Radioactive Waste Management
2023

Sixth International Conference on Geological Repositories (ICGR-6): Advancing Geological Repositories from Concept to Operation

Conference Synthesis
4-8 April 2022
Helsinki, Finland

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NEA No. 7655

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Foreword

The Sixth International Conference on Geological Repositories (ICGR-6) took place in Helsinki (Finland) on 4-8 April 2022. The event was themed "Advancing Geological Repositories from Concept to Operation" and was designed to show the significant progress made in developing geological repositories over the last two decades. It also aimed to provide an international forum for participants to exchange perspectives and experiences and learn from each other. ICGR-6 addressed the latest issues and challenges encountered by stakeholders at different stages of developing geological repositories, including best practices in demonstrating technical reliability and building human capacity and stakeholder confidence in the safe construction and operation of long-term geological repositories. The conference also focused on younger professionals and the need to expand their involvement in the research and development of geological disposal.

Building upon the success of previous conferences held in Denver (1999), Stockholm (2003), Bern (2007), Toronto (2012) and Paris (2016), the 2022 International Conference on Geological Repositories (ICGR-6) brought together senior-level decision-makers from countries advancing programmes for deep geological repositories, from relevant government ministries, regulatory bodies, waste management organisations, research institutes and local stakeholders, as well as young professionals and students.

This synthesis report was drafted by Dr Meritxell Martell (Merience, Spain) under the leadership of the Nuclear Energy Agency, with support from Ms Rebecca Tadesse (NEA) and Ms Morgan Packer (NEA). It was approved by the ICGR-6 Programme Committee, as well as the Radioactive Waste Management Committee on 1st August 2023, and prepared for publication by the NEA Secretariat.

Acknowledgements

The NEA expresses its gratitude to the following individuals and institutions for their assistance and co-ordination of ICGR-6: the ICGR-6 Programme Committee, the Ministry of Economic Affairs and Employment of Finland, the International Atomic Energy Agency (IAEA), the European Commission (EC) and the International Association for Environmentally Safe Disposal of Radioactive Materials (EDRAM).

ICGR-6 and its synthesis report were also made possible by the following ICGR-6 session chairs, co-ordinators and rapporteurs:

Pierre-Marie Abadie, Seif Ben Hadj Hassine, Natalie Bonilla, Martin Brandauer, Riccardo Chebac, Yasmin de Fraiture, Kai Hämäläinen, Jussi Heinonen, Minori Kato, Kristopher Kuhlman, Pascale Künzi, Patrick Landais, Marie Maertens, Karim Peltonen, Lisa Smadja, Rebecca Tadesse, Haimanot Yilma and Piet Zuidema.

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List of abbreviations and acronyms

Andra	National Agency for Radioactive Waste Management (France)
ASN	Nuclear Safety Authority (France)
BASE	Federal Office for the Safety of Nuclear Waste Management (Germany)
BATS	Brine Availability Test in Salts
BEIS	Department of Business, Energy & Industrial Strategy (United Kingdom)
BfS	Bundesamt für Strahlenschutz (Federal Office for Radiation Protection, Germany)
BGE	Federal Company for Radioactive Waste Disposal (Germany)
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Germany)
CNSC	Canadian Nuclear Safety Commission
CoRWM	Committee on Radioactive Waste Management (United Kingdom)
CSN	Nuclear Safety Council (Spain)
DAC	Construction License Application (for Cigéo in France)
DBE	German Service Company for the Construction and Operation of Waste Repositories (Germany)
DGR	Deep geological repository
DiP	Decision in principle
DOE	Department of Energy (United States)
DUP	Declaration of Public Convenience and Necessity (for Cigéo in France)
EA	Environment Agency (United Kingdom)
EBS	Engineered Barrier Systems
EDRAM	International Association for Environmentally Safe Disposal of Radioactive Materials
EDZ	Excavation-disturbed zone
ENEF	European Nuclear Energy Forum
ENRESA	National Company for Radioactive Waste Management (Spain)
ENSI	Swiss Federal Nuclear Safety Inspectorate

ENSREG	European Nuclear Safety Regulators Group
ERDO	Association for Multinational Radioactive Waste Solutions
EU/EC	European Union/European Commission
EURAD	European Joint Programme on Radioactive Waste Management
FANC	Federal Agency for Nuclear Control (Belgium)
FSC	Forum on Stakeholder Confidence (NEA)
GDF	Geological Disposal Facility
GMF	Group of European Municipalities with Nuclear Facilities
gDSSC	Generic Disposal System Safety Case (United Kingdom)
HLW	High-level radioactive waste
HRL	Hard rock laboratory
ICGR	International Conference on Geological Repositories
IAEA	International Atomic Energy Agency
IGD-TP	Implementing Geological Disposal Technology Platform
JAEA	Japan Atomic Energy Agency
JRC	Joint Research Centre
LILW	Low- and intermediate-level radioactive waste
METI	Ministry of Economy, Trade and Industry (Japan)
NAGRA	National Co-operative for the Disposal of Radioactive Waste (Switzerland)
NBG	Nationales Begleitgremium für ein Faires Verfahren (National Citizen's Oversight Committee, Germany)
NDA	Nuclear Decommissioning Authority (United Kingdom)
NEA	Nuclear Energy Agency
NEFC	Nuclear Energy Fuel Cycle
NuBaFA	Nuclear Backend Financial Aspects expert group
Nuleaf	Nuclear Legacy Advisory Forum
NUMO	Nuclear Waste Management Organization (Japan)
NWMO	Nuclear Waste Management Organization (Canada)
NWS	Nuclear Waste Services (United Kingdom)
ONDRAF/NIRAS	Belgian Agency for Radioactive Waste and Enriched Fissile Materials
ONR	Office for Nuclear Regulation (United Kingdom)
PNGMDR	French National Radioactive Materials and Waste Management Plan

POSIVA	Radioactive Waste Management company (Finland)
R&D	Research and Development
RD&D	Research, Development & Demonstration
RTE	Electricity transmission system operator (France)
RWM	Radioactive waste management
RWMC	Radioactive Waste Management Committee
RWMD	Radioactive Waste Management and Decommissioning Division (NEA)
RWM Ltd	Radioactive Waste Management Limited (United Kingdom)
SCK CEN	Research Centre for the Applications of Nuclear Energy (Belgium)
SFOE	Swiss Federal Office of Energy
SFR	Short-lived radioactive waste
SITEX	Sustainable network of Independent Technical Expertise of radioactive waste disposal
SKB	Nuclear Fuel and Waste Management Company (Sweden)
SNF	Spent nuclear fuel
SSM	Radiation Safety Authority (Sweden)
STEM	Science, Technology, Engineering, Mathematics
STUK	Radiation and Nuclear Safety Authority (Finland)
THM	Thermal-Hydrological-Mechanical
THMC	Thermal-Hydrological-Mechanical-Chemical
TRFD	Trial Run of the Final Disposal
TVO	Teollisuuden Voima Oyj (nuclear power company, Finland)
URF	Underground research facility
URL	Underground research laboratory
WIPP	Waste Isolation Pilot Plant (United States)

Executive summary

There is a consensus in the international community that geological repositories provide the necessary long-term safety and security to isolate long-lived radioactive waste from the human environment over extended timescales. It is also feasible to construct these repositories using current technologies. However, despite the technical merit and safety of repositories, challenges remain in many countries. These challenges include building and maintaining public confidence, the availability of skilled staff and the transfer of knowledge. The involvement of younger professionals is also often challenging, albeit a crucial element for the sustainable development of geological repositories.

This report provides a synthesis of the Sixth International Conference on Geological Repositories (ICGR-6), hosted in Helsinki, Finland, on 4-8 April 2022. It was co-organised by the Nuclear Energy Agency (NEA) and the Ministry of Economic Affairs and Employment of Finland. ICGR-6 was built on the success of previous ICGR conferences held in Denver (1999), Stockholm (2003), Bern (2007), Toronto (2012) and Paris (2016), bringing together relevant stakeholders regarding geological repositories, including decision-makers, regulators, government ministries, implementers, engineers, scientists, research organisations, environmental organisations, international organisations, universities as well as young professionals and the general public. More than 250 participants from over 25 countries participated in person and online during ICGR-6.

The 2022 conference was focused on "advancing geological repositories from concept to operation" and was designed to show the significant progress made in developing geological repositories over the past two decades. The conference also focused on sharing experiences, knowledge, approaches to building human capacity and stakeholder confidence in the safe construction and operation of long-term geological repositories, as well as improved practices to demonstrate technical reliability.

ICGR-6 aimed to achieve the following objectives:

- To take stock of progress made since 2016 in developing and implementing geological repositories for long-lived radioactive waste, and to advance mutual learning through the international forum for the exchange of perspectives and experiences.
- To examine the latest issues and challenges encountered by stakeholders by sharing experiences among countries developing geological repositories.
- To enhance international co-operation in transforming research results into practical and reliable technologies for the long-term implementation of disposal facilities.
- To identify opportunities to strengthen co-operation in building and maintaining confidence in the geological repositories' life cycle.
- To improve involvement of younger generations in the development and research of geological disposal.

The order of the material within this report synthesis has been adapted from the precise sequence at the conference to aid in its presentation. The ICGR-6 conference programme is provided in Appendix A.

- Chapter 1 summarises the younger generation session discussion. An important step in supporting continuity in deep geological repository (DGR) programmes is to bring forward and integrate the younger generations at an early stage together with older generations. Motivating professionals to work in the radioactive waste management field over the long term is crucial.
- Chapter 2 summarises the status of national geological repository projects presented at ICGR-6 and the progress achieved. The atmosphere of the ICGR-6 presentations was very much in line with the motto of the conference: "advancing geological repositories from concept to operation". Several radioactive waste management organisations are focused on concrete activities for the immediate start of operation of DGRs and this offers opportunities to learn from each other. The progress seen in one nation helps support the case for DGRs in other countries.
- Chapter 3 discusses the role of underground research laboratories and international collaboration in demonstrating technical reliability for operational and long-term safety. Research, development and demonstration activities and international collaboration greatly contribute to the development of safe methods for final disposal. The purpose of underground research laboratories might change during the DGR programme but they allow a stepwise increase of process understanding and optimisation as well as an enhancement of technological capabilities. International co-operation is essential to continue to enhance existing processes and implement innovative approaches.

- Chapter 4 provides a summary of the discussion around the elements for building and maintaining human capacity from siting to construction to operation. It is important to start the transfer of knowledge to early and mid-career staff sufficiently early in order to avoid a loss of knowledge. Thus, managing knowledge between generations is of paramount importance for advanced programmes.
- Chapter 5 recapitulates how to build and maintain trust, including how scientists communicate uncertainty to the community. Trust building by regulatory authorities is crucial and needs to start at an early stage to clarify the regulator’s role in the process.
- Chapter 6 presents different points of view, including those of the regulator, experts and local community, regarding communication of uncertainties. The future entails uncertainties, but this need not equate to a lack of safety. It is important to constantly consider, update and regularly communicate uncertainties.
- Chapter 7 provides an overview of the ICGR-6 summary and conclusion session. Long-term processes require long-term engagement with a diverse group of stakeholders. Moving from concept to operation implies decisions by the government and continuous and close dialogue with stakeholders in the local area.

Chapter 1. **Younger Generation session**

The Younger Generation session took place on the first day of the conference with 31 participants, including PhD students, consultants, regulators and licensees, from 15 countries. Presentations from the International Atomic Energy Agency (IAEA) and the European Commission (EC) introduced different types of activities to support education and training. After these introductory presentations, four working groups were arranged to discuss three topics:

1. What obstacles have you encountered in the nuclear field?
2. How can employers/policymakers attract more young professionals to the nuclear sector?
3. How could we improve knowledge transfer to younger generations?
4. What is being done or could be done to innovate in this industry?

The Nuclear Energy Agency (NEA) Director-General, William D. Magwood, IV, provided an overview of relevant NEA activities for young professionals and answered questions raised by participants. The questions focused on advice in the realm of career development, ways to navigate political and societal challenges, reasons for being inspired about nuclear and expectations of younger generations.

NEA Director-General, William D. Magwood, IV, gives opening remarks to the ICGR-6 Younger Generation Session.
© Krystal Kenney

A summary is provided from the rapporteurs' feedback of the four working groups in the three topics discussed.

1. Obstacles encountered in the nuclear sector:
   - Short-term projects and uncertainty in work continuation (e.g. post-doc positions for six months);
   - Short-term funding;
   - Lack of policy knowledge in the technical side of nuclear programmes;
   - Lack of technical representation in decision-making may impact the nuclear field;
   - Negative risk perception and low acceptance of nuclear among the general public, the media, policymakers, etc.;
   - Delays or suspensions in the nuclear projects;
   - Knowledge transfer from older to younger generations.
2. Ways to attract young professionals to the nuclear sector:
   - Fellowships and internships at national laboratories, international organisations and government offices;
   - Providing impactful and meaningful work;
   - Providing adequate funding for research to enhance collaboration rather than competition;
   - Good work-life balance, safety of work environment, self-investment on skill development, fulfilling feeling of contribution to society;
   - Outreaching to essential persons for the functioning of nuclear reactors;
   - Interaction with disruptive technologies and integration of artificial intelligence and machine learning into the nuclear sector to attract new people;
   - Encouraging communication with the public:
     - Education: providing students with opportunities to be involved in nuclear engineering as well as policy;
     - Job experience: language skills, mobility skills (e.g. driving skills to get to remote rural areas where nuclear facilities are usually located), better public perception and capacity to explain nuclear issues in plain language;
     - Dialogue with the public: partnerships among local and international organisations, face-to-face interactions, educational visits to nuclear facilities, virtual meetings, and more innovation, such as digital twins of physical facilities.
3. Improving knowledge transfer to newer generations by:
   - Working together on projects and sharing offices and documentation, hiring new staff, encouraging training, knowledge of work opportunities and scholarships, and networking;

- Possibly requiring European Union (EU) and national funding to include young professionals in leadership roles;
- Avoiding gaps in activity in the nuclear sector and encouraging a broader level of knowledge of the nuclear sector;
- Transferring knowledge to non-STEM (Science, Technology, Engineering, Mathematics) groups through education and training;
- Providing mentorships, senior supervision or internal and external workshops;
- Training in and providing support for social media and public engagement.

4. Making innovation a reality:
   - No one solution can address a complex problem and it is therefore essential to share knowledge to help innovation, to continue research and to provide long-term funding. Learning and constructive feedback should be encouraged;
   - The creation of interdisciplinary and international groups would increase knowledge exchange and encourage innovation.

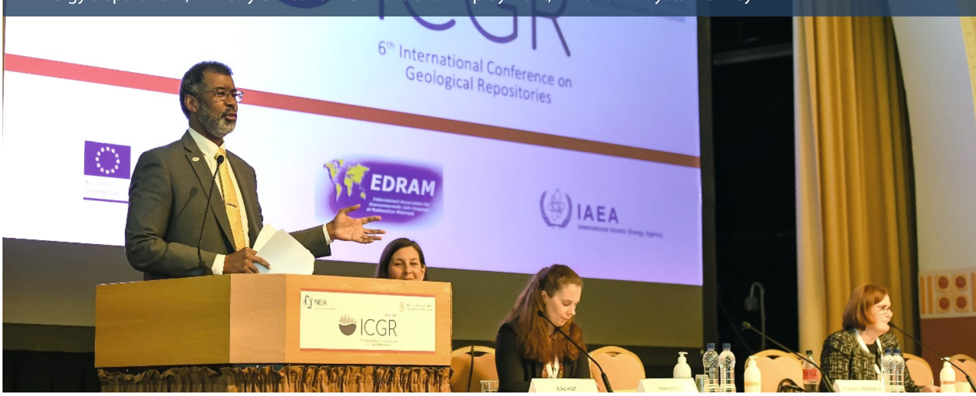
Roger Garbil, Head of Section Fission, EC, presents the EC activities to support education and career development in the nuclear field. © Krystal Kenney

Chapter 2. Status of national geological disposal projects and progress achieved

Since the 2016 International Conference on Geological Repositories (ICGR-5) held in Paris, there has been significant progress made in several geological disposal programmes. The opening speech of Mr William D. Magwood, IV, Nuclear Energy Agency (NEA) Director-General, highlighted key milestones reached within the radioactive waste management community – achievements that attest to the advancement from concept to operation of deep geological repositories (DGRs):

- In 2016, construction began on the final disposal facility at Olkiluoto (Finland). In 2023, Posiva is scheduled to conduct a Trial Run of the Final Disposal (TRFD) before proceeding to the operational phase, which will be the final preparatory phase for DGR operation in Finland.
- In 2021, the Swedish government approved portions of the Swedish Nuclear Fuel and Waste Management Company's (SKB) application for a DGR for spent nuclear fuel (SNF) after SKB submitted to the Land and Environment Court complementary information requested to clarify the function of copper canisters in relation to the long-term safety of the repository. The government also approved an increased storage capacity at the central interim storage for spent fuel. In January 2022, the Swedish government gave SKB the green light to proceed with a DGR for SNF at a site near Vattenfall's 3.2-GW Forsmark Nuclear Power Plant.

Left to right: William D. Magwood, IV, NEA Director-General; Erika Holt, Customer Account Lead, VTT; Linda Kumpula, Senior Specialist, Ministry of Economic Affairs and Employment, Finland; Liisa Heikinheimo, Deputy Director General, Energy Department, Ministry of Economic Affairs and Employment, Finland. © Krystal Kenney



- In 2020, France's National Agency for Radioactive Waste Management (Andra) submitted an application for a Declaration of Public Convenience and Necessity (DUP) for their DGR project, Cigéo. The DUP is a key file that includes a global environmental assessment. If granted, it will allow the submission of other authorisation applications relating to site preparation works that are crucial for constructing Cigéo.
- Notable progress has also been seen in other national DGR programmes, including those in Canada, Germany and the United Kingdom (UK).

While the general consensus is that DGRs will safely operate, further technological and scientific work will need to be undertaken in each country to maintain reliable operations in the long term. In addition, one of the biggest challenges is to establish a transparent process that incorporates stakeholder perspectives and supports confidence building in DGR projects over multiple generations.

ICGR-6 also included several updates on geological repository projects which are summarised in the sub-sections below.

2.1. Canada

Canada's Nuclear Waste Management Organisation (NWMO) has made considerable progress in identifying the site for a DGR and has reached environmental and engineering milestones. Twenty-two communities have expressed an interest in hosting a DGR since the beginning of site identification, and this has been narrowed down to two areas: the Wabigoon Lake-Ignace Area and the Saugeen Ojibway Nation-South Bruce Area. The NWMO continues to deepen understanding in these two areas and a test analysis is underway. The first drilling programme is almost complete. A micro seismic monitoring system and 3D seismic survey have been completed. In 2024, one of these two sites will be selected.

Left to right: Laurie Swami, President and CEO, NWMO, Canada; Jussi Heinonen, Director, Regulatory Oversight Strategic Development, STUK, Finland; Janne Mokka, President, Posiva Oy, Finland; Kimberly J. Petry, Acting Deputy Assistant Secretary, Office of Spent Fuel & Waste Disposition, US DOE; Pierre Marie Abadie, CEO, Andra, France; Magnus Holmqvist, President, SKB International, Sweden; Karen Wheeler CBE, Deputy CEO/Major Capital Programmes Director, Nuclear Waste Services, United Kingdom. © Krystal Kenney

A consent-based approach is critical to success, as is the willingness of First Nations and the process of reconciliation with them. Supporting Indigenous knowledge is crucial to the NWMO's method of work, in particular after the reconciliation policy was formalised in 2019. One of the most important challenges in Canada is the transport of the SNF to the DGR area, which requires a long travelling distance spanning thousands of kilometres.

While work over the past two decades has built towards site selection in 2023, in the next five years the NWMO will move into the regulatory decision-making phase. In this regard, the site selection is not the end point but rather the beginning of a DGR project. The NWMO will proceed with the impact assessment process to demonstrate that the project meets the regulatory requirements for the safety of people and the environment and that it includes opportunities for stakeholders and First Nations to participate. In 2026, Canada's plan will move towards preparing construction of the repository.

2.2. Czech Republic

Since 2020 there have been four potential sites for a DGR project in the Czech Republic, down from a list of nine sites previously. Government documents and policies set clear targets and deadlines for siting a DGR, and the selection of a final site and a backup site for a DGR is expected by 2030.

Key success factors in the site evaluation process undertaken in the Czech Republic include:

- clear definitions of targets and the schedules in government documents and policies;
- support of stakeholders (ministry, regulatory body, scientific community);
- importance of expert interaction with different groups (regulatory body, scientific support, independent experts and civil society, external reviewer);
- preparation of appropriate materials for decisions at different points in the decision-making processes;
- demonstration of high levels of competency from different angles and reviews of each decision.

2.3. Finland

Posiva has developed a solution for the safe disposal of SNF that allows Finland to complete the nuclear life cycle. Olkiluoto will be the first location in the world to provide safe final disposal of SNF/HLW. "In Finland, the management of the entire life cycle is a precondition for climate friendly nuclear electricity production", highlighted the President of Posiva Janne Mokka (Posiva, n.d.). The Finnish solution includes a safe concept, a reliable implementer and a clear regulatory context with competent authorities. In addition, it comprises the funding from nuclear operators and the municipality that will host the DGR. Consistent and long-term political commitment is critical in finding solutions for nuclear waste.

In 2019, Posiva launched the EKA project, which aims at initiating final disposal operations in the 2020s. The operational licence application for the EKA project was submitted on 30 December 2021. This project involves constructing an above-ground encapsulation plant and installing the systems for final disposal in the underground Onkalo facility, obtaining appropriate licences for the final disposal concept, the facility and its systems, and preparing the supply chains needed for production, before initiating final disposal of SNF. The EKA project includes: construction, equipment, installation and commissioning of the encapsulation plant; civil works and heating, ventilating and air-conditioning equipment of the final disposal facility; excavation of the central tunnels and first deposition tunnels[1]; underground disposal equipment; supply chain for canisters and bentonite components compliant with the requirements; operation licence process, which will continue until 2070, and start of the disposal operation in 2024.

The next step of the EKA project is to prepare the TRFD prior to proceeding to the operational phase. The TRFD encompasses the entire disposal process with final disposal systems and machinery, organisation and procedures, but will be performed with dummy fuel assemblies. This involves moving from the construction phase to the installation and commissioning phase of the nuclear facility as well as preparation for disposal operations. Posiva expects that the technical design for the disposal will develop and be optimised as operational experience starts to accumulate. There will be a 100-year period to continue R&D. So far, one of the important aspects has been the change in Posiva as an organisation from focusing on R&D to also including construction and moving towards operation.

2.4. France

France made several announcements at the end of 2021 and beginning of 2022 that will have an impact on the future of nuclear power. In October 2021, President Emmanuel Macron presented the "France 2030" plan, a large-scale investment plan meant to address the green transition challenge by developing small modular reactor technologies and extending the licences of existing nuclear reactors. In addition, France's electricity transmission system operator, RTE, presented in October its report "Energy Pathways to 2050". The RTE report is to serve as a basis for the government's future energy strategy to decarbonise the economy by 2050. The report indicated that the next generation of nuclear reactors can help shift the country's energy mix away from fossil fuels and achieve the goal of carbon neutrality by 2050. In February 2022, President Macron announced plans to relaunch the country's commercial nuclear programme with the construction of at least six new nuclear power reactors, with the possibility of eight more. He also announced a broad public consultation on energy would be held in the second half of 2022 and parliamentary discussions in 2023 to revise the multi-annual energy plan. Cigéo is technically and scientifically a mature project that still requires considerable amount of work. Andra has been reorganised to ensure a smooth transition from the design stages to construction and operation.

An important element in the French case is the National Radioactive Materials and Waste Management Plan (PNGMDR), which is updated every five years and submitted to public debate under the aegis of France's National Public Debate Commission. The PNGMDR is drawn up by the French Ministry for Ecological and Inclusive Transition and the French

1. At the time of writing, 60% of the first programme stage had been excavated.

Nuclear Safety Authority. The 5th PNGMDR, submitted to public debate in 2019, is to be published in 2022.

The Cigéo project is the outcome of a lengthy democratic process involving the passing of three laws (in 1991, 2006 and 2016) and two national public debates, with the result that solutions have been found collectively for managing the most hazardous radioactive waste. The design of the Cigéo facility for the co-disposal of both high-level radioactive waste and intermediate-level waste has been developed since 2010. The French policy for the Cigéo roadmap is based on three pillars: a) governance and stakeholder involvement, including the continuous and strong involvement of the French Parliament; b) step-by-step progression of the project with decisional milestones; and c) an extended R&D programme, supported by an underground research laboratory (URL). The progressive development of Cigéo takes into consideration the potential evolution of technologies, R&D and innovation and energy policies on reprocessing or direct disposal. In the Cigéo safety concept, the geological barrier has a predominant role for safety demonstration and the focus is on the host rock (clay). It is important to keep in mind the size of the repository, the large inventories and the diversity and volumes of the waste.

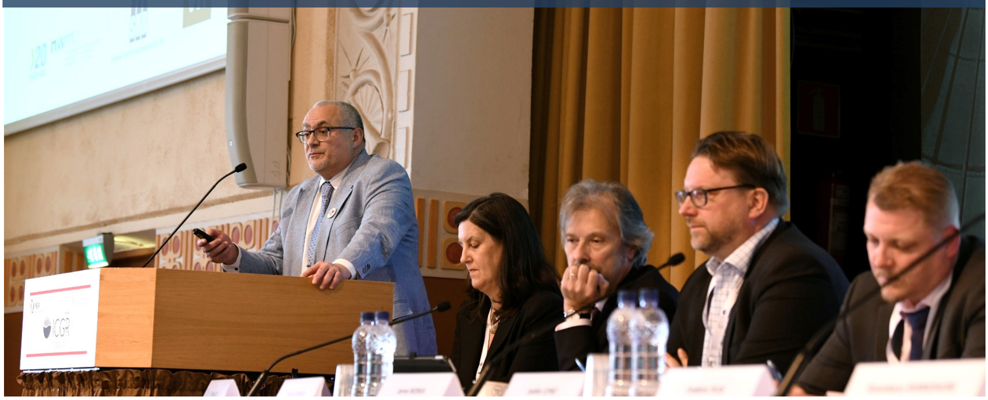
France is entering the permitting phase, which implicates the following authorisations:

1. A declaration of public convenience and necessity (DUP) for land acquisition and preparation of preliminary work, which follows a public enquiry and a favourable opinion in 2021 without reserve. The publication into the French official journal of the Prime Minister's decree recognising the public utility of Cigéo, the French deep geological disposal project for high level and intermediate level long lived radioactive waste is expected to happen in 2022. With the publication there will be an acknowledgment of the general interest of Cigéo as a final disposal solution for the most radioactive waste produced in France.

2. Authorisations for the construction of facilities in non-nuclear zones of Cigéo to allow modifications of existing infrastructures and natural components of the site. These authorisations will be needed in the coming years to prepare the site for the construction of Cigéo, if licenced.

3. Authorisations for the construction of facilities in nuclear zones. The Construction License Application (DAC), which is the result of a full integration of 30 years of work along the roadmap, is to be submitted in the coming year. The review of the Construction License Application by the French Nuclear Safety Authority (ASN) would start in 2023 and is expected to last 3 to 5 years.

With the preparation of the DUP, Andra conducted for the first time a socio-economic study showing that Cigéo provides "an insurance for future generations" against societal uncertainties. The study covers not only the Cigéo facility but the overall project, assessing its interest from an economic, social and environmental perspective. Beyond financial considerations, the models analysed in the study also take into account a more qualitative criterion: the "insurance benefit", that is to say the service provided to the population and the attention paid to future generations. Any large-scale project in France is obliged to perform such a study. In addition, public concertation and involvement are an important part of the project throughout its' lifespan, from the public enquiry, mandatory for the DUP, to the citizen conference on the industrial pilot phase in July 2021 and the insertion of Cigéo in the Meuse/Haute-Marne region.



Left to right: Frédéric Plas, Director of Cigéo Programme, Andra, France; Erika Holt, Customer Account Lead, VTT; Patrick Landais, High Commissioner for Atomic Energy, CEA; Janne Mokka, President, Posiva Oy, Finland; Jaakko Leino, Director, Department of Nuclear Waste Regulation and Safeguards, STUK, Finland. © Krystal Kenney

2.5. Germany

In Germany, the Federal Company for Radioactive Waste Disposal, the BGE, is mandated by the federal government to perform tasks resulting from the Atomic Energy Act and the Repository Site Selection Act. The BGE was established in 2016 and expanded in 2017 by a merger of the repository divisions of the Federal Office for Radiation Protection (BfS) and the operating companies Asse-GmbH and the German Service Company for the Construction and Operation of Waste Repositories (DBE). The merger significantly accelerated construction activities related to waste disposal facilities.

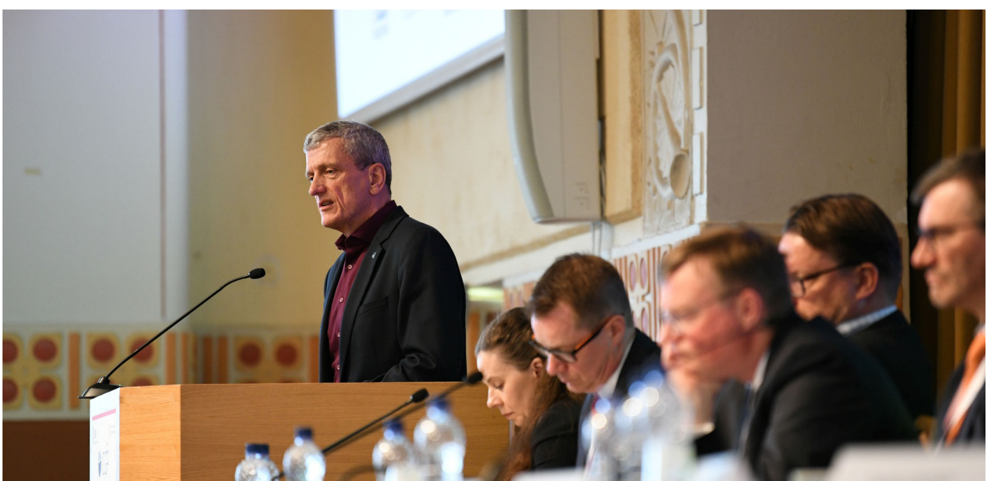
Germany has two legacy projects: the Asse and Morsleben mines. The Asse salt mine was a repository first used for emplacing 49 000 m^3 of low- and intermediate-level radioactive waste (LILW) between 1967 and 1978 and afterwards as a research facility during the 1980s up to 1995. In 2013, the German Atomic Energy Act was amended to allow retrieving the emplaced waste because of geomechanical stability problems and brine inflow. A considerable amount of exploration work has taken place over the last years to gain refined knowledge of the overburden and the salt structure. The waste retrieval operation is to start in 2033, with preparatory underground and surface work ongoing. The licensing process has started with filing the retrieval plan to the licensing authority, accompanied by a public announcement. In addition, a spatial planning procedure was initiated.

The Morsleben repository stores approximately 37 000 m^3 of LILW. This former salt mine is not licensed for continued operation and further waste emplacement, but the mine and existing repository can be safely closed with its existing waste in place, with sealing measures and backfilling of salt-concrete, in accordance with local regulations. Decommissioning documents are to be submitted to the responsible authority by 2026.

In June 2000, the agreement between the German Federal Government and electric utility companies included a moratorium on the planned repository at Gorleben, in addition to the nuclear phase-out. The Gorleben salt dome was subsequently eliminated from the site selection procedure based on geological requirements and criteria as determined by the law. A closing programme has been developed that plans the backfilling of the pit beginning in 2024 and the closure and renaturation of the site by 2031.

The former iron ore mine named "Konrad" has been deemed suitable as a future repository for LILW based on its favourable characteristics regarding long-term isolation. Furthermore, the Konrad repository's plan has been approved. There are two shafts at Konrad site (K 1 and K2) with associated surface plants. The construction of the first buildings at K 1 are finished by now and further buildings are under construction, with approximately 65% of the work completed. Shaft K 2 will be converted from an auxiliary shaft of the former iron ore mine into the main transportation shaft for the radioactive waste. Configuration management is the most important part of this project. The main challenge for the project schedule is the reconstruction and preparation of Shaft K 2 for transporting the casks containing the radioactive waste from surface to underground for final storage. The construction work will not be finished before the end of 2027. Deposit operation will start immediately after the successful commissioning procedure.

The Site Selection Act (StandAG) of 5 May 5 2017 defines the procedure for the search and selection of a site for a repository for high-level waste. The site selection procedure in Germany consists of three phases. In phase 1, there are two steps: the determination of subareas and the determination of siting regions for surface exploration. In 2020, as a result of the first part of phase 1, the BGE published its interim report on sub-areas. Phase 2 consists of surface exploration and a proposal for underground exploration, while Phase 3 is the final site comparison and site proposal. Currently the BGE is working on the proposal for the siting regions for exploration in Phase 2.



Left to right: Thomas Lautsch, Technical Managing Director, BGE, Germany; Linda Kumpula, Senior Specialist, Ministry of Economic Affairs and Employment, Finland; Jussi Heinonen, Director, Regulatory Oversight Strategic Development, STUK, Finland; Magnus Holmqvist, President, SKB International, Sweden. © Krystal Kenney

2.6. Japan

In Japan, development of the DGR stepped into the implementation stage in 2000 according to the Final Disposal Act. However, no significant progress in siting process was achieved until 2015, with the revision of the basic policy based on the Final Disposal Act, which tasked the Japanese government with taking leadership and disseminating a list of the scientifically favourable areas for geological disposal. In 2017, the Japanese government published a nationwide map of scientific features relevant for geological disposal. The Ministry of Economy, Trade and Industry (METI) and the Nuclear Waste Management Organization (NUMO) subsequently began promoting public meetings and dialogues to encourage deeper public understanding of geological disposal in more than 140 locations all over Japan, without focusing on specific regions. The locations of these meetings are determined by taking into account the regional balance of population and transportation accessibility to ensure that as many people as possible can participate.

Japan's site investigation process consists of three stages: literature survey, preliminary investigation and detailed investigation. If the local government opposes an investigation, METI and NUMO will not pursue further the investigation process. In November 2020, NUMO began the literature survey in two Hokkaido municipalities: Kamoenai village (with a population of ~1 000) and Suttu town (with a population of ~3 000).

METI and NUMO continue to hold public dialogues throughout Japan to raise awareness of the DGR project, including in the two Hokkaido-based municipalities. In survey areas, NUMO and METI provide detailed information on the progress of the literature review and local development plans (e.g. social impact, community development), and listen to local stakeholders' requests. The "place for dialogue" was established in April 2021 in Kamoenai village and in Suttu town, where local residents engage in discussions with neutral facilitators. Workshops and site visits to the Horonobe URL (see Section 3.1) are also organised in these two municipalities.

At the international level, co-operation is extremely important to enhance the reliability of geological disposal projects and technologies. An international roundtable was jointly organised by the NEA, the Ministry of Economy, Trade and Industry of Japan and the Office of Nuclear Energy, United States Department of Energy, in October 2019 and in February 2020 to deepen co-operation on final disposals. Representatives from 14 countries, together with the International Atomic Energy Agency (IAEA) and the NEA, shared experiences and knowledge about transparent and open decision-making and trust and confidence in the safety of the DGR project. In November 2022, METI and the NEA will hold a workshop at the Horonobe URL to launch a multi-year international collaborative research project.

2.7. Norway

Norway has four research reactors that have ceased operating (the last one in 2019) and a comprehensive waste management infrastructure needs to be developed to enable decommissioning. The current repository for LILW, built 20 years ago, was not licensed for long-lived intermediate-level waste, spent fuel or other HLW and is almost full. There is a need for a repository for HLW and for LILW. In this regard, Norway follows a dual track policy: 1) handling radioactive waste nationally; and 2) through the Association for Multinational Radioactive Waste Solutions (ERDO), co-operating with other nations and exploring options for shared solutions.

After a large revision of disposal concepts and applicability to the Norwegian context, relevant information has been gathered on:

- potential solutions that are feasible for nations with small waste inventories (DGRs, deep boreholes, direct disposal of transportation casks, etc.);
- assessment of technologies' robustness and availability and comparison on 628 requirements;
- applicability of international safety standards as a framework for development in Norway.

Norway is in the conceptual phase of a DGR, assessing different disposal alternatives. Borehole disposal has been shown to be feasible with existing technology and safety has been demonstrated through generic safety assessments. However, borehole disposal has not been subject to scientific and regulatory review to the same extent as deep geological repositories. Waste minimisation techniques are being discussed on a techno-economical level.

2.8. Sweden

Sweden is the second country in the world to have the approval to build a final repository for SNF/HLW, after 40 years of R&D on a safe repository concept and an open and transparent siting process. The KBS3 repository method was first presented in 1983. Finland adopted KBS3 early on and it is now an international model used in other countries. This concept was continuously reviewed before being approved. The licensing process has taken several years and the final decision was made by the government after the municipalities' approval. The Swedish Radiation Safety Authority (SSM) and the Land and Environment Court have reviewed SKB's applications[2]. The concerned municipalities and county administrative boards, universities and higher education institutions, environmental organisations and the general public have had the opportunity to give their opinions during the review of SKB's applications.

Since the government made its decision, the application is now back with the SSM and the Land and Environment Court, who will stipulate conditions for the facilities based on the updated safety assessment report. The municipalities will also decide whether to grant building permits under the Planning and Building Act. SKB hopes that construction of the SNF repository and the encapsulation plant can begin in the 2020s and take around ten years to complete.

On 27 January 2022 the Swedish government approved the final repository for SNF and the encapsulation plant. On 22 December 2021 the application to extend the final repository for short-lived radioactive waste (SFR), which had been operating since 1988, was also approved. These government decisions will provide long-term solutions for electricity production and will contribute to fossil fuel-free living within one generation. The aspects of the Swedish case that were highlighted during ICGR-6 as success factors include clarity in establishing roles and responsibilities of all parties involved, a comprehensive legislation, the established funding and financing systems and the open and transparent siting and licensing process.

2. SSM's licensing is carried out under the Nuclear Activities Act and the Land and Environment Court application under the Environmental Code.

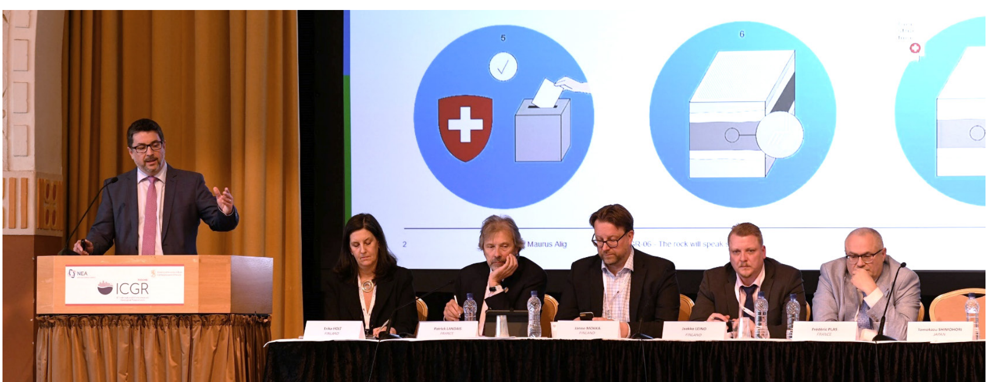
2.9. Switzerland

Switzerland does not follow a voluntary approach for the siting process, but a science-based, criteria-based approach. Site selection is based on the safety concept, implementing the Sectoral Plan for Deep Geological Repositories approved by the Federal Council (government) in 2008. The site selection procedure is organised in three stages:

- Stage 1: selection of geological siting areas (completed);
- Stage 2: selection of at least two sites (completed);
- Stage 3: selection of one site for HLW and LILW (or combined).

The three locations chosen during Stage 2 are all close to the German border. Switzerland has maintained close contacts with the authorities in Germany. Representatives of German communities and population are also members of the regional conferences established under the terms of the sectoral plan. In each location, the regional conferences have published a statement on one location for the surface infrastructure facilities. In 2020, Nagra published a report on advantages and disadvantages of different siting options for a SF/HLW encapsulation plant. From Nagra's point of view, the best solution would be to realise the encapsulation plant at the deep geological repository or at the interim storage facility (ZWILAG) in Würenlingen. This report served as a basis for discussion for the transregional collaboration with the siting regions and Cantons.

In the ongoing stage, Nagra will choose its favoured site based on geology. The final DGR site for the general licence application will be announced in the autumn of 2022 and the general licence application will be submitted by the end of 2024.



Left to right: Maurus Alig, Coordinator Major Project Sectoral Plan Stage 3/General Licences, Nagra, Switzerland; Erika Holt, Customer Account Lead, VTT; Patrick Landais, High Commissioner for Atomic Energy, CEA, France; Janne Mokka, President, Posiva Oy, Finland; Jaakko Leino, Director, Department of Nuclear Waste Regulation and Safeguards, STUK, Finland; Frédéric Plas, Director of Cigéo Programme, Andra, France. © Krystal Kenney

Nagra, the co-operative responsible for the development and implementation of radioactive waste, will propose a combined repository for the full range of radioactive waste. Cost calculations are carried out every five years, and have been made for both options:

- two individual repositories for HLW and for LILW; and
- a combined repository for all types of waste.

The latest cost calculations are very similar, but once the location and the type of repository are decided, the associated cost calculations will become more accurate.

2.10. United Kingdom

The context of radioactive waste in the United Kingdom is unique. There is a great amount of legacy waste located at multiple sites across the United Kingdom and a large and diverse inventory for geological disposal (approximately 750 000 m^3 when packaged). Most of the current radioactive waste inventory will arise at Sellafield.

In 2018, a new UK government policy was published that sets out a consent-based process for working in partnership with communities to identify suitable sites with a willing community. A further community guidance document explains the process of collaborating with communities throughout the siting process, and a site evaluation document explains how candidate areas and sites will be evaluated based on six site evaluation factors (i.e. safety and security; community; engineering feasibility; environment; transport and value for money). Nuclear Waste Services (NWS)[3], the organisation responsible for the disposal of the United Kingdom's nuclear waste, was formed in 2022. NWS is responsible for the development of a geological disposal facility (GDF).

Building on lessons learnt and international experience, the 2018 UK government policy is clear that a GDF will only be built where there is both a suitable site and a willing host community. The potential host community will decide whether they want to host a GDF through a test of public support. A willing community process shall build support from the bottom up through engagement, identifying and addressing concerns, and building trust and confidence through a transparent and open process. As of April 2022, three GDF community partnerships have been formed (i.e. South Copeland; Mid Copeland and Allerdale on the west coast) and one working group on the east coast (i.e. around Theddlethorpe in Lincolnshire). The focus of current considerations is the inshore coastal setting at these sites, though each presents different technical and site considerations (e.g. geology, access ways, transport). While the community partnerships on the west coast in Cumbria have some knowledge of nuclear activities, the Theddlethorpe working group is a non-nuclear community. Site investigations have commenced to assess the potential of the host geology for GDF development, beginning with an inshore seismic survey of Mid Copeland. It is the aim to select two sites for borehole investigations by 2026. At the earliest, the operational phase would start in the 2050s.

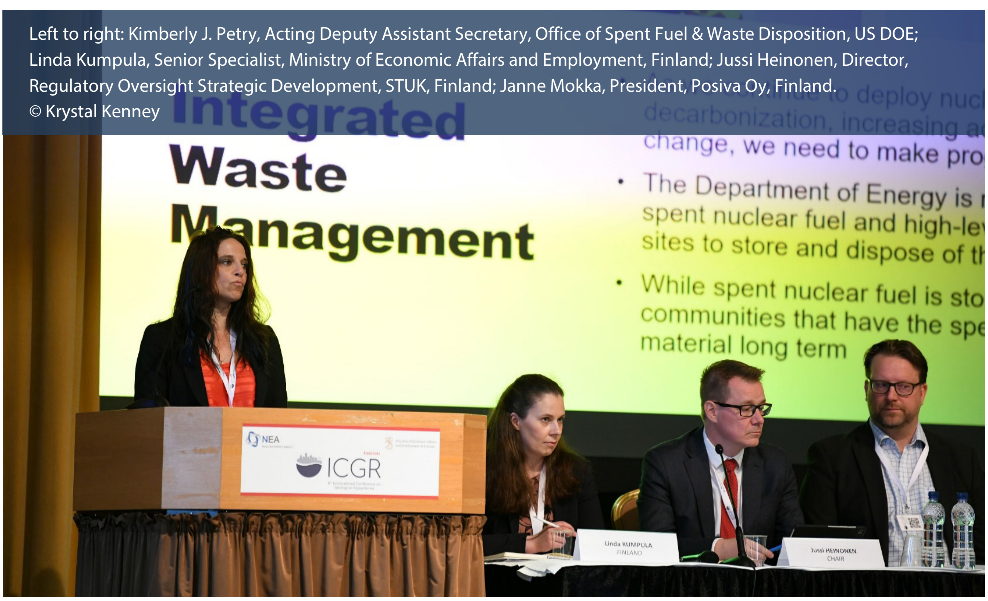
3. NWS integrates the expertise of three organisations: Low Level Waste Repository, Radioactive Waste Management Limited and the Nuclear Decommissioning Authority group's Integrated Waste Management Programme.

Successful factors include: using a consent-based policy, engaging communities, effective waste packaging guide, growing capability throughout the process, and building a delivery programme transforming a research organisation into an implementing organisation. Ensuring a consistent national commitment is one of the key challenges. Also crucial to the project's success are funding, technical capability and developing community support and partnership.

2.11. United States

As the United States continues to deploy nuclear energy to meet net zero emissions by 2050, progress on the back end of the fuel cycle is needed. The US Department of Energy (DOE) is working to develop a comprehensive radioactive waste management system that includes the need to site storage and permanent disposal facilities. While the DOE is not currently searching for a repository site, R&D in the United States continues to reduce uncertainties on final geological disposal.

In December 2020, the "Consolidated Appropriations Act, 2021" was signed into law, allocating USD 27.5 million toward dealing with SNF, USD 20 million of which would fund an interim storage programme. The Act also directs the DOE to move forward with interim storage to support near-term action in managing the nation's SNF. Interim storage will enable near-term consolidation and temporary storage of SNF, which will allow for removal of SNF from reactor sites. The DOE anticipates that an interim storage facility would need to operate until the fuel can be moved to final disposal.



Left to right: Kimberly J. Petry, Acting Deputy Assistant Secretary, Office of Spent Fuel & Waste Disposition, US DOE; Linda Kumpula, Senior Specialist, Ministry of Economic Affairs and Employment, Finland; Jussi Heinonen, Director, Regulatory Oversight Strategic Development, STUK, Finland; Janne Mokka, President, Posiva Oy, Finland.
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Storing SNF is done safely across the United States at both private commercial sites (co-located with reactor facilities and at sites away from reactors) and federal DOE sites. This includes two licensed but not constructed private consolidated interim storage facilities (plus one currently in the licence review process). However, the current facilities are not intended for long-term storage and the local communities never agreed to host this material long-term. The DOE has subsequently committed to using a consent-based siting process to identify federal interim storage facilities – an approach to siting facilities that focuses on the needs and concerns of local stakeholders. Communities that participate in the siting process will work with the DOE to complete a series of phases and steps that should help the community determine whether and how hosting a facility that manages SNF aligns with the community's goals. A consent-based siting process could lead either to a negotiated consent agreement or to a determination that the community is not interested in serving as a host.

On 1 December 2021, the DOE issued a Request for Information on a consent-based siting process that would be used to identify sites to store the nation's SNF. Responses gathered by this Request for Information will be used to further develop the DOE's consent-based siting process and overall waste management strategy in an equitable way. It is the first step in the process of developing a federal interim storage programme that will remove SNF from reactor sites. Responses to the DOE's public information request on identifying a federal interim storage facility using a consent-based siting process were submitted by 4 March 2022. The DOE will consider the comments submitted as part of the Request for Information, as well as comments submitted as part of a 2017 consent-based siting process draft. Subsequently, an updated draft consent-based siting process will be released. The DOE pays special attention to ensure equity and environmental justice in the consent-based siting process. A funding opportunity to allow interested groups to engage more in the process is planned for the end of 2022.

2.12. Overview of EU-funded activities and policy on geological repositories

The Council Directive 2011/70/Euratom established a framework for the responsible and safe management of spent fuel and radioactive waste. This Council Directive highlights a number of matters that European Union (EU) member states need to focus on, including aspects related to deep geological repositories, waste minimisation and post-assessments covered by financing schemes.

The European Commission has published a number of studies to support EU member states on technical and financial issues related to RWM and decommissioning. A study on radioactive waste classification and key performance indicators for monitoring implementation is in progress.

Half of the EU member states are considering shared disposal solutions but their national programmes do not provide concrete milestones or measures towards the implementation. Under provisions of the Radioactive Waste Directive, two or more EU member states are free to co-operate in the field of management of RW and nuclear spent fuel. This also includes joint disposal. Realisation of a joint disposal solution would require:

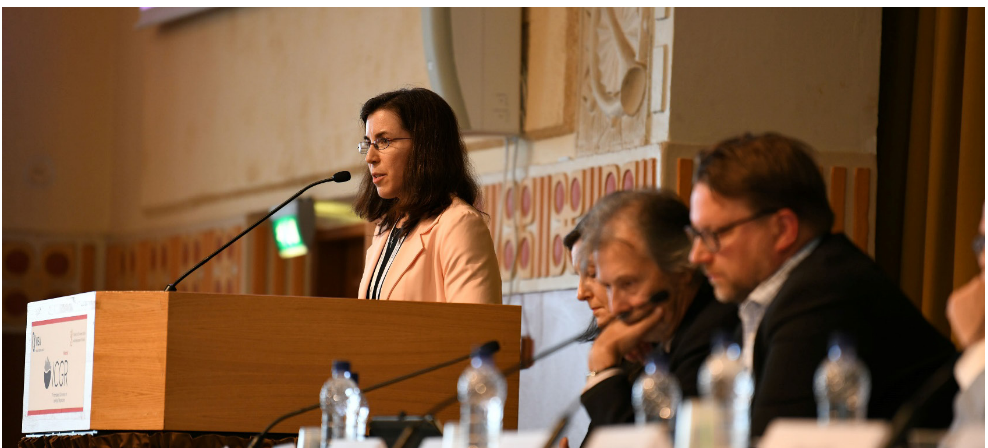
- Defining the allocation of responsibilities and financial liabilities between the waste generators and EU member states co-operating on the joint repository.
- A common classification system of radioactive waste.

2.13. Multinational repository concept

The multinational repository concept is a potential solution for countries that have small volumes of radioactive waste or lack competences, resources or political acceptance to build a DGR, or the resources or trained workforce required to develop, build and operate a national disposal facility for SNF or HLW. It is likely that these countries will continue managing their SNF/HLW in compliance with international standards through extended in-country storage. They are not currently in a position to build and operate a DGR but may be more open over time to considering a multinational repository.

The dual track policy is not a wait-and-see policy, but actively supports exploration of multinational options and a national disposal programme in parallel. Exploration of one track can contribute to the development of the other.

Although the multinational repository concept is not yet fully developed, countries with shared interests can increase the likelihood of its deployment by taking action now.



Left to right: Zuzana Petrovicova, Head of Unit, Nuclear Energy, Nuclear Waste and Decommissioning, European Commission; Erika Holt, Customer Account Lead, VTT; Patrick Landais, High Commissioner for Atomic Energy, CEA, France; Janne Mokka, President, Posiva Oy, Finland. © Krystal Kenney

Chapter 3. Demonstrating technical reliability for operational and long-term safety

ICGR-6 devoted one session to providing an overview of the roles of URLs around the world in demonstrating the technical reliability of geological repositories for operational and long-term safety and in promoting international collaboration. This session also addressed how to demonstrate technical reliability through the safety case.

URLs play a key role in the implementation of DGRs.

There are two types of URL:

- a generic URL, located in rock similar to that of a DGR (but not in an identified or designated DGR location), which allows the information to be adapted; and
- a site-specific URL in the DGR facility itself or nearby.

Some programmes are in the conceptual and/or site selection state and prefer generic URLs (Canada, Switzerland, United States), while others have identified a site and are preparing for construction (France) or operation (Finland) of specific facilities. A site-specific URL may be key for the site-specific safety case, but a generic URL provides important information in early phases of DGR implementation.

The main purposes for developing a URL include:

- process understanding and disposal concept testing;
- site and host rock investigation;
- education of experts;
- opportunities for the public to see concrete examples of Engineered Barrier Systems (EBS) components; and
- design demonstration, which is seen more in mature programmes.

Not every country needs a generic URL. The decision to have one will depend on national objectives, costs and benefits. A large amount of data from URLs already exists, and experiments that have run for a long time can be used for model verification.

3.1. Belgium: HADES URL

The Belgian Research Centre for the Applications of Nuclear Energy, SCK CEN, started studies on geological disposal in 1974, focusing on poorly indurated clay present under the zone of Dessel and Mol. A generic URL (HADES) has existed since the inception of the DGR programme in the 1980s. This URL, located in poorly indurated clay at a depth of 225 metres, has served a key role in guiding geological disposal RD&D through novel experimentation and costing.

In 2021, ONDRAF/NIRAS submitted to the federal government a policy proposal for geological disposal that was based on 40 years of RD&D and a Strategic Environmental Assessment. At the time of writing, the policy proposal was yet to be approved. Even though there is not yet a geological disposal policy in place nor a site, the HADES URL helps apply knowledge to other depths and clays. It also optimises testing and can increase basic understanding of clay behaviour.

The HADES URL is 40 years old and over the last decades the focus has shifted from feasibility studies to confirmation experiments, from basic data gathering to confirmation RD&D and from pioneering feasibility to industrialisation. This has also meant that experiments have become more complicated. Currently the focus is on demonstration and the PRACLAY large-scale heater test.

URL experiments have supported the development of monitoring sensors and equipment, including better understanding of their limitations. This supports the development of the DGR monitoring strategy. Additionally, HADES served as a place for extensive international co-operation. However, URLs operating over several decades also face challenges in knowledge management. The first and second generations of scientists and engineers involved with HADES are retiring, and even if all experiments have been comprehensively documented, there is unique knowledge and experience that cannot be written in reports. An important focus of the current work in HADES is to maintain competent teams, integrate assessments and revisit past experiment results in light of new ones.

Left to right: Philippe Lalieux, Director, Long Term Waste Management, ONDRAF/NIRAS; Erika Holt, Customer Account Lead, VTT; Kristopher Kuhlman, Principal Technical Staff Hydrologist, Sandia National Laboratories, United States; Frédéric Plas, Director of Cigéo Programme, Andra, France. © Krystal Kenney

HADES has also served as a source of information that the public may visit to learn about disposal and, more specifically, to build trust in the scope and quality of RD&D work. HADES helps to enable dialogue with key stakeholders, to promote collaboration with academics and to illustrate the work and investments behind the development of a disposal strategy. HADES has nearly 3 000 visitors a year.

The URL will remain essential for the Belgian RD&D programme on waste disposal. But as the Belgian programme evolves, the focus of the URL might change to meet the needs of upcoming phases, e.g. monitoring development, optimisation testing, training, knowledge management, communication and building trust.

3.2. China: Beishan URL

The People's Republic of China (China) national strategy foresees a closed nuclear fuel cycle with disposal of vitrified HLW in a DGR in granite or clay. Area-specific URLs are established in granite and clay, are large in size, and expandable. These URLs are open for international co-operation.

The URL site in Beishan was confirmed in 2016. The URL is financed by the government and electricity companies. The design, functions and in situ test plan have been developed. Construction began in June 2021 and will last until 2027. The Beishan URL allows for site investigation underground and the development and testing of construction and operation technologies, while also serving as a platform for public communication.

3.3. Finland: Onkalo URL

Finland follows a step-by-step approach, with generic studies in the early phase followed by confirmation of site-specific properties in the Onkalo URL. Information from URLs is needed in various implementation phases of a disposal programme as it helps to develop concepts and components, prepare a site-specific safety case, support training of personnel and foster international co-operation.

Aspects addressed in URL experiments include upscaling, components testing, development of machines and equipment, full-scale in situ tests and monitoring techniques. For instance, projects conducted at Onkalo studied EBS components, excavation-disturbed zone (EDZ) behaviour and radionuclide retention.

URL information is necessary for developing:

- rock suitability classification;
- machinery for final disposal;
- demonstrations that serve for training;
- addressing retrievability.

3.4. France: Andra URL in Bure

In France, the URL in Bure is part of the DGR development roadmap. Andra already has 20 years of experience with the Bure URL, and has contributed to several key decisions. The reliability and readiness of Cigéo rests upon two pillars: a robust concept and a stepwise approach with safety case iterations. Tests at Bure, a site-specific URL, support the development of a safety case and the development of construction and disposal technology.

Andra's main objectives with the Bure URL are:

- to characterise host rock properties;
- to characterise the host rock's response over time to disposal facilities construction and other repository loading;
- to characterise the behaviour and durability of the engineering components and radioactive waste in their interactions with the clay host rock;
- to demonstrate the technological feasibility of underground facilities (shafts, galleries/drifts, junctions, disposal cells, seals);
- to support design choices with respect to safety functions (operating, post-closure).

Andra has planned the use of the Bure URL to support Cigéo's development and to provide input to the following key decision steps:

- 2000-2005: feasibility demonstration;
- 2006-2009: choice of disposal location;
- 2010-2015: safety options dossier before submission of licence application;
- 2016-2022: licensing application;
- from 2022: further R&D and technological programme.

The Bure URL has been used in numerous European projects as part of international co-operation. Andra's approach has been to collaborate with other URLs and some of its experiments have been performed in other URLs. This has provided Andra with feedback and benchmarking possibilities.

3.5. Japan: Horonobe URL

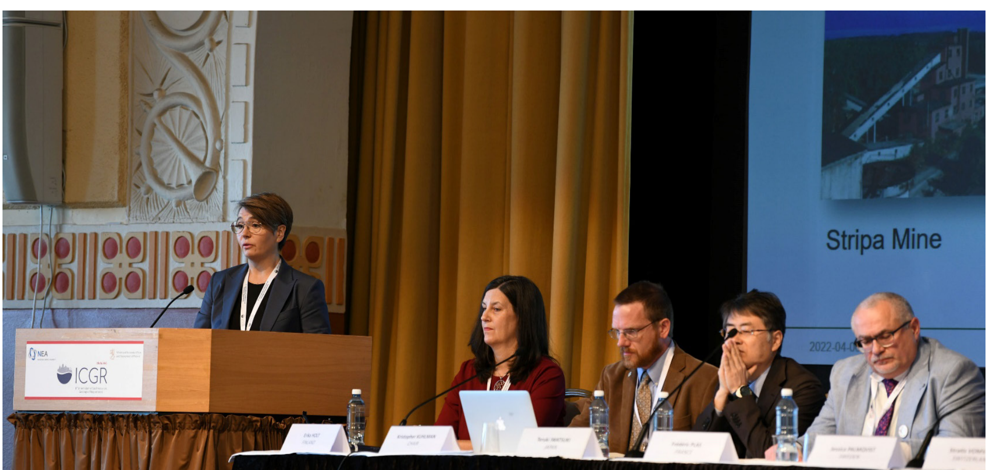
In Japan, the geologic phenomena with potential safety-related effects include volcanism, earthquakes and related faulting, and uplift and erosion. URLs are used for geoscientific research, including long-term geological stability, and/or for R&D of geological disposal technology. There are two off-site URLs in Japan operated by the Japan Atomic Energy Agency (JAEA): the Mizunami URL project in crystalline rock and fresh water (currently closed and under monitoring) and the Horonobe URL project in sedimentary rock and saline water for R&D use. The Horonobe R&D has been performed in a stepwise manner. Its phases include (JAEA, n.d.):

- Phase 1: Surface-based investigations;
- Phase 2: Investigations during construction;
- Phase 3: Investigations in the underground facility.

Current R&D activities focus on EBS emplacement technology and performance evaluation, excavation effects and the geological characteristics at different URL depths. Horonobe also serves as a place for international collaboration projects and for educational purposes for young people from other Asian countries.

3.6. Sweden: Äspö URL

SKB has long had a programme for spent fuel management and DGR development. It started underground research in 1970s in the Stripa mine, which turned into an international project until the 1990s. This work provided good process understanding of the URL. In 1983, when the KBS3 concept was published, the need for an undisturbed site arose, and a decision was made to build the Äspö hard rock laboratory (HRL). The HRL has had a central role in the development of Sweden's disposal method and bedrock understanding for more than 35 years. R&D performed in the Äspö laboratory has provided input to the DGR safety case development and to the iterative development of the disposal's design. The URL supports the research, development and demonstration (RD&D) needs for all phases: policy and planning, concept, siting and RD&D, construction, operation and decommissioning and closure. At Äspö it has been possible to gradually increase process understanding and demonstrate the feasibility and safety functions of barriers from small to full scale. In addition, experiments at Äspö have increased the technology readiness levels of repository construction methods, barrier components and installation equipment. The opportunity to study long-term installations provides important verification of models and hypotheses for safety assessments.



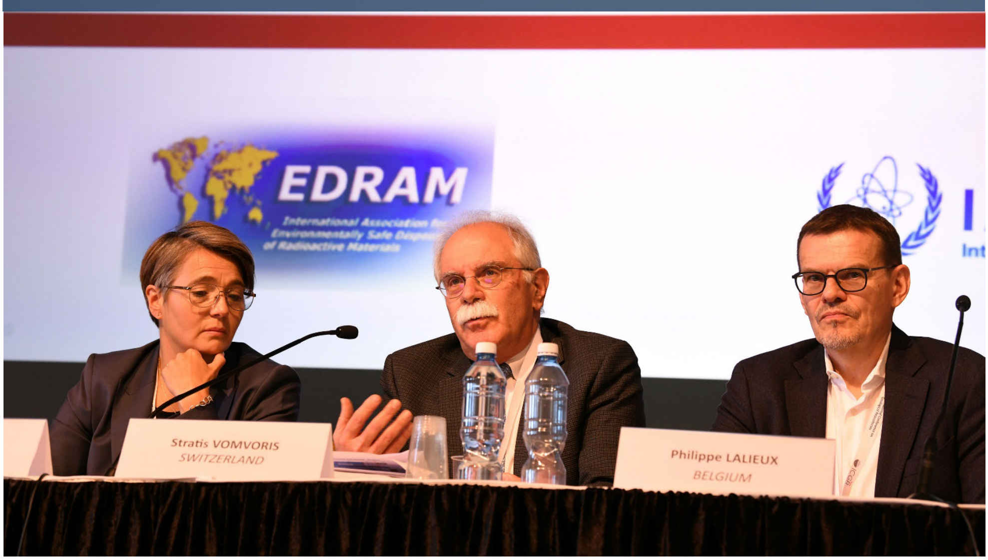
Left to right: Jessica Palmqvist, Head of Research and Development, SKB, Sweden; Erika Holt, Customer Account Lead, VTT; Kristopher Kuhlman, Principal Technical Staff Hydrologist, Sandia National Laboratories, United States; Teruki Iwatsuki, Director, Horonobe Underground Research Department, Horonobe Underground Research Center, JAEA, Japan; Frédéric Plas, Director of Cigéo Programme, Andra, France. © Krystal Kenney

The URL allows R&D on the development of the disposal method in all phases. Building and operating the URL has also served as practice for coming DGR site investigations, preparations for construction and site modelling. A URL provides the possibility for full scale and long-term experiments in a realistic environment. International collaboration has been a part of the RD&D at the Äspö HRL from the beginning. The HRL has also served as a place where the public can learn about disposal and what it could look like. It has been important for communication, engagement and acceptance. Äspö will soon have fulfilled its purpose for the Swedish programme and SKB is now studying how Äspö could be used in the future.

3.7. Switzerland: Grimsel Test Site and Mon Terri project

URLs were part of the Swiss HLW programme from an early stage, selected to support R&D in possible host formation types and the development of the national DGR programme. Switzerland has two generic URLs that are also used extensively in international collaboration projects: the Grimsel Test Site in crystalline rock and the Mont Terri project in Opalinus Clay. Mont Terri is owned by the canton of Jura and managed by Swisstopo. This URL, located along an existing infrastructure tunnel, allows for horizontal access, which reduces operational costs.

Left to right: Jessica Palmqvist, Head of Research and Development, SKB, Sweden; Stratis Vomvoris, Executive Advisor, International Services and Projects, Nagra, Switzerland; Philippe Lalieux, Director, Long Term Waste Management, ONDRAF/NIRAS. © Krystal Kenney



Every five years, Nagra develops a R&D plan that steers the work carried out in the URLs. These URL activities complement laboratory studies and site-specific investigations through:

- exploration of intrinsic properties of the geological environment;
- verification of characteristic parameters of processes expected during the lifetime of a repository and in the post-closure phase;
- long-term demonstrations and experiments under more realistic boundary conditions; and
- system optimisation.

Both Swiss URLs provide a hands-on opportunity for younger researchers to get involved with waste disposal.

A generic URL can ease the amount of testing and demonstration need to be performed during DGR site-specific underground investigations. The objective is to not repeat in the chosen site all the demonstrations that have already been carried out in the URL. It should also be highlighted that URLs may contribute to increased acceptance of DGRs as they rely on international collaboration and their results are visible and accessible through publications and through the involvement of the scientific community.

3.8. United Kingdom: Demonstrating technical reliability for operational and long-term safety

The United Kingdom is launching a consent-based siting process for geological disposal with early engagement with potential communities and with a wide range of potential geological environments (i.e. higher strength rocks, lower strength sedimentary rocks or evaporites).

In 2016, the Generic Disposal System Safety Case (gDSSC) was published (NDA, 2016). The gDSSC established the feasibility for geological disposal of the UK waste inventory, outlined disposal concepts and compiled arguments and evidence to demonstrate safety. Current work defines, arranges and manages requirements; develops feasible engineering solutions; or prepares later exploration work (borehole sealing, seismic surveys), and is informed by international experience. The next major phase will develop site-specific concept designs for selected potential sites, supported by deep boreholes to characterise the geology. For this, permits are needed from environmental regulators. Appropriate verification and validation is set out at every stage. In the UK programme, early technical demonstration is done above ground, alongside construction. There are likely to be continued underground investigations and testing of the geology to make sure that a GDF meets the necessary high standards of safety, security and environmental protection.

3.9. United States: Sandia National Laboratories

The current US geological disposal programme runs generic RD&D activities in the conceptual stage, primarily addressing technical reliability in the development of software for simulation and analysis. The programme considers three types of host rocks: crystalline, salt and clay.

Sandia National Laboratories focuses on the development of a model-based Geological Disposal Safety Assessment Framework. A safety assessment framework for geologic disposal is developed at Sandia with the integrated PFLOTRAN code combining a near field model, a geosphere transport model and a biosphere model. The primary objectives are the flexibility and transparency of the development process and easy accessibility.

URL experiments produce data that can be used in different modelling efforts. It is important to have large-scale experiment data that can be used in performance assessment model verification. For instance, some projects are using salt, as it has good long-term properties for waste disposal (i.e. no flowing groundwater, low porosity and permeability, high thermal conductivity and self-sealing ability). However, a salt environment is aggressive for measurement equipment and presents challenges related to constructability and construction effects. BATS (Brine Availability Test in Salts) is a salt heater experiment that provides information about, among other things, brine migration in salt. These ongoing borehole experiments are conducted underground at the Waste Isolation Pilot Plant (WIPP) and investigate generic disposal concepts for heat-generating radioactive waste.

Decovalex 2023 is another international programme focusing especially on Thermal-Hydrological-Mechanical/Thermal-Hydrological-Mechanical-Chemical (THM/THMC) couplings and modelling and it utilises URL data. These projects are training the next generation of modellers and salt experimentalists.

Chapter 4. **Building and maintaining human capacity**

Each DGR programme requires a strong knowledge management programme with defined capabilities. However, the loss of human capacity is an ongoing challenge for the nuclear sector, in particular waste management. RWM and DGR programmes require highly qualified individuals who have the appropriate experience and are capable of applying knowledge and integrating information. Disposal programmes must attract experienced scientists and integrate younger scientists. International collaboration and joint activities enable networking within the scientific community. The European Joint Programme on Radioactive Waste Management EURAD is one example of a joint co-operation activity between EU member states that supports the timely implementation of RWM activities and serves to foster mutual understanding between joint programme participants.

4.1. Elements for building and maintaining competence from the regulators' perspective

Given the long lifespan of any geological repository project (from siting to closure), a systematic approach that holistically encompasses tools, technology, processes and people is crucial. Staff working in the regulatory body have three key competences: regulatory competences, technical competences (including the new and advanced technologies such as robotics, artificial intelligence or small modular reactors), and behavioural competences. Behavioural competences are just as important as the traditional regulatory and technical competences. Additional skills such as public communication can also be developed by training and supported by management and the human resources department of the regulatory body.

It is also important that the mechanisms for knowledge management be interlinked, documented, reviewed regularly and updated to meet the organisational needs. Knowledge management can integrate systematic training and tools, going beyond documentation. New platforms and e-learning might facilitate the international transfer of skills and experience from older to younger staff. In this regard, the NEA serves as a mediator for international co-operation, facilitating the exchange of practices among member countries.

The Canadian Nuclear Safety Commission (CNSC) provided the following examples to help build and maintain competence:

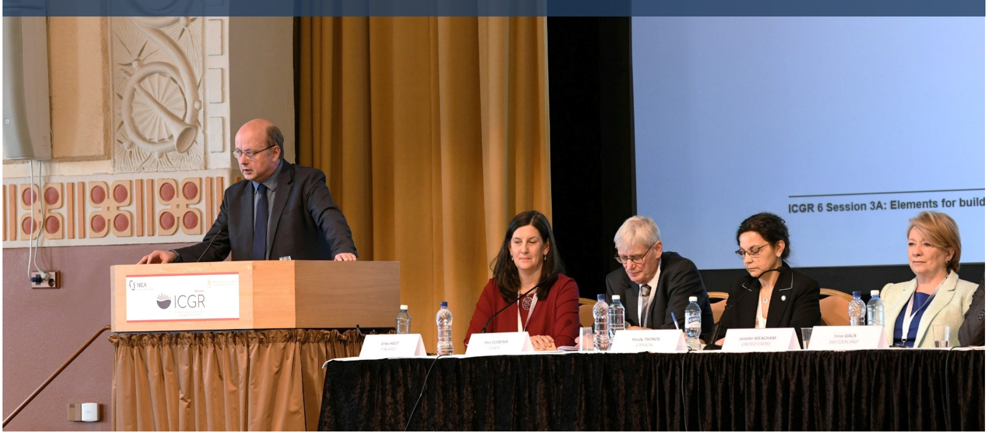
- Conduct independent regulatory research with primary objectives (support regulatory oversight activities, support staff review of the safety case, inform science-based conclusions) as well as secondary objectives (build in-house expertise and promote knowledge transfer and long-term knowledge management; communicate objective scientific information through peer-reviewed publications).

- Use international platforms to share knowledge, such as: site visits, information exchange, different IAEA initiatives (i.e. the Underground Research Facilities Network for Geological Disposal).
- Integration of the CNSC's independent advisory group, which provides objective, independent advice to CNSC staff on scientific aspects for the safe long-term management of used nuclear fuel, and reviews and advises on academic research in the field of geological repositories.
- Involving Indigenous populations in a structured, formalised and continuous way. There is a need to acknowledge and respect the land and incorporate Indigenous knowledge, traditions and experience into Canada's regulatory process. This allows the CNSC to create stronger relationships with the communities and provide information about the regulatory role.
- Outreach and engagement activities: present and explain the regulatory role at community liaison committee meetings with potential host communities; present and answer questions during Indigenous learning and sharing gatherings; hold presentations and hands-on activities with youth groups.

CNSC outlined several ways to build and maintain competence in the following fields:

- Communication: simplify and clarify highly technical information; clearly explain roles and responsibilities between implementer and regulator; virtual settings are not ideal to build relations and trust; find ways to integrate Western science and traditional Indigenous knowledge and experience.

Left to right: Felix Altorfer, Director, Radioactive Waste Management Division, ENSI, Switzerland; Erika Holt, Customer Account Lead, VTT; Piet Zuidema, Chief Scientific Officer, European Joint Programme on Radioactive Waste Management (EURAD); Haidy Tadros, Director General, CNSC, Canada; Janette Meacham, NWM Licensing & Knowledge Management Lead, Nuclear Energy Fuel Cycle Program, Sandia National Laboratories, United States. © Krystal Kenney



- Processes: there is a need for structured strategies to prevent loss of expert knowledge and experience through attrition or departure; better integration of mechanisms for knowledge and talent management; more focus on continuous and consistent (criteria-based) performance management.
- Training: training of technical disciplines needs to be systematic, structured and continuous throughout a career; deliberative tacit knowledge transfer mechanisms are needed.
- Tools: information from document repositories needs to be easily retrievable; fragmentation of data architecture needs to be prevented; legacy systems need to be avoided and instead information infrastructures need to be integrated across the information life cycle (technology changes quickly and retrieving information quickly must be possible).

4.2. Elements for building and maintaining competence from the implementers' perspective

Competencies for disposal need to be developed and maintained during long-term projects. One of the key challenges to maintaining competencies is the loss of expert knowledge in nuclear waste management organisations. An example was provided during ICGR-6 by Enresa of Spain, where the DGR programme was low priority for approximately 15 years and staff were either reallocated or retired. Support from experts of different research organisations, universities and private companies was also limited. However, now the Spanish DGR programme is being relaunched through a working group consisting of the ministry, the regulator and the implementer to study and develop proposals for legislative, regulatory and procedural frameworks for DGR licensing. The most critical factor is the support at the country level. Collaboration and continuous support at the national level from all institutions (e.g. implementer, regulator and government) is necessary to avoid disruption in DGR programmes. Maintaining capacity building and knowledge management is also critical in DGR development.

It is important to adequately organise building and maintaining competence needs at the international level and at the level of individual implementers by defining and implementing effective initiatives. These initiatives can relate to:

1. addressing societal challenges such as climate change;
2. enhancing trust in geological disposal;
3. ensuring career perspective;
4. financial optimisation.

An immediate way to help maintain competence is to develop a knowledge management project that identifies critical organisation knowledge and captures historical knowledge from experts before they retire. This allows organisations to embed processes in work routines in order to systematically capture critical knowledge. A well-run knowledge management programme increases trust in DGRs, supports career planning and increases efficiency.

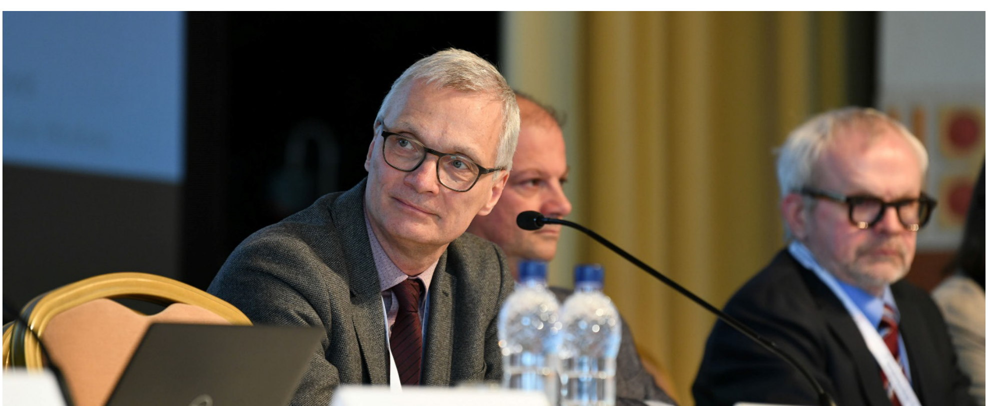
A safety assessment can also serve as a tool for gaining competence as it enables, in an iterative manner, staff development, system conceptualisation, workflow improvement and data management (as it becomes available). The safety assessment is a key component of the site selection process.

An important instrument for building and maintaining competence in Europe is the Implementing Geological Disposal Technology Platform (IGD-TP), which brings together waste implementers. The IGD-TP aims for the industrialisation of radioactive waste disposal in Europe by 2040. For this, competences are required over long project timescales and they evolve as disposal programmes mature from site selection to construction and operation. The IGD-TP is a means of maintaining competence as it pools EU resources, co-ordinates projects around a common Strategic Research Agenda, secures financing for the implementation of projects and creates synergies with other international initiatives and organisations.

For the implementers of the IGD-TP, the benefits of the platform include:

- the quality of the programme;
- competitive career paths when investing in personnel development;
- international peer networks to fall back on and increase efficiency;
- financial benefits through budget and knowledge sharing in collaborative projects.

Implementers are currently transitioning from being science-based organisations to engineering and delivery organisations. In this new context, a balance should be sought between the safety case base and the technical knowledge base. To facilitate the retention of young staff and foster generalist profiles, it is useful to design a career pathway that touches upon various parts of the implementer's work. In addition, international mentoring events and staff exchanges between implementers are important and should be encouraged.



Left to right: Klaus Jürgen Röhlig, Clausthal University of Technology (TUC), Germany; Fabrice Puyade, Director of the Human Resources Division, Andra, France; Gerald Nieder Westermann, Waste Technology Specialist, Waste Technology Section, Division of Nuclear Fuel Cycle and Waste Technology, IAEA. © Krystal Kenney

Managing long-term projects is one of the challenges faced by implementers' departments of human resource. In France, Andra has a human resources strategy for preparing the construction of Cigéo. This strategy is built on five pillars:

- remaining an attractive employer by developing the brand;
- implementing a programme of prospective exploration of human capital and offering career progression prospects;
- increasing loyalty to keep productive employees;
- investing in non-financial remuneration systems;
- offering a work environment that focuses on quality of life at work through corporate social responsibility initiatives.

The brand development of Andra as an employer consists of:

- communication about their activities via social networks;
- promotion of the meaning of their action and the reason they exist (make waste safe);
- development of a proactive, high-quality apprenticeship policy;
- signing innovative agreements with trade unions that anticipate societal issues.

The loyalty effect, by which employees are retained, is achieved through two key principles:

- non-financial remuneration (sharing opportunities, continuing professional development, mobilisation and fostering responsibility of line managers, internal mobility to offer opportunities for career progression); and
- investment in quality of life at work (health and well-being, good work/life balance, internal innovation and new working methods, links to sustainable development concepts like organic food, etc.).

4.3. Elements for building and maintaining competence from academia and research

Two examples were provided during ICGR-6 of how to build and maintain competence in academia and research: one from Germany, a country phasing out nuclear, and one from the United States, where radiological protection programmes are in decline and there is a lack of government funding.

In Germany, nuclear issues are no longer interesting for many young scientists. Although there is a persistent need for competence in the nuclear field as decommissioning and RWM will continue for years, nuclear is seen by many as a dying technology. Numerous types of expertise are needed in RWM, such as geoscience, engineering, nuclear safety or law. Moreover, generalist knowledge about the technical and societal aspects of RWM is required. There are two avenues to supply this knowledge: through a specialised curriculum with expertise in one specific field that is then supplemented with generalist knowledge (via supplementary courses or later vocational training and on-the-job experience) or through a generalist curriculum with a holistic perspective of the RWM field. The majority of staff working in RWM take the first path (i.e. specialised curricula).

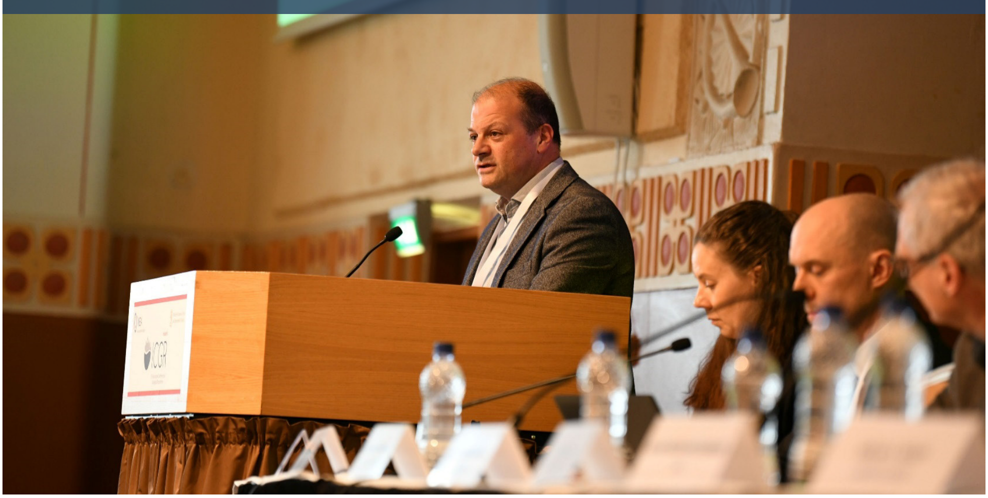
In the United States, the school of nuclear sciences and engineering at Oregon State University has identified the important factors for retaining students in science, technology, engineering and mathematics (STEM) as:

Having a sense of community and belonging (most significant influence).

- Giving importance to student mental health, well-being and their micro-community.
- Cost of higher education, particularly for students in undergraduate programmes.
- Experiential engagement building on community, foreshadowing their employment and engendering resilience. The school decided to have small classes instead of classes of 500 people to help students find a community of peers.
- Combining general education and core education: what they need to be good students, good citizens and get out in the larger world.

In general, decision-makers should be made aware that there is a need to build and maintain competence and a need for funding projects, equipment, programmes, etc. Co-operation between academia, implementers and technical support organisations is also needed in the framework of R&D projects, theses, mobility programmes, lectures, graduate programmes and course specialisations.

Left to right: Fabrice Puyade, Director of the Human Resources Division, Andra; Linda Kumpula, Senior Specialist, Ministry of Economic Affairs and Employment, Finland; Kai Hämäläinen, Section Head, Regulation of Nuclear Waste Facilities, STUK, Finland; Klaus Jürgen Röhlig, Clausthal University of Technology (TUC), Germany. © Krystal Kenney



4.4. The role of the IAEA in building and maintaining competences

The IAEA has developed a Roadmap for Implementing a Deep Geological Disposal to support IAEA member states in building their national DGR programmes. An accompanying training course has also been developed and has been held several times. The role of a URL is recognised as a major work element in the IAEA's "Roadmap for Implementing a Deep Geological Disposal Programme" (IAEA, forthcoming). Specific to the underground research facility (URF) roadmap element, the IAEA is also developing a compendium of research and experiments that have been carried out in URFs around the world over the last several decades. Further, the IAEA has begun work on producing a guide to capture best practices and lessons learnt in planning for the construction and monitoring of URLs supporting the DGR.

4.5. The role of the European Commission in maintaining human capacity

The European Waste Directive (Council Directive 2011/70/Euratom, 2011) and Nuclear Safety Directives (Council Directive 2014/87/Euratom, 2014) require member states to maintain expertise and skills and to have adequate human resources in terms of both quantity (i.e. number of experts) and quality (i.e. level of knowledge).

At the European level, there are different organisations to help maintain human capacity. The European Human Resources Observatory for the Nuclear Energy sector helps to support member states in their effort to assess the situation in terms of human resources gaps and to harmonise job classification. The Joint Research Centre (JRC) is active in the field of nuclear knowledge production (through the implementation of its research programmes), management and education and training. The latter is based upon providing different types of opportunities: access to research infrastructure for students and young researchers, knowledge dissemination, courses (including hands-on demonstration), contribution to and/or organisation and co-ordination of relevant activities, including networking. It helps to foster competencies in the fields of radioactive waste management, decommissioning, nuclear safety, nuclear security, safeguards and non-proliferation, nuclear data and radioactivity measurements. The number of JRC nuclear research infrastructures open to young researchers is expected to be increased in the future.

4.6. The Nuclear Energy Fuel Cycle Knowledge Management pilot project

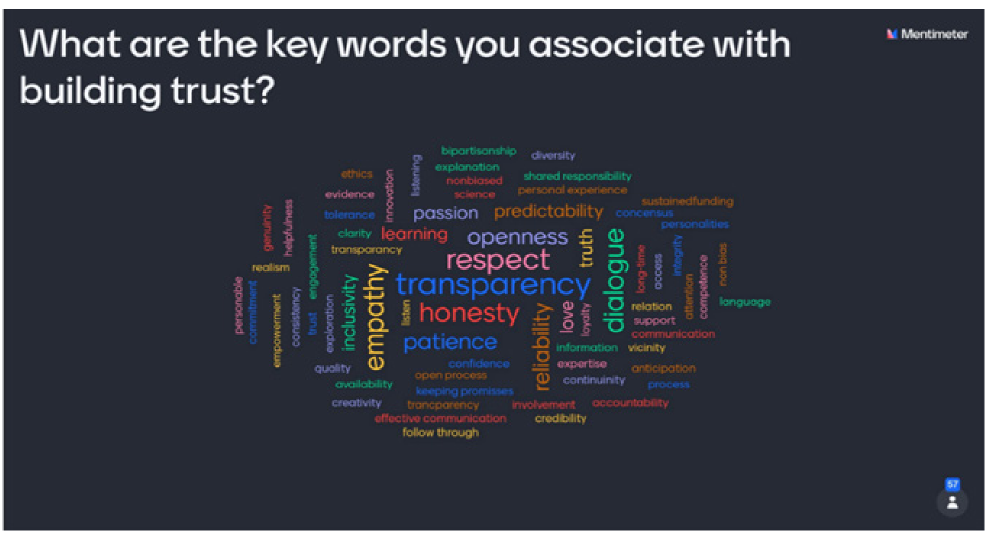
Sandia National Laboratories in the United States presented their knowledge management pilot programme, which began in 2019. The Nuclear Energy Fuel Cycle (NEFC) Knowledge Management project intends to capture the tacit knowledge of senior staff before they retire. The scope of the project included the following elements:

- knowledge management strategy;
- focus groups to collect staff opinions and preferences about mechanisms for accessing preserved knowledge;
- workshop to capture and document critical tacit knowledge;
- deep dives into complex topics requiring addition in-depth discussion and to inform early and mid-career staff;
- lessons learnt;
- database repository creation filled in with a formal taxonomy of nuclear waste management work.

Chapter 5. **Building and maintaining trust**

This session started with a brainstorming exercise, with ICGR-6 in-person and virtual participants contributing key words associated with building trust. These words were then compiled into a word cloud (see image of word cloud below). The Chair of the NEA Forum on Stakeholder Confidence (FSC) highlighted numerous elements necessary for building trust, and that trust is built by individuals. Despite the fact that the word "people" was not among all the words suggested by participants, "people" are essential for building trust. It is not organisations themselves that build trust, but people working in these organisations.

Figure 5.1. **What are the key words you associate with building trust?**



The session continued with presentations that highlighted the importance of dialogue and communication with different stakeholder groups to build and maintain trust.

5.1. Approaches to youth engagement

The FSC has a task group on youth involvement, as a specific approach is needed to communicate, raise awareness and dialogue with the young generations. Some of the activities developed by the FSC include a flyer, called "Intergenerational connections in radioactive waste management: involving children and youth" (NEA, 2022), with examples from different countries on how to engage with young people. The table below shows material developed by age groups.

Age group	Objective	Communication material
Elementary school (6-12 years)	Raising interest by using fun communication materials and simple words.	Creation of engaging characters to help tell the story of geological disposal (e.g. UK RWM flyers with Rocky, Ray and ROB); augmented reality application; videos.
Secondary school (12-18 years)	Providing scientific and technical knowledge through class debates, presentations by experts, on-site exhibitions and web conferences.	Class debates, computer-based games, board games (e.g. Disposal game in Belgium; scape box in El Cabril in Spain; social media with Youtubers in France).
University students (18 years and more)	Engaging in a trustful dialogue through learning and raising awareness.	Video production contest (e.g. Japan) ; debates (France).
Young adults	Discussion about ways they would like to be approached and included in the process.	Workshops (e.g. "having a voice in the site selection process" in Germany); digital and social media.

5.2. The importance of dialogue with local communities

The OECD has published a number of studies about trust in public policies (OECD, 2017). They generally confirm that trust in institutions is driven not only by the substance of policies, but also by the process through which policies are made. There are two elements affecting trust: a) transparency and b) inclusion and citizen engagement. Trust is an objective and has to be achieved by three aspects that need to be balanced in communication: ethos (calls upon ethics or values), pathos (elicits emotions in the audience) and logos (puts logic into play by using evidence and facts).

The FSC published an update of the 2010 report "Partnering for Long-term Management of Radioactive Waste: Evolution and Current Practice in Thirteen Countries" (NEA, 2010) in 2021. The report *The Forum on Stakeholder Confidence Report on Dialogue in the Long-term Management of Radioactive Waste* (NEA, 2021) updates the countries' experiences of different types of collaboration with potential host communities and includes different ways in which countries approach dialogue at different stages of the RWM process. For 14 countries, the report presents information on the authorities and organisations involved; how young people are involved; how communication is implemented in practice; added value approaches are considered; the preservation of memory and markers and lessons learnt over time.

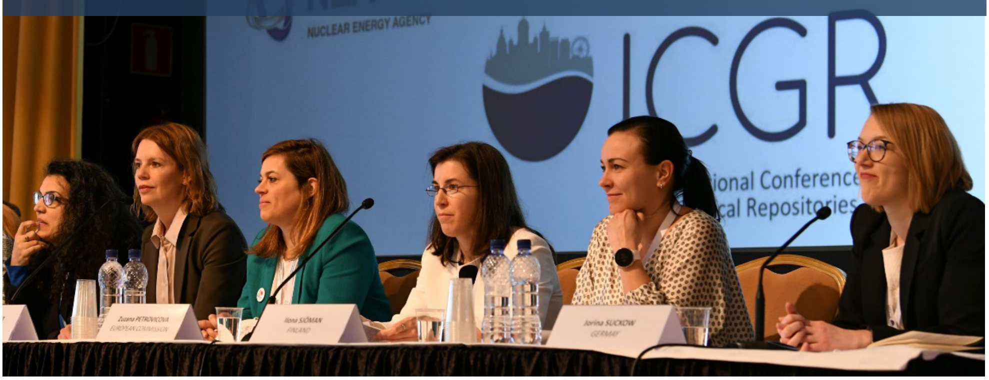
In Sweden, communication has been an integral part of the SKB approach for building trust at the local level. When the programme started in 1986, SKB had technicians and engineers investigating the bedrock without having prepared any dissemination or publication. After protests and demonstrations, SKB changed to a volunteering approach based on willing municipalities and the veto right, which proved important in the decision-making process. Building trust is a long-term mission.

The siting process was based on the agreement of SKB and municipalities to make them more attractive in the long term. Important factors in this agreement include:

- safety;
- voluntary participation;
- stepwise implementation;
- added value programme;
- funding for all participants;
- clear distribution of roles between the authority, SKB and municipalities.

SKB has the approval of the Oskarshamn and Östhammar municipalities to continue working on the encapsulation plant and the extension of the interim storage in the former and on the spent fuel repository in the latter.

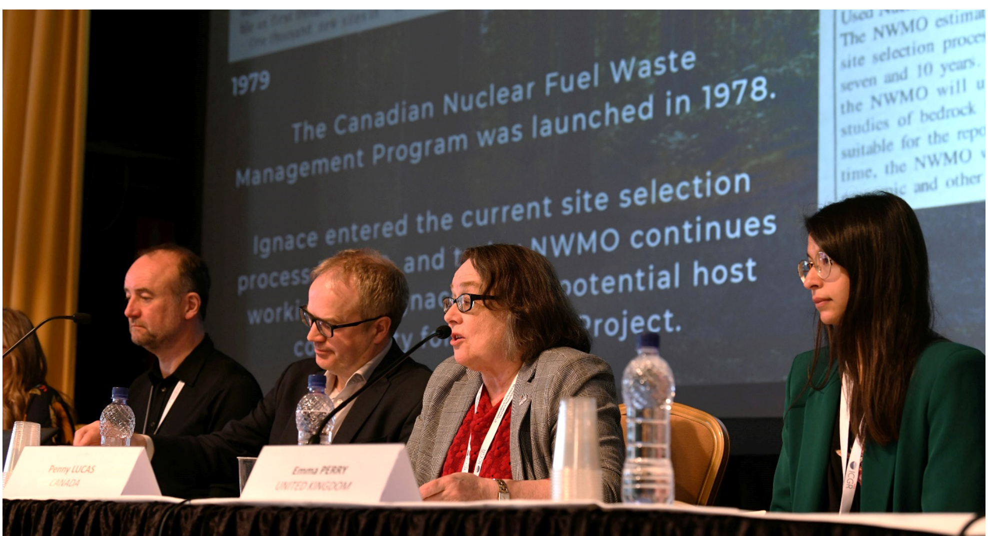
Left to right: Nuria Prieto Serrano, Lawyer, Technical Division, Department of International Relations, ENRESA, Spain; Anna Porelius, Head of Communications and Stakeholder Relations, SKB, Sweden; Annabelle Quenet, Head of Public Involvement Department, Andra, France; Zuzana Petrovicova, Head of Unit, DG ENER D.2 (Nuclear Energy, Nuclear Waste and Decommissioning), EC; Ilona Sjöman, Chair of the Municipal Council of Eurajoki Involvement of Local People in the Development of Geological Repositories; Jorina Suckow, Graduate Student, Member of Nationales Begleitgremium (National Civil Society Board), Germany. © Krystal Kenney



5.3. Public information for effective public involvement

For Andra, in France, communication is a corporate objective. While tools, context and rules for communication have changed since the creation of Andra 30 years ago, the principles of communication and the will to engage in dialogue with the public remain the same. According to Andra, the pillars for building and maintaining trust include:

- Creating interest and being visible by reinforcing Andra's image; maintaining the link with local communities; innovating in communication (e.g. with a video game, local TV channel, virtual tours) and participating in the activities of local communities.
- Informing and explaining through the use of the visitor centre in Bure, and creating exhibitions, brochures, websites and educational material.
- Enabling dialogue: a proactive approach is needed where key targets for dialogue are mapped (e.g. digital influencers, elected officials, young people, industry and business, civil society). The tools for dialogue include press tours, door to door campaigns in local communities led by ambassador employees, the use of social media, etc. Innovation is also needed, and this may include science fiction novels, street art or podcasts on radioactivity.
- Consulting and organising public participation: it is important to involve and consult people on defined topics and issues in order to integrate the project at the local level.



Left to right: Gaston Meskens, Centre for Ethics and Value Inquiry, University of Ghent, Belgium; Philip Matthews, Executive Director, Nuclear Legacy Advisory Forum (Nuleaf), United Kingdom; Penny Lucas, Mayor for the Township of Ignace, Canada; Emma Perry, PhD student, Department of Earth Sciences, University of Cambridge. © Krystal Kenney

Lessons learnt regarding communication and trust in the siting process include:

- Time is required to build trusting relationships with stakeholders.
- Space: not targeting a single municipality, but rather holding discussions across an extended area.
- Content: building projects aimed at promoting territorial development with elected representatives and population.
- Support: having local and national elected representatives to support the implementer's project.

5.4. Building and maintaining trust in the EU

The European Commission is building trust through certain practices, which are summarised below.

- Euratom secondary legislation: reporting requirements on radioactive waste, international peer reviews through Artemis.
- Financial aspects: Nuclear Backend Financial Aspects expert group (NuBaFA) to help analyse financial aspects of nuclear decommissioning, spent fuel and radioactive waste management.
- Implementing regulatory standards and guidelines through the European Nuclear Safety Regulators Group (ENSREG).
- EU taxonomy on sustainable finance: classification tool to guide investments towards activities that can be considered sustainable and contribute to decarbonisation by 2050.
- Research and training: e.g. EURAD.
- International level reports: Euratom report on the Joint Convention.
- Public involvement through the European Nuclear Energy Forum (ENEF) and participation of the EC in organised events by other organisations (e.g. Aarhus Convention and Nuclear round tables).

5.5. Local community involvement: the Finnish example

In Eurajoki, Finland, the majority of inhabitants support final disposal and there is a strong will to host the repository as this is regarded part of the success story of the municipality. At the local level, people are much better informed about nuclear issues than at the national level. In Eurajoki, communication has been ongoing since the nuclear power plants were commissioned 40 years ago. For the municipality, the following factors are considered essential:

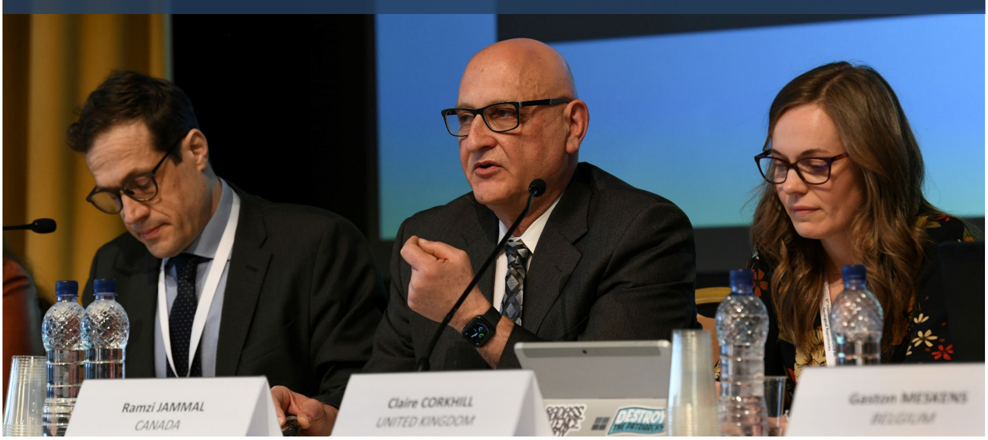
- Safety is the most important factor. In this regard, safe management of nuclear waste is a precondition for the existence of nuclear energy and new builds.
- Safety risks have to be minimised.

- The operator must take care of its nuclear waste (fairness and responsibility).
- No need to delay final disposal without important reasons.
- Retrievability of the waste is an option during the operational period, but without safety risks.
- Long-term political commitment.

In addition, other important factors include:

- Solutions have to be based on existing technology.
- Roles and responsibilities have to be clear.
- Up-to-date requirements and control over the whole cycle.
- The Finnish Radiation and Nuclear Safety Authority (STUK) verifies suitability of the site as part of the safety case.
- STUK prepares, nominates and overlooks safety requirements.
- STUK is independent of subscriber, supplier and political decision-making.

The municipality has a veto right when making decisions in principle.



Left to right: Karim Peltonen, Director, Department of Emergency Preparedness, Communications and International Cooperation, STUK, Finland; Ramzi Jammal, Executive Vice President, CNSC, Canada; Claire Corkhill, Member of CoRWM, Reader in Nuclear Material Corrosion, EPSRC Early Career Research Fellow, Department of Materials Science and Engineering, The University of Sheffield, United Kingdom. © Krystal Kenney

Since 1995, there has been a co-operation group between the Eurajoki municipality, the industrial power corporation, TVO, and Posiva. TVO and Posiva's main policy is unconditional transparency, which has developed the necessary confidence at the local level. In addition to active communication, welfare policies are also important for the municipality and these include:

- TVO and Posiva pay real estate taxes to Eurajoki municipality.
- There is a steady income and it is easy to make long-term plans.
- Employees pay income taxes.
- Business opportunities for local companies.
- New jobs, as many locals work at the site.
- Co-operation with Posiva concerning the Vuojoki mansion[4], which was an economic benefit straight away after the site selection.
- TVO's and Posiva's sponsorship of local organisations.

5.6. Building and maintaining trust at national level: the example of Germany

Germany decided to phase out nuclear power in 2011 after the Fukushima Daiichi accident. This was followed by a new site selection process for the DGR which aims to build and maintain trust and considers public participation essential. The National Citizens' Oversight Committee (NBG) was established at the end of 2016 as an independent, pluralistic body to accompany the site selection process, in particular concerning public participation. This Board is composed of 18 members: 12 recognised public figures who are elected by the German Bundestag and Bundesrat and 6 individual citizens selected randomly. Two seats among these 6 members are for younger people (16 to 27 years old). No knowledge is required in advance to be part of this committee. The members are appointed for three years. Re-appointment is possible two times. The members are granted access to all records and documents of the federal company for radioactive waste disposal, BGE mbH, and the Federal Office for the Safety of Nuclear Waste Management, BASE. The NBG is not only to accompany the procedure with a commitment to public welfare but also with the aim of enabling trust in the execution of the procedure. The NBG appoints a representative for participation. This person will assist in settling disputes or mediating in case of conflict. The NBG can consult a scientific council or individual experts for its deliberations, its structures or to obtain scientific expert opinions.

4. The Vuojoki Mansion was a communal nursing home that was leased by the Eurajoki municipality to Posiva. Posiva renovated the mansion for its own use as the company's headquarters and congress centre. In return, Posiva loaned to Eurajoki approximately EUR 7 million for the construction of a new nursing home.

Chapter 6. **Communicating uncertainties**

Uncertainties are not synonymous with a lack of safety, but the way they are communicated about and perceived by the public is related to trust. In the case of DGRs, uncertainties might be a foundation for misinformation.

Scientists are generally not trained in communicating uncertainties and their differing views may cause mistrust in the public. The RWM community has to prioritise the ability to communicate uncertainty and use language that can be understood and generates trust and confidence in the public. It is important to create opportunities for engagement and the building of public confidence.

6.1. The perspective of the regulator

The safety case is the foundation to communicating uncertainty. The main role of the regulatory body in the safety case is in the process rather than the publication itself. Uncertainties in the DGR safety case cannot be eliminated but all the activities that are part of the safety case help to gain knowledge on the level of risk associated with the remaining uncertainties. In this context, natural analogues are tangible and are key to communicating the safety case.

The challenges faced by the regulator to communicate uncertainties include:

- The long timeframes: how do we know what will happen more than 1 000 years in the future?
- The information is very technical and there is a need to develop better communication tools.
- Disinformation and misinformation: there is a need for a trusted source of unbiased information.

6.2. The role of experts

Grouping together experts might help to support the decision to use a DGR to manage radioactive waste. This is the case, for example, in the United Kingdom, where the Committee on Radioactive Waste Management (CoRWM) was set up in 2003 to make recommendations for the long-term management of the United Kingdom’s higher activity wastes that would protect the public and the environment and inspire public confidence (CoRWM, n.d.).

In 2006, the CoRWM published a series of recommendations to the UK government on the long-term management of radioactive waste that they believed provided a basis for inspiring public and stakeholder confidence (CoRWM, 2006). Alternatives to geological disposal were carefully considered and both the United Kingdom's radioactive waste management organisation and CoRWM continue to keep options under review. At present, other alternatives are either not technically achievable or not environmentally safe.

Following completion of their work, the CoRWM was reconstituted in 2007 to provide ongoing independent scrutiny and transparent advice to the UK government on the long-term management of higher activity radioactive wastes. The CoRWM currently has 12 members, who are experts in different aspects of radioactive waste management.

The CoRWM regularly publishes position papers that provide the experts' views on specific topics of interest to stakeholders, e.g. deep borehole disposal, retrievability, regulation and inshore geological disposal.

The CoRWM members seek to use their independent position to facilitate dialogue and an open exchange on topics associated with radioactive waste management and disposal. It holds open plenaries that any member of the public can attend.

6.3. Ethical challenges at the science-policy interface

There are four ethical challenges where science meets policy:

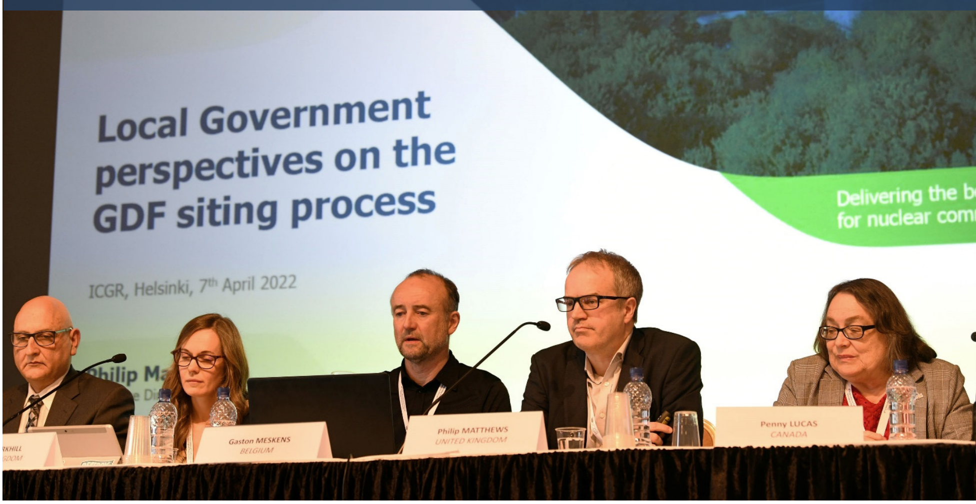
- Constructing credible hypotheses with regard to the possibility of a DGR for long-lived nuclear waste that can be proven in research but create scepticism in the public. A hypothesis is not fully proven in the lab and has many interpretations in society.
- Dealing with moral pluralism with regard to technological choices: even based on the same scientific knowledge, opinions vary, depending on values.
- Dealing with political pressure to deliver evidence that cannot always be delivered (yet): the only way is to be more transparent about the scientific method and process and to construct credible hypotheses publicly (openness).
- Holding moral authority over future generations: it is important to explain why decisions were made in order to share knowledge with future generations.

Overall, research should be organised as an advanced form of dialogue enabling reflexivity and deliberation.

6.4. The local government and community perspectives

Two complementary perspectives were presented at ICGR-6 on the role of local governments and communities on the geological disposal siting process. One was presented by the Nuclear Legacy Advisory Forum (Nuleaf) and the other by the Mayor of the candidate township of Ignace in Canada.

Nuleaf was created in 2003 and represents over 100 local authorities and national parks across England and Wales. It works to influence strategy, policy and practice across all areas of decommissioning and nuclear waste management and has a growing international profile, as it is a member of the Group of European Municipalities with Nuclear Facilities (GMF) and engages with the IAEA, NEA and the EURAD programme. Nuleaf engages with government and the nuclear industry to help shape strategy and policy as well as the practicalities of the DGR siting process. It also provides support to local authorities. Overall, the organisation exists to deliver the best economic and environmental outcomes for local authorities and the communities they serve. It is important to have a responsive organisation that interfaces with the local authorities in the best way possible given the huge technical, engineering and political challenges involved in the nuclear field.



Left to right: Ramzi Jammal, Executive Vice President, CNSC, Canada; Claire Corkhill, Member of CoRWM, Reader in Nuclear Material Corrosion, EPSRC Early Career Research Fellow, Department of Materials Science and Engineering, University of Sheffield, United Kingdom. Gaston Meskens, Centre for Ethics and Value Inquiry, University of Ghent, Belgium; Philip Matthews, Executive Director, Nuclear Legacy Advisory Forum (Nuleaf), United Kingdom; Penny Lucas, Mayor for the Township of Ignace, Canada. © Krystal Kenney

For the local governments represented in Nuleaf, the GDF is not seen in isolation as a distinct and important process, but as having clear links to the United Kingdom's wider decommissioning and waste management mission. Local authorities are crucial to success, UK policy requiring their engagement for a community to formally enter and remain in the process. Different communities have different knowledge and perspectives but communicating and debating uncertainties regarding geology, safety and retrievability is important for all of them.

In Canada, Ignace entered the current site selection process in 2010 and since then it has worked with the NWMO as a potential host community for the Adaptive Phased Management System project. The Council of Ignace created the Ignace Community Nuclear Liaison Committee, which has met once a month since 2010. The community continues to learn about Canada's plan to safely store used nuclear fuel. This happens through different mechanisms, such as:

- The Ignace Learn More Centre, an important site for ongoing engagement with the northwest region on the DGR.
- A satellite office to facilitate engagement and bring information to people in the area surrounding Ignace.
- The Ignace Community Liaison Committee Office, which will be a key location for community discussion and information sharing.

As the township has been involved in this process for more than ten years, there is a certain amount of fatigue in the community from this extended preparatory process. From June to October 2021 residents of Ignace were asked "what should be the community's willingness decision-making process on the adaptive phased management project look like?" The Willingness Decision Working Group has sought broad public engagement. Ignace would need to decide in favour of the project before it can proceed.

6.5. Online engagement

During the COVID-19 pandemic, online engagement became the primary means of communicating with the public. There are many challenges with online engagement but also plenty of benefits compared to in-person engagement, as shown in the table below.

Challenges	Advantages
Critical nature of people on the internet Getting attention Keeping attention Without making use of two-way communication functionality there is a less natural "human" interaction.	Building an online resource available 24/7. A huge audience if you can tap in to it. Diversity of presenters and audiences. If you embrace the digital, multimedia can offer more engaging options. Online engagement metrics are inbuilt and quite standardised. It is possible to capture personality and maintain authenticity.

Chapter 7. **Concluding remarks**

ICGR-6 showed the significant progress that many countries have made in developing geological repositories over the last two decades. The conference presentations showed that countries are at different phases in their DGR projects, with some at the conceptual stage and others close to being operational. Radioactive waste management organisations are focusing on concrete activities that not only provide plans for the future but implement DGR projects. The policies, strategies and programmes are in place to support this development. The technology has demonstrated that there are safe solutions for managing radioactive waste and technology is not an obstacle to progress. It is now possible to pull all the experience, research and science of the last 30 years together and move towards implementation. Additional project-specific work and continuous adaptations are still needed for implementation, including accurate cost calculations after a location and a type of disposal are determined.

Transferring knowledge to future generations needs a systematic approach and mentoring schemes that treat younger people with respect and inclusivity. At ICGR-6, younger professionals were involved in all sessions and provided important contributions.

Safety is the key parameter, but decision-making regarding a DGR needs to be holistic. In several countries, a consent-based siting process is used to establish an appropriate location. The role of the municipality is pronounced in the siting and early steps of DGR development. However, public engagement and confidence building are part of many decisions and evaluation steps. Stakeholder confidence, community engagement and support, and trust and transparency are of key importance in DGR programmes. Furthermore, it is imperative to have a strong government that is fully committed to developing the DGR programme as well as a national framework with clear roles and responsibilities.

Multinational repositories face greater challenges than national ones, as they involve several countries and radioactive waste would cross international borders. The multinational repositories concept is not mature today, but actions taken now by countries with shared interests can increase the likelihood of its deployment in the future.

The conference showcased the possibilities and value of learning from each other and of international co-operation to implement innovative approaches. The success of all DGR projects depends on mutual support. Progress in one country supports the case for DGRs elsewhere. URLs are also important facilities for international collaboration. They can meet many objectives and their purpose can change during the programme: from design demonstration to optimisation, process understanding, disposal concept testing, education and public engagement. URLs can be a useful source for building safety cases and technical reliability using a stepwise approach. They can also encourage younger generations to be more involved in the field of radioactive waste management and develop and maintain skills.

Knowledge and human resources are key elements of a successful programme and it is the responsibility of all actors to help build and maintain competence. Bringing new workers and keeping experienced workers in the field is essential and a common goal in the sector. Knowledge and human resources are easily lost with a political decision and rebuilding is a long path. To avoid loss of knowledge, it is important to start a transfer of knowledge to early and mid-career staff sufficiently early, integrating subject matter experts (specialists) and integrators (generalists). It is necessary to build an open and supporting family-like community to help integrate younger people, share information and provide interesting opportunities for experienced workers as mentors. Making RWM an attractive career option includes creating interdisciplinary groups, properly funding training programmes for universities and offering possibilities via international research centres. The IAEA, NEA, European projects like EURAD and technology platforms like the IGD-TP, which make it possible to share and connect information and experience within the waste management community, are crucial to providing continuity.

Communication needs to be targeted to the audience. For municipalities, safety is the most important factor. While the future inherently brings uncertainties, that does not necessarily mean a lack of safety. Indeed, reassessing uncertainties regularly and communicating about them in plain language should be part of an organic process through the lifetime of the DGR.

Institutions gain trust not only through the policies they implement, but through the processes they use to adopt those policies. When such processes are transparent and inclusive, trust is enhanced. Trust needs to be built from an early stage and earned every day. Technology is not an obstacle to the implementation of geological disposal. The real challenge is political and societal, making trust and transparency of paramount importance.

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Appendix A. ICGR-6 programme

Younger Generation Session

Chair

- Rebecca Tadesse, Head of NEA Division of Radioactive Waste Management and Decommissioning

Speakers

- Gerald Nieder-Westermann, Waste Technology Specialist, Waste Technology Section, Division of Nuclear Fuel Cycle and Waste Technology, International Atomic Energy Agency (IAEA)
- Roger Garbil, Head of Section Fission, DG RTD C.4 (Euratom Research), European Commission (EC)

Facilitators

- Richard S. Jayne, R&D Geosciences Engineer, Applied Systems Analysis & Research Department, Nuclear Energy Fuel Cycle Program, Sandia National Laboratories, United States
- Heidar Gharbieh, Senior Advisor, Section for Nuclear Safety, Norwegian Radiation and Nuclear Safety Authority, Norway
- Ville Rinta-Hiiro, Research Scientist, VTT Technical Research Centre of Finland Ltd, Finland
- Shogo Nishikawa, Technology Integration Group (International Coordination), Science and Technology Department, Nuclear Waste Management Organization of Japan (NUMO), Japan

Closing remarks and Q&A

- William D. Magwood, IV, Director General, Nuclear Energy Agency

Welcome address and introductory remarks

- William D. Magwood, IV, Director General, Nuclear Energy Agency
- Liisa Heikinheimo, Deputy Director General, Energy Department, Ministry of Economic Affairs and Employment, Finland

Master of Ceremonies:

- Linda Kumpula, Senior Specialist, Ministry of Economic Affairs and Employment
- Erika Holt, Customer Account Lead, VTT

Session 1: **Present status of national geological disposal projects**

1A. ***Status of national geological repository projects***

Chair

- Jussi Heinonen, Director, Regulatory Oversight Strategic Development, Radiation and Nuclear Safety Authority (STUK), Finland

Speakers

- Janne Mokka, President, Posiva Oy, Finland
- Kimberly J. Petry, Acting Deputy Assistant Secretary, Office of Spent Fuel & Waste Disposition, United States Department of Energy (DOE)
- Pierre-Marie Abadie, CEO, French National Radioactive Waste Management Agency (Andra), Chair of International Association for Environmentally Safe Disposal of Radioactive Materials (EDRAM)
- Johan Dasht, Managing Director, Swedish Nuclear Fuel and Waste Management Company (SKB), Sweden
- Karen Wheeler CBE, Deputy CEO/Major Capital Programmes Director, Nuclear Waste Services, United Kingdom
- Laurie Swami, President and CEO, Nuclear Waste Management Organisation (NWMO), Canada
- Thomas Lautsch, Technical Managing Director, Federal Company for Radioactive Waste Disposal (BGE), Germany
- Håvard Kristiansen, Senior Advisor, Norwegian Nuclear Decommissioning (NND), Norway
- Antti Ikonen, Project Manager, Fennovoima Oy
- Timo Saanio, Vice President, AINS Group, Finland

1B. ***Panel debate on progress achieved***

Co-Chairs

- Johan Dasht, Managing Director, Swedish Nuclear Fuel and Waste Management Company (SKB), Sweden
- Patrick Landais, High Commissioner for Atomic Energy, French Alternative Energies and Atomic Energy Commission (CEA), France

Panellists

- Janne Mokka, President, Posiva Oy, Finland
- Jaakko Leino, Director, Department of Nuclear Waste Regulation and Safeguards, Radiation and Nuclear Safety Authority (STUK), Finland
- Frédéric Plas, Director of Cigéo Programme, French National Radioactive Waste Management Agency (Andra), France
- Tomokazu Shimohori, Director, Radioactive Waste Management Policy Division, Electricity and Gas Industry Department, Agency for Natural Resources and Energy (ANRE), Ministry of Economy, Trade and Industry (METI), Japan
- Maurus Alig, Coordinator Major Project Sectoral Plan Stage 3/General Licences, Member of the Executive Board, National Cooperative for the Disposal of Radioactive Waste (Nagra), Switzerland
- Lukáš Vondrovic, Head of RAW Development Department, Radioactive Waste Repository Authority (SÚRAO), Czech Republic
- Sean Tyson, Co-Chair, IFNEC RNFSWG; Office of International Nuclear Energy, Office of Nuclear Energy, U.S. Department of Energy (DOE)
- Zuzana Petrovicova, Head of Unit, DG ENER D.2 (Nuclear Energy, Nuclear Waste and Decommissioning), European Commission (EC)

Session 2: **Demonstrating technical reliability for operational and long-term safety (including peer-reviews)**

2A. ***The role of underground research laboratories and international collaboration***

Chair

- Kristopher Kuhlman, Principal Technical Staff Hydrologist, Sandia National Laboratories, United States

Speakers

- Teruki Iwatsuki, Director, Horonobe Underground Research Department, Horonobe Underground Research Center, Japan Atomic Energy Agency (JAEA), Japan
- Frédéric Plas, Director of Cigéo Programme, French National Radioactive Waste Management Agency (Andra), France
- Jessica Palmqvist, Head of Research and Development, Swedish Nuclear Fuel and Waste Management Company (SKB), Sweden
- Stratis Vomvoris, Executive Advisor, International Services and Projects, National Cooperative for the Disposal of Radioactive Waste (Nagra), Switzerland
- Philippe Lalieux, Director, Long Term Waste Management at ONDRAF/NIRAS
- *Young Professional Representative*: Richard S. Jayne, R&D Geosciences Engineer, Applied Systems Analysis & Research Department, Nuclear Energy Fuel Cycle Program, Sandia National Laboratories, United States

2B. *Panel debate on demonstrating technical reliability*

Chair

- Pierre-Marie Abadie, Chair of International Association for Environmentally Safe Disposal of Radioactive Materials (EDRAM); CEO, French National Radioactive Waste Management Agency (Andra), France

Panellists

- Shunsuke Kondo, President, Nuclear Waste Management Organization of Japan (NUMO)
- Tiina Jalonen, Development Director, Posiva Oy, Finland
- Emily Stein, Technical Manager, Sandia National Laboratories, United States
- Frédéric Plas, Director of Cigéo Programme, French National Radioactive Waste Management Agency (Andra), France
- Cherry Tweed, Special Advisor – GDF Programme, Nuclear Waste Services, United Kingdom
- Tim Vietor, Division Head of Safety, Geology and Radioactive Materials, Member of the Executive Board, National Cooperative for the Disposal of Radioactive Waste (Nagra), Switzerland
- Ju Wang, Vice President, Beijing Research Institute of Uranium Geology (BRIUG), China
- Pär Grahm, Head of Repository Technology, Swedish Nuclear Fuel and Waste Management Company (SKB), Sweden

Session 3: **Elements for building and maintaining competence (from siting to construction to operation)**

3A. *Elements for building and maintaining competence*

Chair

- Piet Zuidema, Chief Scientific Officer, European Joint Programme on Radioactive Waste Management (EURAD)

Speakers

- Haidy Tadros, Chair of NEA Committee on Decommissioning of Nuclear Installations and Legacy Management (CDLM); Director General, Canadian Nuclear Safety Commission (CNSC)
- Janette Meacham, NWM Licensing & Knowledge Management Lead, Nuclear Energy Fuel Cycle Program, Sandia National Laboratories, United States
- Irina Gaus, Head of Research and Development, National Cooperative for the Disposal of Radioactive Waste (Nagra), Switzerland; Chair, Implementing Geological Disposal of radioactive waste Technology Platform (IGD-TP)

- Felix Altorfer, Director, Radioactive Waste Management Division, Swiss Federal Nuclear Safety Inspectorate (ENSI), Switzerland
- Joaquín Farias Seifert, Head of Department of International Relations and R&D, Spanish Radioactive Waste Management Organization (ENRESA), Spain
- Gerald Nieder-Westermann, Waste Technology Specialist, Waste Technology Section, Division of Nuclear Fuel Cycle and Waste Technology, International Atomic Energy Agency (IAEA)
- *Young Professional Representative*: Mark Gobien, Section Manager, Safety Assessment Models, Nuclear Waste Management Organization (NWMO), Canada

3B. ***Panel debate on building and maintaining human capacity***

Chair

- Kai Hämäläinen, Section Head, Regulation of Nuclear Waste Facilities, Radiation and Nuclear Safety Authority (STUK), Finland

Panellists

- Vincenzo Rondinella, Head of Department, DG JRC G.III (Nuclear Decommissioning), Joint Research Centre, European Commission (EC)
- Klaus-Jürgen Röhlig, Professor, Clausthal University of Technology (TUC), Germany
- Fabrice Puyade, Director of the Human Resources Division, French National Radioactive Waste Management Agency (Andra), France
- Gerald Nieder-Westermann, Waste Technology Specialist, Waste Technology Section, Division of Nuclear Fuel Cycle and Waste Technology, International Atomic Energy Agency (IAEA)
- Kathryn Ann Higley, Interim Director CQLS - Center for Quantitative Life Sciences, Oregon State University

Session 4: **Building and maintaining trust**

4A. ***Best practices to build and maintain trust***

Chair

- Pascale Künzi, Chair of NEA Forum on Stakeholder Confidence (FSC); Regional Participation Specialist (Stakeholder Involvement Specialist), Swiss Federal Office of Energy (SFOE), Switzerland

Speakers

- Sigrid Eeckhout, Head of Communication and Participation Department, Belgian Agency for Radioactive Waste and Enriched Fissile Materials (ONDRAF/NIRAS), Belgium

- Nuria Prieto Serrano, Lawyer, Technical Division, Department of International Relations, Spanish Radioactive Waste Management Organization (ENRESA), Spain
- Anna Porelius, Head of Communications and Stakeholder Relations, Swedish Nuclear Fuel and Waste Management Company (SKB), Sweden
- Annabelle Quenet, Head of Public Involvement Department, French National Radioactive Waste Management Agency (Andra), France
- Zuzana Petrovicova, Head of Unit, DG ENER D.2 (Nuclear Energy, Nuclear Waste and Decommissioning), European Commission (EC)
- Ilona Sjöman, Chair of the Municipal Council of Eurajoki
- *Graduate Student Representative*: Jorina Suckow, Graduate Student, Member of Nationales Begleitgremium (National Civil Society Board), Germany

4B. ***Panel debate on communicating uncertainty from the scientist to the community***

Chair

- Karim Peltonen, Director, Department of Emergency Preparedness, Communications and International Cooperation, Radiation and Nuclear Safety Authority (STUK), Finland

Panellists

- Ramzi Jammal, Executive Vice-President, Canadian Nuclear Safety Commission (CNSC), Canada
- Claire Corkhill, Member of Committee on Radioactive Waste Management (CoRWM), Reader in Nuclear Material Corrosion, EPSRC Early Career Research Fellow, Department of Materials Science and Engineering, The University of Sheffield, United Kingdom
- Gaston Meskens, Centre for Ethics and Value Inquiry, University of Ghent, Belgium
- Philip Matthews, Executive Director, Nuclear Legacy Advisory Forum (Nuleaf), United Kingdom
- Penny Lucas, Mayor for the Township of Ignace, Canada
- *Graduate Student Representative*: Emma Perry, PhD student, Department of Earth Sciences, University of Cambridge

Session 5: **Outcome Session**

Rapporteur

- Seif Ben Hadj Hassine, Scientific and Policy Officer, DG RTD C.4 (Euratom Research), European Commission (EC)

Session Chairs

- *Younger Generation Session*: Rebecca Tadesse, Head of NEA Division of Radioactive Waste Management and Decommissioning
- *1A*: Jussi Heinonen, Director, Regulatory Oversight Strategic Development, Radiation and Nuclear Safety Authority (STUK), Finland
- *1B*: Patrick Landais, High Commissioner for Atomic Energy, French Alternative Energies and Atomic Energy Commission (CEA), France
- *2A*: Kristopher Kuhlman, Principal Technical Staff Hydrologist, Sandia National Laboratories, United States
- *2B*: Pierre-Marie Abadie, Chair of International Association for Environmentally Safe Disposal of Radioactive Materials (EDRAM); CEO, French National Radioactive Waste Management Agency (Andra), France
- *3A*: Piet Zuidema, Chief Scientific Officer, European Joint Programme on Radioactive Waste Management (EURAD)
- *3B*: Kai Hämäläinen, Section Head, Regulation of Nuclear Waste Facilities, Radiation and Nuclear Safety Authority (STUK), Finland
- *4A*: Pascale Künzi, Chair of NEA Forum on Stakeholder Confidence (FSC); Regional Participation Specialist (Stakeholder Involvement Specialist), Swiss Federal Office of Energy (SFOE), Switzerland
- *4B*: Karim Peltonen, Director, Department of Emergency Preparedness, Communications and International Cooperation, Radiation and Nuclear Safety Authority (STUK), Finland

Session 6: **Summary and Closing Session**

Closing addresses

- Hiroyuki Umeki, Chair of NEA Radioactive Waste Management Committee (RWMC); Executive Director, Nuclear Waste Management Organization of Japan (NUMO)
- Liisa Heikinheimo, Deputy Director General, Energy Department, Ministry of Economic Affairs and Employment, Finland

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Sixth International Conference on Geological Repositories (ICGR-6): Advancing Geological Repositories from Concept to Operation

There is a consensus in the international community that geological repositories provide the necessary long-term safety and security to isolate long-lived radioactive waste. However, despite the technical merit and safety of repositories, challenges remain in many countries. These challenges include building and maintaining public confidence, the availability of skilled staff and the transfer of knowledge, as well as the involvement of younger professionals.

As a synthesis of the Sixth International Conference on Geological Repositories (ICGR-6) hosted in Helsinki, Finland in April 2022, this report discusses the significant progress made in developing geological repositories over the past two decades and addresses the challenges that remain in many countries. It covers various aspects of the geological repository, including the younger generation's involvement, the status of national geological repository projects, research and development activities, building and maintaining human capacity, and ensuring stakeholder confidence. This publication provides valuable insights for decision-makers, regulators, implementers, scientists, young professionals and other stakeholders interested in the safe construction and operation of long-term geological repositories.

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