-level staff and technical experts. Senior persons could be more impactful as they have the potential to change broad levels of organisational understanding and culture.

3.7 Multinational advisory and review groups

Many programmes have formed multinational advisory groups, consisting of internationally known experts working in or for other programmes, to follow, comment and help improve the work of the organisations setting up this group. For example, such groups have been formed and used both by the Swedish WMO (SKB) and regulator (former SKI), by the Finnish WMO (Posiva) and regulator (STUK), by the Japanese WMO (NUMO), by the Canadian WMO (NWMO), by the French WMO (Andra) and by the Swiss WMO (Nagra).

In contrast to the international experts groups assembled for review by the international agencies, see section 3.4, these advisory groups typically are active for many years so they can follow developments and adjust their advice as the programme progresses and evolves. Typically, these advisory groups are gathered for meetings on a relatively regular schedule (at least annually) depending on the progress of the programme. They are presented with plans for work, preliminary results or outstanding issues, and then asked to provide advice.

At later stages, members of these advisory groups are often asked to review reports, or sections of reports being produced. Since the advisory groups should have an in-depth understanding of the programme they are assessing such reviews can provide insights and be more specific than reviews offered by independent reviewers and could thus be very helpful, before the work is subject to independent review.

All cost for these advisory groups is handled by the inviting organisation. Sometimes this is handled through bilateral agreements, see section 3.5.

3.8 Generic Underground Research Facilities

Today there is a comprehensive set of generic underground research facilities (URFs) covering many of the potential host rocks being considered for a DGR. Examples of such facilities include, but are not limited to,

- The HADES underground research laboratory (https://www.euridice.be/en/content/hades-underground-research-laboratory), located in the Belgian Boom Clay (poorly indurated clay) at a depth of 225 metres, is used to develop and test industrial technologies for building, operating and closing a waste repository in deep clay. Scientists conduct large-scale experiments under realistic conditions in the deep clay formation over a long period of time to assess the safety of geological disposal in poorly indurated clay.
- The Mont Terri Project, in Switzerland, is an international research project for the hydrogeological, geochemical and geotechnical characterisation of a clay formation (Opalinus Clay; https://www.mont-terri.ch).
- The Horonobe Underground Research Center in Neogene argillaceous marine sedimentary rock in Japan (https://www.jaea.go.jp/english/04/horonobe/) conducts R&D on geological disposal of high-level radioactive waste and geoscientific research to verify the technical reliability of geological disposal through testing and research conducted in actual deep geological environments.
- SKB's underground hard rock laboratory experiments at Äspö north of Oskarshamn, Sweden, placed almost 500 metres underground, are conducted in collaboration with Swedish and international experts (https://www.skb.com/research-and-technology/laboratories/the-aspo-hard-rock-laboratory/).
- The Grimsel Test Site (GTS) is located in the Swiss Alps and was established in 1984 as a centre for underground R&D supporting a wide range of research projects on the geological disposal of radioactive waste. International partners from Europe, Asia and North America are working together at this unique facility (https://www.grimsel.com/).

These generic facilities usually host tests with participants from many different programmes and are examples of CoPs, especially by the support of the IAEA URF Network for geological disposal (https://nucleus.iaea.org/sites/connect/URFpublic/Pages/default.aspx). The URF Network provides its members with a platform to assess and share best practices in developing, evaluating and implementing geological disposal solutions for intermediate-level waste, high-level waste and spent nuclear fuel. Emphasis is placed on the role and use of URFs to support successful disposal programme development and implementation.

The cost of participation in generic URF programmes of course varies depending on the nature of work. Participation in the IAEA URF networks is free of charge for member states, whereas getting more close access to the URF work usually requires a membership fee. Setting up and executing specific tests are funded by cost sharing through individual contracts.

3.9 Technology transfer

Some programmes, notably NWS (the UK WMO, former RWM), have explored the benefits of undertaken technology transfer exercises with other international disposal programmes to benefit from latest advancements, specifically relevant technology that could be utilised in the national programme. Where appropriate, this has been achieved through establishing bilateral agreements or other formal or informal mechanisms.

It is noted that technology suitable for different areas of the disposal system or suited to the disposal of specific types of waste may be transferred from particular WMOs or industries with that specific expertise. Technology transfer from other industries with expertise judged important, e.g. tunnelling or digitalisation, could also be an option. It may be appropriate to transfer technology from a number of different providers depending on the stage of the implementation programme and/or the disposal solution required.

The technology transfer strategy considers (NDA, 2016):

- The type of technology to be transferred.

Whether the technology relates to all or some of the disposal system needs.Technology transfer potentially provides a number of benefits, and importantly allow for international benchmarking, training opportunities and access to information, which may otherwise not be available. It could also provide a basis for entering into commercial arrangements where appropriate.

Typically, the organisation being subject to the technology transfer is financially compensated.

3.10 Training courses

Training courses directed to international audiences have been and are organised both by some of the international agencies (see section 3.2), by EURAD and by some of the more advanced programmes (see section 3.11). In the latter case, this is done on a pure commercial basis.

3.11 Purchase of consultancy services or management solutions

International competence is also available on a commercial basis. There is a wealth of knowledge assembled by consultants, contractors and suppliers of specific equipment working with clients from different programmes. In addition, some WMOs in the more advanced programmes own or support subsidiary organisations offering the knowledge of their mother organisation on a commercial basis. Examples of such services are Andra-Services (https://international.andra.fr/international-consultancy/andra-services), Posiva Solutions (https://www.posivasolutions.com/), Nagra International Services and Projects (https://nagra.ch/en/knowledge-centre/international-services-and-projects/) and SKB International (https://www.skbinternational.se/).

3.12 Shared repositories

According to the IAEA Joint Convention, safe disposal is a national responsibility, but multi-national cooperation is not excluded. However, legislation in many states explicitly clarifies that radioactive waste disposal would only, with minor exceptions, be allowed for waste produced within the nation. Still some initiatives to seek shared or multinational, multi-user, storage and disposal facilities have been undertaken considering the potential strong technical, economic and strategic arguments for having access to such facilities especially for smaller nuclear power nations, see e.g. www.arius-world.org or www.erdo-wg.com. However, to date none of these initiatives have come anywhere close to offer such solutions.

4. Critical background information

International cooperation is an essential component for keeping and advancing all knowledge areas connected to managing radioactive waste and spent fuel including all other domains of the EURAD WBS. All programmes and all organisations being parts of such programmes are advised to encourage international cooperation and also to, as freely as possible, share their knowledge and insights with others.

5. Maturity of knowledge and technology

International cooperation is, and has been, instrumental for developing the high quality and relative success of radioactive waste and spent fuel management programmes as can be seen today. In the future, international cooperation will be even more important and developing, sharing and managing the knowledge is needed. Guidelines and other recommendations issued by the international agencies will not only be important for developing programmes, but would also serve as a fundamental memory in more developed programmes when the experts once authoring such guides, now have retired or soon will retire. International cooperation is also essential for sharing competences where the national contexts is too small, especially on issues essentially only of interest to the nuclear waste community. Participation in international work may also be an inspiration and reason to carry on for internal staff, as well as for researchers at universities, to consider the work sufficiently interesting.

6. Costs

International cooperation does not come free of charge. The international organisations are basically funded by member states. Waste management programmes often have to cover their costs for participation in meetings etc., and services obtained from sister organisations usually need to be paid for. In addition, much knowledge and information is only available on a commercial basis. However, needless to say, that these costs are usually small compared to the costs involved in developing the knowledge individually in each programme.

7. Guidance, Training, Communities of Practice and Capabilities

This section provides links to resources, organisations and networks that can help connect people with people, focussed on the domain of *International Cooperation.*

Guidance
IAEA: www.iaea.org *OECD/NEA; www.oecd-nea.org* *ARTEMIS www.iaea.org/services/review-missions/integrated-review-service-for-radioactive-waste-and-spent-fuel-management-decommissioning-and-remediation-artemis*
Training
IAEA: www.iaea.org *Nagra ISP nagra.ch/en/knowledge-centre/international-services-and-projects/* *SKB International: www.skbinternational.se* *EURAD: https://euradschool.eu/events/category/eurad-training-course/*
Active communities of practice and networks
EURAD: https://www.ejp-eurad.eu/ *OECD/NEA: www.oecd-nea.org* *IAEA URF Network nucleus.iaea.org/sites/connect/URFpublic/Pages/default.aspx*
Capabilities (Competences and infrastructure)
See above and reference list

8. Further reading, external Links and references

8.1 Further Reading

EURAD (2021), EURAD Roadmap, extended with Competence Matrix (https://www.ejp-eurad.eu/sites/default/files/2021-09/EURAD%20-%20D1.7%20Roadmap%20extended%20with%20Competence%20Matrix.pdf)

IAEA. Disposal of Radioactive Waste, IAEA Safety Standards Series No. SSR-5, Specific Safety Requirement, IAEA, Vienna (2011)

IAEA, Geological Disposal Facilities for Radioactive Waste. IAEA Safety Standards, Specific Safety Guide SSG-14, IAEA Vienna (2011)

IAEA. The Safety Case and Safety Assessment for the Disposal of Radioactive Waste. IAEA Safety Standards, Specific Safety Guide SSG-23, IAEA Vienna (2011)

NEA (2005), International Peer Reviews for Radioactive Waste Management, OECD, Paris

8.2 External Links

IAEA www.iaea.org,

OECD/NEA www.oecd-nea.org

EURAD https://www.ejp-eurad.eu.

ARTEMIS (https://www.iaea.org/services/review-missions/integrated-review-service-for-radioactive-waste-and-spent-fuel-management-decommissioning-and-remediation-artemis

IAEA URF Network https://nucleus.iaea.org/sites/connect/URFpublic/Pages/default.aspx

HADES www.euridice.be/en/content/hades-underground-research-laboratory

Mont Terri Project www.mont-terri.ch

Horonobe Underground Research Center www.jaea.go.jp/english/04/horonobe

Äspö HRL www.skb.com/research-and-technology/laboratories/the-aspo-hard-rock-laboratory

Grimsel Test Site www.grimsel.com.

8.3 References

Council Directive 2011/70/Euratom of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste, ELI: http://data.europa.eu/eli/dir/2011/70/oj

IAEA, The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management https://www.iaea.org/topics/nuclear-safety-conventions/joint-convention-safety-spent-fuel-management-and-safety-radioactive-waste

IAEA, Fundamental Safety Principles, Safety Fundamentals, IAEA SAFETY STANDARDS SERIES No. SF-1, IAEA, Vienna (2006)

IAEA. Disposal of Radioactive Waste, IAEA Safety Standards Series No. SSR-5, Specific Safety Requirement, IAEA, Vienna (2011)

IAEA, Geological Disposal Facilities for Radioactive Waste. IAEA Safety Standards, Specific Safety Guide SSG-14, IAEA Vienna (2011)

IAEA. The Safety Case and Safety Assessment for the Disposal of Radioactive Waste. IAEA Safety Standards, Specific Safety Guide SSG-23, IAEA Vienna (2011)

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NDA Report no. NDA/RWM/141#Geological Disposal Design Status Report, Nuclear Decommissioning Authority UK, October 2016

POSIVA and SKB (2017). Safety functions, performance targets and technical design requirements for a KBS-3V repository. Conclusions and recommendations from a joint SKB and Posiva working group. Posiva SKB Report 01, January 2017, Posiva Olkiluoto, Finland, SKB Stockholm Sweden. www.skb.se

End of document.