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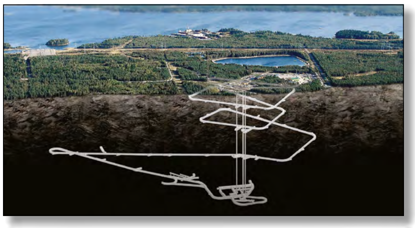
Deep Geological Repositories and Nuclear Liability



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Deep Geological Repositories and Nuclear Liability

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- to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes;
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Specific areas of competence of the NEA include the safety and regulation of nuclear activities, radioactive waste management and decommissioning, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

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The Working Party on Deep Geological Repositories and Nuclear Liability (WPDGR) of the OECD Nuclear Energy Agency (NEA) prepared this report under its Chair, Mr Benjamin Maquestieau (Belgian Agency for Radioactive Waste and Enriched Fissile Materials) and WPDGR Bureau members, Mr William Boyle (United States Department of Energy), Mr Michael Egan (Swedish Radiation Safety Authority), Mr Andrew Mayall (United Kingdom Environment Agency), Ms Nuria Prieto Serrano (Spanish Radioactive Waste Management Agency) and Mr Thierry Schneider (French Nuclear Protection Evaluation Centre). The report was approved for publication by the NEA Nuclear Law Committee by written procedure on 7 October 2022.

The conception, drafting and overall co-ordination of the report was led by Ms Ximena Vásquez-Maignan, Head of the NEA Office of Legal Counsel, along with NEA Legal Advisers Mr Pierre Bourdon, Mr Hiroyuki Hase and Mr Kaan Kuzeyli.

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List of speakers of the 1st Workshop on Deep Geological Repositories and Nuclear Liability

Name	Organisation*	Country
Mr Roland Dussart-Desart	FPS Economy, SMEs, Self-employed and Energy	Belgium
Mr Jean-Paul Minon	Agency for Radioactive Waste and Enriched Fissile Materials	Belgium
Mr Risto Paltemaa	Radiation and Nuclear Safety Authority	Finland
Mr Jean-Noël Dumont	National Radioactive Waste Management Agency	France
Mr Marc Léger	Alternative Energies and Atomic Energy Commission	France
Mr Thierry Schneider	Nuclear Protection Evaluation Centre	France
Ms Florence Touïtou-Durand	Alternative Energies and Atomic Energy Commission	France
Mr Norbert Pelzer	University of Göttingen	Germany
Mr Sebastiaan Reitsma	Senior Nuclear Insurance Expert	Switzerland
Mr Mark Tetley	Price Forbes & Partners Ltd.	United Kingdom
Mr Mark Lombard	Nuclear Regulatory Commission	United States
Mr Ben McRae	Department of Energy	United States
Ms Gloria Kwong	Nuclear Energy Agency	
Mr Edward Lazo	Nuclear Energy Agency	
Ms Julia Schwartz	Nuclear Energy Agency	
Ms Ximena Vásquez-Maignan	Nuclear Energy Agency	

* The organisations mentioned in the table are those to which the speakers belonged in 2016 when the 1st Workshop on Deep Geological Repositories and Nuclear Liability was held.

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List of abbreviations and acronyms

CSC	Convention on Supplementary Compensation for Nuclear Damage (1997)
CRPPH	Committee on Radiological Protection and Public Health (NEA)
DGR	Deep geological repository
DOE	Department of Energy (United States)
EPA	Environmental Protection Agency (United States)
EU	European Union
FEP	Features, Events and Processes
HLW	High-level radioactive waste
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
INLEX	International Expert Group on Nuclear Liability (IAEA)
NEA	Nuclear Energy Agency
NLC	Nuclear Law Committee (NEA)
NRC	Nuclear Regulatory Commission (United States)
OECD	Organisation for Economic Co-operation and Development
RWMC	Radioactive Waste Management Committee (NEA)
SF	Spent fuel
SKB	Nuclear Fuel and Waste Management Company (Sweden)
SSM	Radiation Safety Authority (Sweden)
WPDGR	Working Party on Deep Geological Repositories and Nuclear Liability (NEA)

Executive summary

The disposal of long-lived radioactive waste in a deep geological repository (DGR) is a scientifically and technically credible solution that meets the need for long-term safety without reliance on active monitoring and management.

At present, most countries with DGR programmes are at an early stage in their development. A few countries are contemplating either the start of operation or of the construction of their DGR within the next ten years.

In most countries, it is expected that the financial resources required for a DGR project originate from payments made by waste generators, pursuant to the "polluter-pays" principle. These resources are also meant to cover the costs of any financial security coverage that may be required by the nuclear liability regimes (also referred to as nuclear third party liability or civil liability for nuclear damage regimes) for as long as these apply to the disposal facility.

Comprehensive answers to the question of how nuclear liability should be applied to DGRs in the long term will ultimately be provided by future generations, taking into account the evolution of legal frameworks. Nevertheless, it is important, at present, to identify and address potential issues regarding nuclear liability against the background of currently applicable legal frameworks for project and financing considerations, as well as to set a clear framework for the applicable nuclear liability regime during the first phases of operation of the DGR.

This report generally recommends that any country developing, or intending to develop, a DGR adhere to one of the modernised nuclear liability regimes (the Paris Convention, the Revised Vienna Convention and/or the Convention on Supplementary Compensation [CSC]) and adopt consistent legislation if they have not already done so.

Deep geological repositories and the definition of "nuclear installation" under the nuclear liability regimes

The Nuclear Energy Agency (NEA), through its Working Party on Deep Geological Repositories and Nuclear Liability (WPDGR), has been analysing the issue of applicability of nuclear liability conventions to DGRs in their pre- and post-closure phases since its establishment in 2016. There is a consensus among legal and technical experts of NEA member countries represented at the WPDGR that the nuclear liability conventions will apply to DGRs in their operational phase, although additional legal certainty could be provided under the Vienna Convention, the Revised Vienna Convention and the CSC.

With the exception of the Paris Convention, which expressly includes the post-closure phase, it is unclear whether the nuclear liability conventions apply to a DGR in its post-closure phase.

Closure is not defined under the nuclear liability regimes, but the termination of the operating licence for a DGR is considered to be an appropriate reference point to define it, as this marks the time when the government recognises that requirements for closure are fulfilled, i.e. that no further work on the facility is required to ensure its long-term safety.

Legal and regulatory requirements on DGR operators to facilitate the reversibility of decisions or the retrievability and recoverability of the waste may affect the achievement of closure, including under the nuclear liability regimes.

The nuclear liability conventions, except for the Vienna Convention, provide for the possibility to either set a lower amount of nuclear liability for "low-risk" installations (by a unilateral national decision) or exclude an installation from their scope of application (by a unanimous decision of the parties to the concerned convention).

As such, it would be beneficial to have a decision of the International Atomic Energy Agency Board of Governors to provide additional legal certainty regarding the scope of the application of the Revised Vienna Convention to installations for the disposal of radioactive waste, including DGRs.

In addition, states should provide a clear definition of nuclear installation in their national legislation detailing whether and to which corresponding stages of their life cycle DGRs would be subject to the national nuclear liability regime, in accordance with the applicable convention, if any.

States considering to classify a DGR as a "low-risk" installation for the purpose of the nuclear liability regime or to exclude a DGR from the application of such regime should perform a careful assessment of the risks associated with such a facility at the corresponding stage of its life cycle. States would benefit from continued information exchange in international fora concerning the potential classification of DGRs as "low-risk" installations, notably with a view to support their respective risk assessments and to identify appropriate liability amounts.

The risk assessment made in view of excluding a DGR from the nuclear liability regime should also include an assessment of an alternative liability regime that would best address the risk of damage arising from a potential nuclear incident at the DGR.

Decisions to exclude a DGR from the nuclear liability regime should be considered for the post-closure phase. If states have made the decision to facilitate the reversibility of decisions and/or the retrievability or recoverability of the waste during a specified timespan, a DGR should not be excluded from the nuclear liability regime until such a timespan expires.

The operator of a deep geological repository

Under the nuclear liability regimes, the operator is the sole entity liable to compensate potential victims for nuclear damage. It is therefore of primary importance to clearly define who is the operator of a DGR throughout its life cycle, during which the nuclear liability regime applies.

The nuclear liability conventions will apply similarly to the operator of a DGR regardless of its legal structure; however, the corporate structure of a DGR operator may entail specificities regarding nuclear liability, such as the choice of the financial security.

The maintenance of institutional memory is of significant importance to allow future generations to make informed decisions in the event of a nuclear incident and to apply any civil liability regime, especially when the operator has changed during the life cycle of the DGR.

If the nuclear liability regimes are considered to continue to apply to a DGR after closure, an entity must be designated or recognised by the competent public authority as the operator of the DGR, who will bear the nuclear liability for as long as the nuclear liability regime continues to apply.

Some experts consider that this role should be transferred to the state at some point during the post-closure phase, similarly to the provisions of other international legal instruments in the field of nuclear safety for waste management. Such a transfer would require payment of an adequate fee to the state in line with the "polluter-pays" principle.

States should provide legal frameworks that clearly identify the DGR operator throughout the life cycle of the installation for the purpose of nuclear liability and that account for any changes in operator.

To the extent possible, states should consider including in their legal frameworks the terms and conditions of a possible transfer of the nuclear liability to the state at some stage in the DGR's post-closure phase, acknowledging that such a decision should be made by future generations and that stakeholders other than the state (including but not limited to the host community) may have a legitimate interest in such a decision.

Nuclear liability coverage for deep geological repositories

Under the nuclear liability conventions, operators are required to maintain financial security up to the liability amount provided in the national law of the state where the DGR is located (the "installation state") and no less than the amount provided in the applicable nuclear liability convention. If the installation state provides for unlimited liability under its nuclear liability legislation, the operator must cover its nuclear liability with the relevant financial security up to the limit required under the national law (provided that such a limit is not less than the amount of liability provided in the nuclear liability convention to which the installation state is a party to).

Private insurance is the primary source of financial security for nuclear operators, even though alternative financial security mechanisms may be available from the private and public sectors.

Some national insurance markets do not yet cover certain risks, i.e. some "nuclear damage" as defined under the modernised nuclear liability conventions, creating gaps in the insurance coverage of the operators. Some of these risks are common to most types of nuclear installations, including nuclear power plants, such as loss of life or personal injury after 10 years following a nuclear incident; some risks appear particularly relevant to DGRs, such as the gradual release of radionuclides over an extended period of time.

Under the Paris Convention, the Vienna Convention, the Revised Vienna Convention and the CSC, the installation state has the residual responsibility of paying nuclear damage compensation claims where the insurance or other financial security is not available or sufficient, up to an amount no less than the general liability amount set under the applicable convention.

Financial security mechanisms are already being provided or considered by governments to cover foreseen gaps in the insurance coverage, such as those mentioned above.

It is difficult to assess the costs of maintaining financial security over the DGR life cycle to which the nuclear liability regime will apply, due to significant uncertainties regarding future legal frameworks and the availability and pricing of certain types of financial security. Some experts nevertheless consider that the nuclear liability-related costs would likely only amount to a fraction of funds set aside for the DGR programmes.

States, DGR implementers and national nuclear insurance pools should give priority to identifying the potential gaps in the insurance coverage for the national DGR, with a view to organising appropriate alternative private or public financial security mechanisms. To this end, potential providers of financial security should be provided with the information necessary to assess the technical risks of the DGR to be covered and the applicable legal framework, so that they can provide the appropriate financial security.

Nuclear incidents at deep geological repositories in the post-closure phase

A "safety case" is elaborated as part of any DGR programme as a formal compilation of evidence, analyses and arguments that quantify and substantiate a claim that the repository will be safe. Safety cases notably contain scenarios of the potential evolution of the DGR system and its environment, including conditions that can reasonably be expected to occur, as well as less likely conditions that might adversely affect the performance of the DGR.

Among these less likely conditions, there are two primary categories of scenarios by which radionuclides might cause human exposure after the closure of a DGR:

- the gradual release of radionuclides over a long period of time in the biosphere associated with larger than anticipated releases from the engineered disposal system, leading to the gradual build-up of significant radioactive contamination in groundwater and/or soils and thereby causing damage to the environment and/or human health; and
- the inadvertent human intrusion into a DGR, which could cause harm to any person exposed to the waste.

The low probability of occurrence of the aforementioned scenarios may further be reduced through the siting of the DGR and indirect oversight measures, but cannot be completely eliminated. In particular, it is difficult to meaningfully quantify the likelihood of human intrusion far into the future.

The capability to prevent, or respond to, a nuclear incident at a DGR in the post-closure phase would largely depend on the degree of oversight, which is related to the preservation of institutional memory regarding the existence and nature of the facility.

The definition of "nuclear incident" under the nuclear liability conventions does not take into account the level or the foreseeability of the incident, and automatically applies as long as there is "nuclear damage" as defined under the conventions and a causal link is established. It includes a series of occurrences having the same origin, such as a gradual release or nuclear damage caused by emissions that remain within the limits prescribed by the applicable national law.

The definitions of nuclear damage have been expanded under the modernised nuclear liability conventions to cover new types of damage, all of which (with the exception of preventive measures) must arise out of the radioactivity-related properties of nuclear substances in a nuclear installation or in the course of transport.

The two main scenarios envisaged during the post-closure phase of DGRs, combined with the very long time frame over which such scenarios may take place, may challenge the application of the nuclear liability regimes (or that of any other liability regime), as it may be difficult to prove the causal link or determine with certainty whether the prescription or discovery period have expired.

Introduction

The development and use of nuclear technology, such as nuclear power plants, has produced a substantial amount of radioactive waste that needs to be isolated from humans and the environment. Some of this waste can produce hazardous levels of ionising radiation that may persist for a long time. Disposal in a deep geological repository (DGR) is a scientifically and technically credible solution for such waste that meets the need for long-term safety without relying on active monitoring and management. After closure, a well-designed repository offers a passive system for maintaining isolation of the waste over necessary timescales based on the combined performance of robust engineered and natural barriers.

Nevertheless, it is important to assess the potential risks that may be associated with such a nuclear installation and to ensure that an appropriate regime is in place to adequately compensate third parties in case they suffer nuclear damage caused by a DGR.

Given the unusually long life cycles of such installations, this report discusses issues that concern future generations against the background of the legal framework that is currently applicable to the operation of nuclear installations, as well as existing technical knowledge. However, this report takes into consideration the fact that both the legal frameworks and the technical knowledge will evolve in time and that the approaches discussed today may need to be adapted in the long term.

The question of the civil liability regime applicable to DGRs has been raised by stakeholders involved in the development of DGR projects who wish to understand the legal risks associated with the operation and closure of these facilities and how to mitigate them through insurance or other financial security. However, the answer will also be of interest to all stakeholders, in particular the population living around the site, the suppliers and insurers. It is important to stress that this report focuses exclusively on the application of the legal regimes for third party (or civil) liability for nuclear damage, as established under the existing international nuclear liability conventions and the national legislations of countries that have ratified them. This report does not take into account other liability regimes that may be applicable in case of radiological damage caused by an incident at a DGR (such as general tort law, product liability regime), nor any other type of liability or responsibilities that organisations involved in the construction and operation of DGRs may bear (such as, but not limited to, contractual liability or the financial responsibilities dealing with the management of the radioactive waste).

In order to assess the applicability of the nuclear liability regime(s) to DGRs, three Standing Technical Committees of the Nuclear Energy Agency (NEA), namely the Committee on Radiological Protection and Public Health (CRPPH), the Nuclear Law Committee (NLC) and the Radioactive Waste Management Committee (RWMC), agreed to work together to enhance common understanding among legal and technical experts of nuclear liability regimes and the long-term hazards posed by radioactive waste disposal. Specifically, the identified aims were: to assess the technical and radiological aspects of DGRs that must be taken into account when addressing nuclear liability issues; to examine and assess how nuclear liability regime(s) should be applied to DGRs throughout the pre- and post-closure phases, as well as related financial security and insurance, taking into account current management practices for radioactive waste; and to assess subsequently whether the outcomes agreed for DGRs can also be applied to near-surface disposal facilities, noting that this specific question is left for future discussions.

The 1st Workshop on Deep Geological Repositories and Nuclear Liability, which was held on 14-15 November 2016 in Paris, was the first initiative of this joint undertaking of the three NEA committees. This workshop was organised for the legal and technical experts to understand each other's approaches and concerns with regard to DGRs and to encourage discussion on the nuclear liability regime(s) applicable to these installations. Fifty-seven people participated in the workshop from the CRPPH, NLC and RWMC, as well as regulators and representatives from international organisations and the insurance industry.

The Working Party on Deep Geological Repositories and Nuclear Liability (WPDGR)[1] was established following the 2016 workshop and held several meetings to investigate further the outstanding issues. The WPDGR also performed a survey circulated to NEA member countries to collect additional information on national programmes for the development of DGRs.

This report is the result of the aforementioned workshop, meetings and survey organised by the WPDGR over the 2016-2021 period and of the collaboration of the CRPPH, NLC and RWMC to present the most up-to-date information on nuclear liability as applicable to DGRs.

1 The working party was renamed "Working Party on Nuclear Liability and Radioactive Waste Disposal Facilities" (WPLDF). For more information, visit www.oecd-nea.org/wpdgr.

Chapter 1. Overview of deep geological repository projects and nuclear liability

1.1. Overview of repository projects worldwide

It is internationally accepted that the best way to safely manage long-lived intermediate and high-level radioactive waste in the long term is through disposal in a deep geological repository (DGR). DGR concepts involve making use of a combination of engineered and natural "barriers" to isolate and confine the radioactive waste in stable geological formations, allowing radioactive the decay of the radionuclides within the waste to occur. Most countries with programmes to develop DGRs are planning their disposal facilities at depths of between 250 and 1 000 m so as to provide a substantial natural barrier. The depth of the host rock, and its properties, such as low permeability to water and gas and well-characterised geological stability, should provide conditions favourable to confinement of the radionuclides within the geosphere for a long period of time (typically tens of thousands of years). Engineered barriers, such as the disposal container and buffer or backfill (which serve to isolate the waste from its surroundings as well as to inhibit the transport of any radionuclides that might be released), are also placed around the waste to prevent or delay radionuclides from reaching the surface environment (biosphere). The combination of multiple barriers enhances the safety of disposal and ensures that such safety does not solely rely on any one component of the disposal system. "Safety assessment" modelling of the DGR and its environment over time provides an indication of the protection that it offers, for comparison with today's established criteria for long-term safety.

Plans for DGRs are at various stages of development in over countries all over the world. While the design of the repository system and the selection of a suitable host geology are important, other factors, such as the willingness of a host community and a legitimate decision-making process, are also crucial in developing a DGR. While this report focuses on HLW and SF, its findings also apply to DGRs that will contain other types of waste, as long as those are considered nuclear substances under the nuclear liability regimes, as explained in Section 2.2.

1.2. Overview of radiological aspects of deep geological repositories

HLW and SF are highly radioactive and require a period of storage to enable radiation levels and decay heating to subside before disposal can be undertaken. During storage, transport and the subsequent emplacement in the DGR, it is essential that the waste is adequately cooled, shielded and contained. There are well-established practices within the nuclear industry, built on decades of experience, for the safe handling of such materials. These involve procedures, controls and suitable equipment, underpinned by appropriate quality assurance, monitoring and training.

While the heat produced by HLW and SF will diminish substantially over a period of a thousand years or so, the radiological hazards they present will be appreciable for much longer than any procedures, controls and equipment can be relied upon: well in excess of 10 000 years. Leaving the waste to be actively managed to ensure its isolation from humans and the environment over such periods of time is considered to place an unacceptable burden on future generations. A DGR is intended to provide isolation and confinement of the radioactivity by passive means (see Chapter 2), without relying on the actions of future generations.

After the closure of the DGR, there are two primary types of scenario by which radionuclides might cause human exposure:

- a degradation of the barrier system, leading to the eventual release of radionuclides into groundwater, or as gas, and their gradual migration to the biosphere; and

- an inadvertent intrusion by people into the facility following a loss of oversight and control over the DGR site, resulting in direct exposure of the intruders or the release of some of the waste directly to the surface.

The first type of scenario is the inevitable consequence of events and processes associated with the natural evolution of the engineered and other barriers. The second encompasses situations in which the DGR's barriers are by-passed by an event in the far future that, however unlikely, might be beyond the control of those disposing of the waste. In addition, whereas the repository barrier system will typically incorporate a degree of robustness against uncertainties relating to the scale and impact of natural processes and events, there may remain the potential for very unlikely or extreme circumstances to either bypass one or more of these barriers or enhance their degradation.

The absolute confinement of very long-lived radionuclides cannot be indefinitely assured, as waste containers will ultimately begin to fail due to natural events and processes, and radionuclides can be released into groundwater or as gas. Nevertheless, the DGR barrier system, as a whole, confines radionuclides by limiting the rate at which they can migrate to the biosphere. This is achieved by the physical properties (e.g. low permeability materials) and chemical properties (e.g. providing conditions that limit dissolution and/or migration of radionuclides) of the waste form and barrier system. Collectively, by protecting the waste from its surroundings and by limiting migration, the system of barriers can provide sufficient time for radioactive decay to mitigate the concentrations of radionuclides in releases to the biosphere in the far future to levels that satisfy today's requirements for radiological protection.

While safety assessments can indicate it will take many tens of thousands of years for radionuclides to be released from the waste and reach the surface, and that any concentrations reaching the surface would be small due to retardation, radioactive decay and dilution, it is not possible to know with precision what the surface conditions will be, what life forms would be exposed and where any such release would occur. From the perspective of radiological protection, it has been judged ethically necessary to assume that life exposed in the far future would be as life today,[2] and as such, future life should be protected to the same standards as used today.[3] Safety assessment studies will typically account explicitly for a range of uncertainties associated with the disposal system and the magnitude of projected releases to the biosphere in the far future. Other uncertainties are accommodated by adopting reference assumptions intended to facilitate interpretation of the radiological significance of such releases. While estimates of harm are necessarily based on such assumptions, the intention is to provide a robust basis for decision making consistent with affording standards of protection that are at least as robust as those currently applicable.

Inadvertent human intrusion is a different and very specific situation that could lead to human exposure or release of radionuclides to the environment. Although a DGR is isolated from the surface and is considered preferable to the indefinite active maintenance and supervision of waste stores, it is not possible to guarantee over very long periods of time that any institution can provide oversight and control of the DGR site. The possibility that engineered and natural barriers may be inadvertently by-passed (e.g. by drilling an exploration borehole through the repository) cannot therefore be totally discounted. If this were to occur, relatively high radionuclide concentrations could be encountered. This risk is a direct consequence of the principle of concentrating and containing the hazard. Apart from the depth of disposal, the likelihood of inadvertent human intrusion can be reduced by siting the DGR away from any exploitable natural resources.

2. NEA (1995), *Environmental and Ethical Aspects of Long-lived Radioactive Waste Disposal – A Collective Opinion of the Radioactive Waste Management Committee of the NEA*, OECD Publishing, Paris.
3. ICRP (1998), *Protection Recommendations as Applied to the Disposal of Long-lived Solid Radioactive Waste*, ICRP Publication 81, Ann. ICRP 28(4) and ICRP (2013), *Radiological protection in Geological Disposal of Long-lived Solid Radioactive Waste*, ICRP Publication 122. Ann. ICRP 42(3).

Because of the uncertainties associated with the long timescales of DGRs, it is necessary to build a multi-faceted "safety case". This brings together scientific and technical knowledge concerning the DGR and its environment with the aim of demonstrating confidence in its capability to provide sufficient isolation and confinement of the radiological hazard posed by the waste in the long term.

1.3. Overview of the international nuclear liability regimes

Radiological incidents have the potential to cause detrimental impacts on health, property, the environment and economies, as well as potential transboundary damage. Governments have established a specific liability regime to, on the one hand, ensure adequate compensation to persons who suffer damage caused by nuclear incidents and, on the other hand, not hinder the development of the production and uses of nuclear energy by protecting investors and suppliers of a nuclear installation from ruinous liability claims, which would dissuade them from developing nuclear energy-related activities.

The scope of this exceptional liability regime is limited to risks of an exceptional character for which general tort law rules and practice are not suitable. General tort law rules may not help the victims of nuclear damage in obtaining adequate compensation in a timely manner as it would put the burden of proof on them which, in case of a complex technology such as nuclear energy, would be a costly and time-consuming endeavour. Whenever risks, even those associated with nuclear activities, can properly be dealt with through existing legal processes and may be covered by general insurance in the ordinary course of business, they are left outside the scope of the conventions.

1.3.1. The international nuclear liability regimes

There are three nuclear liability regimes:

- **<u>The Paris (or Paris/Brussels) regime</u>:** the **1960 Paris Convention on Third Party Liability in the Field of Nuclear Energy** (the "Paris Convention"), the first international nuclear liability instrument, was adopted under the auspices of the Organisation for Economic Co-operation and Development (OECD). It entered into force in 1968 and has 16 contracting parties,[4] the majority of which are also members of the European Union (EU).[5] The 1963 Brussels Convention Supplementary to the Paris Convention (the "Brussels Supplementary Convention") was adopted to provide compensation to victims beyond that provided under the Paris Convention through the establishment of a three-tier system. The first tier is provided by the operator for an amount established under the national law, which cannot be lower than the minimum amount provided in the Paris Convention; the second tier is provided by the state in which the nuclear installation of the liable operator is situated (the "installation state"), unless the national law transfers the obligation to the operator; and the third tier is contributed jointly by all the Contracting Parties to the Brussels Supplementary Convention. Entering into force in 1974, it has been ratified by all the Contracting Parties to the Paris Convention (CPPC), with the exception of Greece, Portugal and Türkiye.[6] On 12 February 2004, the Protocol to Amend the Paris Convention and the Protocol to Amend the Brussels Supplementary Convention (the "2004 Protocol(s)")[7] were

4. For more information on the Paris Convention, see www.oecd-nea.org/law/paris-convention.html. See also the Exposé des Motifs of the previously applicable Paris Convention, the Exposé des Motifs of the Paris Convention and the Explanatory Report of the Paris Convention.
5. Among the CPPCs, only Norway, Switzerland, Türkiye and the United Kingdom are not member states of the European Union.
6. For more information on the Brussels Supplementary Convention, see www.oecd-nea.org/law/brussels-supplementary-convention.html.
7. The Paris Convention as amended by the 2004 Protocol is referred to herein as the "Paris Convention", and the Brussels Supplementary Convention as amended by the 2004 Protocol is referred to herein as the

adopted to increase the operator's liability amount, to compensate a broader range of damage, and to benefit more victims by widening the geographical scope of the regimes. These Protocols entered into force on 1 January 2022.

- **The Vienna regime:** the **1963 Vienna Convention on Civil Liability for Nuclear Damage** (the "Vienna Convention"), was adopted under the auspices of the International Atomic Energy Agency (IAEA).[8] It entered into force in 1977 and has 44 contracting parties from all geographical regions, except Oceania. The 1997 Protocol to Amend the Vienna Convention (the "1997 Protocol") was adopted for the same reasons as for the 2004 Protocols mentioned above.[9] Entering into force in 2003, it has 15 contracting parties. The Vienna Convention and the 1997 Protocol exist concurrently, with states having the possibility to adhere to either or both.
- **The CSC:** the **1997 Convention on Supplementary Compensation for Nuclear Damage** (CSC) was adopted to establish a mechanism for mobilising supplementary funds to compensate nuclear damage in addition to the funds to be provided by the liable operator. It provides in its annex the nuclear liability principles reflected in the three conventions mentioned above (i.e. the Paris Convention and the Vienna Conventions), as well as a two-tier funding mechanism modelled in part on the Brussels Supplementary Convention. Entering into force in April 2015, it has 11 contracting parties. It is open to ratification by states that are parties to the Paris Convention or the Vienna Conventions, as well as states whose national legislation is consistent with the provisions of the annex to the CSC (the "Annex States").

In the aftermath of the Chernobyl accident, it was considered necessary to clarify which of the regimes (i.e. the Paris or Vienna regime) would apply in the case where a nuclear incident occurring in a state that is a party to one caused damage in a state that is a party to the other. The **1988 Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention** (the "Joint Protocol"), which entered into force in 1992 and has 33 contracting parties, creates a bridge between the two regimes to clarify that only one convention will apply: the Convention to which the installation state is a party. For example, when a nuclear incident occurs for which an operator in a state that is a party to both the Paris Convention and the Joint Protocol is liable and damage is suffered in a state that is a party to both the Vienna Convention and the Joint Protocol, the Paris Convention will apply. In principle, the victims situated in the Vienna Convention/Joint Protocol state will be able to claim compensation for their damage against the liable operator in essentially the same manner and to the same extent as if they were victims in a Paris Convention state.

*1.3.2. **Nuclear liability principles***

The Paris Convention, the Vienna Conventions and the CSC provide for similar nuclear liability principles, which can be summarised as follows:

- Strict liability of the operator: the operator (i.e. the licensee or the entity designated or recognised by the competent authority as the operator of a nuclear installation) is strictly liable for all nuclear damage resulting from an incident occurring at its installation, which means that the victims do not need to prove fault or negligence when seeking compensation, only the causal link between the nuclear incident and the nuclear damage suffered. However, the operator is not liable for nuclear damage caused by a nuclear incident when (i) such damage is directly due to an act of armed conflict,

"Brussels Supplementary Convention". Reference to the previously applicable Paris Convention is made in this report mainly with the purpose of illustrating the differences with the current Paris Convention.

8. For more information on the nuclear liability conventions under the IAEA auspices, see https://ola.iaea.org/ola/treaties/multi.html.
9. The Vienna Convention as amended by the 1997 Protocol is referred to herein as the "Revised Vienna Convention". The Vienna Convention and the Revised Vienna Convention are jointly referred to herein as the "Vienna Conventions".

hostilities, civil war or insurrection (no exoneration in case of terrorism) or (ii) if provided under the national law, such damage results wholly or partly either from the gross negligence of the person suffering the damage or from an act or omission of such person done with intent to cause damage. Under the previously applicable Paris Convention, the Vienna Convention and the CSC, the operator is not liable if the nuclear incident is due to a grave natural disaster of an exceptional character, unless the national legislation states otherwise. Such exoneration (in case of a grave natural disaster of an exceptional character) has been deleted by the 2004 Protocol and the 1997 Protocol, as the risk is now covered by the insurance industry.

- Exclusive liability of the operator: the operator is exclusively liable for the nuclear damage (i.e. loss or damage arising out of or resulting from ionising radiation) suffered by third parties and caused by a nuclear incident occurring at its nuclear installation or during the course of transport of nuclear materials to or from its installation; no other person may be held liable for such nuclear damage. It is said that the nuclear liability is "channelled" to the operator. In addition, this principle requires that the operator shall not be held liable under any other law than the applicable nuclear liability law.
- Liability amount: the previously applicable Paris Convention, current Paris Convention, Vienna Conventions and the CSC provide for minimum liability amounts that their contracting parties cannot disregard when providing for the operator's nuclear liability in their national legislation. All nuclear liability conventions, with the exception of the Vienna Convention, provide for different liability amounts for "nuclear installations" and for "low-risk nuclear installations". The term "nuclear installation" is defined in the conventions, which is not the case for "low-risk nuclear installations"; each state will have to specify the criteria according to which a nuclear installation may be considered as "low-risk" "having regard to the nature of the nuclear installation involved and to the likely consequences of a nuclear incident originating therefrom" [Paris Convention, Article 7(b)(i)]. Unlimited liability has been adopted by only a few countries, such as Germany, Japan and Switzerland.[10]

Table 1. **Minimum amounts provided under the nuclear liability conventions for the operator's nuclear liability in case of a nuclear incident occurring at a nuclear installation**

	Minimum nuclear liability amounts for	
Nuclear liability convention	Nuclear installation	Low-risk nuclear installation
Previously applicable Paris Convention	SDR* 150 million	SDR 5 million
Paris Convention	EUR 700 million	EUR 70 million**
Vienna Convention	USD 5 million (based on USD gold value of USD 35/oz. at 29 April 1963)	
Revised Vienna Convention	SDR 300 million	SDR 5 million**
CSC	SDR 300 million	SDR 5 million**

Note: * SDR means the "Special Drawing Right", an international reserve asset created by the International Monetary Fund (IMF) in 1969 to supplement its member countries' official reserves. The exchange rate of this currency is available at www.imf.org/external/np/fin/data/rms_sdrv.aspx.

** The installation state shall ensure that public funds shall be made available up to the minimum amount provided for nuclear installations.

Source: Overview of the international nuclear liability regimes, presented by the NEA Secretariat at the 1st Workshop on Deep Geological Repositories and Nuclear Liability, Paris, November 2016.

10. A Table on Operator Liability Amounts and Financial Security Limits is available at www.oecd-nea.org/liability-amounts.

- Compulsory financial security: to ensure availability of funds, the operator is required to maintain financial security to fully cover its liability or, in case of unlimited liability, up to an amount specified by law, which cannot be less than the minimum liability amount required under the nuclear liability convention adopted by the installation state. The operator is not required to cover its liability only with insurance, but may opt for other forms of financial security, such as mutual insurance coverage or state financial securities, as long as such type and terms are acceptable to the competent public authority.
- Limitation in time: as for any claim under civil law, nuclear liability claims must be filed within a limited time period. The prescription period provided under the previously applicable Paris Convention, the Vienna Convention and the CSC is of 10 years from the date of the nuclear incident; however, the Paris Convention and the Revised Vienna Convention have extended such period to 30 years for loss of life and personal injury. In any event, the victim must bring an action to claim compensation within two or three years from the date on which the person suffering nuclear damage had knowledge or should have had knowledge of the damage and of the operator liable for the damage, provided that it does not go beyond the applicable prescription period (see Table 3, Section 5.2).
- Unity of jurisdiction and non-discrimination: the previously applicable Paris Convention, current Paris Convention, Vienna Conventions and the CSC also incorporate additional principles, which are designed to address the complexities posed by potential transboundary damage and cross-border compensation claims. They provide that jurisdiction over nuclear damage claims lies only with the courts of the installation state. The judgements rendered by the competent court are enforceable in any state that is a contracting party to the same convention as the installation state. The courts having jurisdiction will apply the relevant convention and their own national law over claims arising out of a nuclear incident, and that law shall apply to all substantive and procedural matters and to all victims, without any discrimination based upon nationality, domicile or residence. These principles only apply between states that have treaty relations, i.e. have adhered to the same international convention(s) or have adhered to the Joint Protocol.

1.3.3. When do these regimes apply?

Pursuant to the nuclear liability conventions, a nuclear operator will be liable, up to a certain amount and during a certain time period, to compensate victims having suffered nuclear damage caused by a nuclear incident which occurred at its nuclear installation or during transport of nuclear substances.

1.4. Main challenges

It is generally agreed that nuclear liability regimes would apply to DGRs during their operational phase, as for any other nuclear installation; however, the applicability of such regimes during the post-closure phase requires further consideration. In this regard, several factors should be taken into account, including the very long nature of the post-closure phase, the profile of the radiological risk over time (noting that nuclear liability regimes are not intended to cover risks that can be appropriately dealt with under common tort law), the presence or absence of an identifiable operator bearing nuclear liability over time, as well as the level and duration of oversight and control over the DGR. To address these questions, several key notions will be further investigated in this report, including those of "nuclear installation" (Chapter 2), "nuclear operator" (Chapter 3), "liability amount" (Chapter 4) and "nuclear incident" (Chapter 5).

Another important issue for DGR operators concerns the funding for the nuclear liability coverage throughout the lifetime of a DGR. As explained in Section 1.3.2, the operator of a DGR will be required to maintain financial security coverage for as long as the nuclear liability regimes are applicable to it. Regardless of its nature, the securing of any financial security to meet this requirement over extended periods will require funding and therefore the operator of the DGR will be required to maintain the necessary resources to this effect. In most countries that are considering a DGR, it is expected that DGR operators' resources directly originate from funds set aside by the radioactive waste and SF producers, pursuant to the "polluter-pays" principle. It is therefore important that DGR operators are able to calculate how much should be paid by waste generators to fund the maintenance of a financial security for the whole life cycle of a DGR to which the nuclear liability regimes will apply. As detailed in Chapter 4 of the report, the situation appears more complicated in countries that opted for the unlimited liability (in amount) of the operator in case of a nuclear incident.

Chapter 2. **Deep geological repositories and the definition of "nuclear installation" under the nuclear liability regimes**

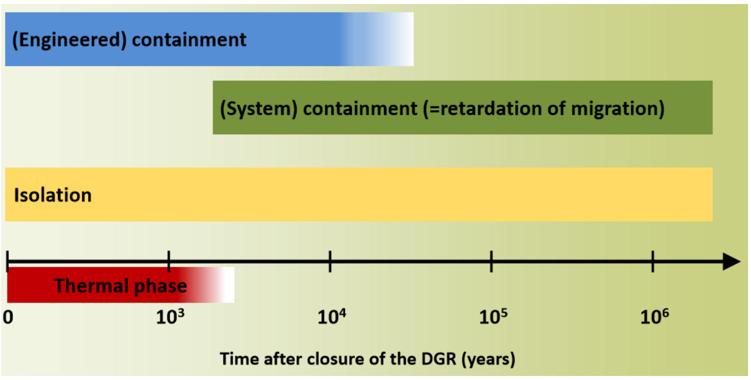
2.1. **Description of deep geological repository concept and life cycle**

The protection of human health and the environment, now and in the future, is achieved by DGRs via the concepts of "isolation" and "confinement".

- Isolation is achieved by the physical separation of the waste from people and the surface environment. It contributes to safety by placing the waste in a stable environment which is highly unlikely to be affected by natural disruptive events or human activities.
- Confinement is achieved by the containment of radionuclides within an engineered system for long periods of time, and retardation of any release of radionuclides from that system. Retardation slows both the rate of release and the transport of radionuclides towards the surface, and in doing so ensures that any releases to the surface environment occur in very small quantities and only after a sufficiently long period of time has passed for radioactive decay to reduce the hazard to levels that are not unacceptable.

Whereas the use of "passive" safety functions (design features that do not require human intervention or a source of power to operate effectively) is a recognised element in nuclear facility design, in the case of DGRs every barrier function on which post-closure protection of human health and the environment depends must be fully independent of any form of intervention, whether in terms of oversight, power supply, control or maintenance. Dependence on passive safety functions in every aspect of disposal system design is necessary because of the timescales over which confinement has to be achieved (shown in Figure 1). Here, "engineered" containment is ultimately limited by the physical resilience of containers (e.g. to corrosion, as well as potential mechanical failure), which varies according to different disposal concepts and different geological environments. Beyond this, containment is not absolute, but the physical and chemical properties of the system as a whole (both natural and other engineered barriers) limit the rate of release and transport of contaminants by retardation.

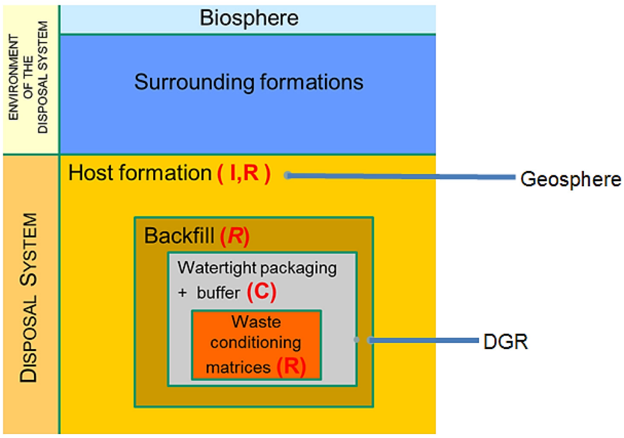
Figure 1. **Timescales over which containment and isolation of waste in a DGR apply**



Source: Minon, J. P (2016) "Description of the deep geological repository concept and life cycle", presented at the 1st Workshop on Deep Geological Repositories and Nuclear Liability, Paris, November 2016.

A schematic illustration of the specific barriers within a disposal system that provide these safety functions is shown in Figure 2. The waste and the radionuclides that it contains will typically be conditioned within a matrix, such as cement or glass (or, in the case of SF, the fuel itself), which provides a retardation function, limiting the initial rate at which radionuclides may be released. The waste matrix is usually enclosed within a physical container, which is typically protected by some form of buffer material. Together these provide containment (e.g. by preventing water from contacting the waste for a period of time). These waste packages will often themselves be surrounded by backfill that stabilises the DGR and fills voids, and also contributes to retarding the migration of radionuclides. Precisely how these functions are distributed between different barrier components depends on the nature of the waste and how the disposal concept is adapted to the geological environment in which it is situated. The final barrier is the host rock, which provides a stable environment (and thereby the primary isolation function), protecting the engineered system from disruption as well as being a barrier to radionuclide migration.

Figure 2. **Containment and isolation functions in a DGR**



Note: I = isolation, R = retardation, C = containment

Source: Minon, J. P (2016) "Description of the deep geological repository concept and life cycle", presented at the 1st Workshop on Deep Geological Repositories and Nuclear Liability, Paris, November 2016.

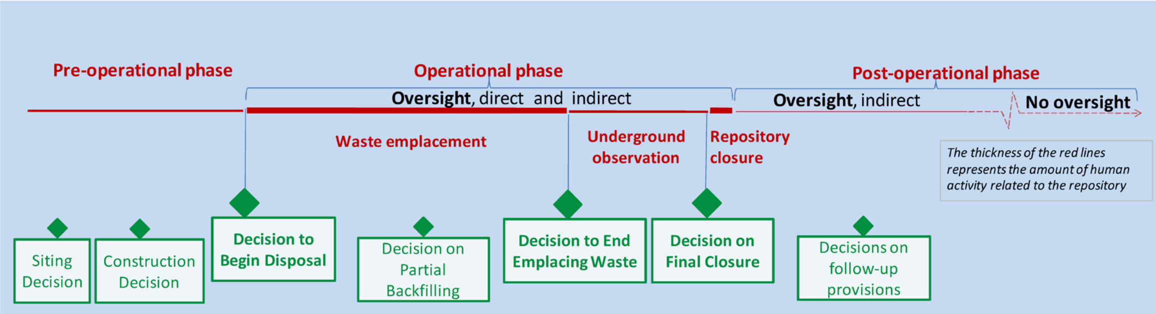
Although there are uncertainties due to the long timescales relevant to a DGR, the physical and chemical processes that control the evolution of the disposal system and the release and subsequent migration of radionuclides from the engineered and geological containment can be modelled in a safety assessment. In this way, the future safety of the DGR system can be assessed against relevant criteria and the safety assessment can be used to provide confidence in the capability of the DGR to provide an appropriate long-term waste management solution. The role of the safety assessment as an essential tool in the design and development of a DGR is discussed further in Chapter 5.

Many countries are developing DGRs using a stepwise approach, which allows decisions to be revisited and their premises verified on a regular basis. This means that, should significant problems be encountered, changes can be made and alternative decisions taken, if necessary reverting to previous steps in the process. This verification process provides confidence that the DGR will perform as planned. After a suitable host geology is identified, the disposal concept needs to be developed into an optimised engineering design and then constructed. Waste emplacement and the subsequent closure of the DGR needs to be carefully quality controlled to provide assurance that conditions at closure are consistent with those on which the safety case for the DGR is predicated. Monitoring activities will be undertaken prior to the installation of the final closure engineering and some form of continued environmental monitoring may even be required for a period of time afterwards as part of overall confidence-building measures.

DGRs therefore have a characteristic life cycle with a number of phases:

- Pre-operational phase (before waste emplacement): the DGR is designed, sited and constructed over a period of a few decades, typically in the final stage of the relevant licence, but contains no waste or nuclear materials. If waste is temporarily stored in ancillary facilities on the site where the DGR is situated, such facilities will be considered as nuclear installations under the nuclear liability regimes (see Section 2.2), but not the DGR itself.
- Operational phase (waste emplacement) of the DGR: the DGR is now a nuclear installation under the nuclear liability regimes. This phase will last several decades, potentially including further construction activities in parallel with emplacement operations, and encompasses the final closure of the DGR;
- Post-operational or post-closure phase: even when no longer operational, the DGR is expected to remain a nuclear installation at least under one of the nuclear liability regimes (see Section 2.3.2). At some stage after closure, however, depending on national legal and regulatory arrangements (e.g. with respect to responsibility for any continued monitoring), the facility may be released from direct regulatory oversight. Subsequent to this, it can be anticipated that there will be:
  - a period of indirect oversight, including the maintenance of records of the facility and verification of restrictions on land use, at least lasting a few centuries, followed by
  - a subsequent period when memory of the disposal facility is assumed to be lost, or insufficient to provide for any form of oversight.

Figure 3. **Life cycle of a DGR**



Source: International Commission on Radiological Protection (ICRP [2013], *Radiological protection in Geological Disposal of Long-lived Solid Radioactive Waste*, ICRP Publication 122. Ann. ICRP 42(3)).

In the pre-operational phase, the site is selected and characterised and the design developed. There is supporting research to determine the characteristics and properties of the disposal system that are important for operational and long-term safety. At this point, one or more safety assessments will be undertaken to understand the safety performance of the system and the associated uncertainties. Based on the information gathered, a submission can be made to the regulatory body for approval to begin construction.

During the construction and post-construction stages of the pre-operational phase and during the operational phase, the DGR will be under regulatory oversight and control in the same manner as any other nuclear installation. In the pre-operational phase, the potential for harm will be limited to incidents arising from non-nuclear mining hazards. During the operational phase, there are potential radiological accident risks and the DGR operator will be subject to direct oversight in relation to nuclear safety. The nature of a DGR means that the consequences of any unplanned incident are most likely to be mainly confined to the facility itself. A radiological release into the environment cannot, however, be excluded and the impacts of any potential accident (e.g. an on-site fire) must be assessed in an operational safety case. Construction and operation of a DGR are subject to the application of safety standards in the same way as would be applied to any other nuclear facility. International safety standards, requirements and guidance have also been developed specifically for DGRs by organisations including the IAEA, NEA, European Commission and others.

After operations cease and the DGR is closed, there will be a transition into a period of complete dependence on the passive safety functions that are built into its design and verified during its construction, operation and final closure. Initially, indirect oversight of the DGR will remain in place (sometimes referred to as the "institutional control period"). This can include monitoring of the environment, as part of overall confidence-building measures, and controls on the use of the land above the DGR. Indirect oversight provides two main benefits:

- a period during which certain aspects of the performance of the DGR can be confirmed, contributing to confidence that the assessed performance will be achieved in the future; and
- additional assurance that unacceptable exposures will be prevented while the waste is at its most hazardous.

In this post-operational phase, responsibility for the DGR is likely to transfer from the DGR operator to another institution more suited to long-term stewardship. The reference assumption is one of permanent disposal, and approval of the long-term safety case for disposal of the waste following installation of the final closure engineering is a prerequisite for such a transfer of responsibility.

Institutional controls and memory of the DGR cannot be relied upon to continue indefinitely and it is generally assumed that, after a certain period, these will be substantially weakened or lost altogether. Once such knowledge has been lost, inadvertent human intrusion is possible. Furthermore, it is conceivable that no knowledge of the repository will remain by the time that the engineered barriers have degraded (and confinement of the waste is lost) to the extent that radionuclide releases to the surface environment may take place. However, the preceding period of indirect oversight will have both provided time for substantial reduction in hazard, due to radioactive decay, and indirect confirmation that the engineered and natural barriers are functioning as intended.

In addition, several national DGR programmes provide for additional principles of reversibility and retrievability (also referred to as recoverability), which are intended to provide additional confidence to both regulatory authorities and the public regarding the development of the DGR. The notion of reversibility describes the possibility in principle to reverse or reconsider decisions taken during the progressive implementation of the disposal system. The notion of retrievability (or recoverability) describes the possibility that the emplaced waste may be partly or wholly retrieved from the DGR – including, in some countries, during a defined period in the post-closure phase.[11] Regardless of whether retrievability is built into the DGR programme as a design objective, a governing principle is typically that any measures taken to enhance the potential for retrievability of the waste should not be to the detriment of post-closure safety.

2.2. Definition of "nuclear installation" under the international nuclear liability conventions

One of the first questions that must be addressed regarding the applicability of the international nuclear liability conventions to DGRs is that of the definition of "nuclear installation" under these regimes and whether such definition includes DGRs at their various life cycle stages. In this regard, it should be noted that the international nuclear liability conventions have adopted slightly different definitions of "nuclear installations".

11. For more information on the concepts of reversibility and retrievability, see NEA (2011), *Reversibility and Retrievability (R&R) for the Deep Disposal of High-level Radioactive Waste and Spent Fuel: Final Report of the NEA R&R Project (2007-2011)*, OECD Publishing, Paris.

2.2.1. *Paris Convention*

Article 1(a)(ii) of the Paris Convention provides that "nuclear installation" includes "facilities for the storage of nuclear substances other than storage incidental to the carriage of such substances". The term "nuclear substance" [Article 1(a)(v)] means both nuclear fuel (other than natural uranium and depleted uranium) and radioactive products or waste. The term "radioactive products or waste" [Article 1(a)(iv)] means any radioactive material produced in or made radioactive by exposure to the radiation incidental to the process of producing or utilising nuclear fuel but does not include (1) nuclear fuel and (2) radioisotopes outside a nuclear installation which have reached the final stage of fabrication so as to be usable for any industrial, commercial, agricultural, medical, scientific or educational purpose.

In 1984, a decision of the NEA Steering Committee for Nuclear Energy (the "Steering Committee") clarified that "Installations for the disposal of nuclear substances shall, for the pre-closure phase, be considered as 'nuclear installations' within the meaning of [the definition of nuclear installation provided under] the [previously applicable] Paris Convention" [NE/M(84)1 as referenced in NEA [1990]].[12] The consensus had been that there was no significant difference from the viewpoint of third party liability between the pre-closure phase activities and other stages of the nuclear fuel cycle which were already covered by the previously applicable Paris Convention. However, it was necessary to specify that "disposal" should also be covered by the convention, in addition to "storage". In the report by the Group of Governmental Experts on Third Party Liability in the Field of Nuclear Energy concerning the above decision, it is explained that the previously applicable Paris Convention was not drafted with the case of radioactive waste disposal specifically in mind. But if installations to be used for the disposal of nuclear substances "are not so included, then the person operating a disposal installation would not be considered as the operator of a nuclear installation within the meaning of the [previously applicable] Paris Convention and therefore the operator of the last installation in which the substances concerned were before the occurrence of the nuclear incident would be held liable for any damage caused after disposal (unless of course the substances had meanwhile been taken in charge by another operator) [see Article 5(c)]." The experts felt that such a situation was not satisfactory and agreed to expressly include installations for the disposal of nuclear substances within the scope of the Paris Convention.

The 2004 Protocol amended Article 1(a)(ii) of the Paris Convention to clearly include "installations for the disposal of nuclear substances" during their operational and post-closure phases. The CPPCs believed that it was desirable to have such facilities considered as "nuclear installations" in their post-closure phase as well, and decided to include all installations for the disposal of nuclear substances in the definition of "nuclear installation", without distinction.[13]

12. Article 1(a)(ii) of the previously applicable Paris Convention and current Paris Convention provide the possibility for the Steering Committee to extend their scope of application to "other installations in which there are nuclear fuel or radioactive products or waste". This possibility is also granted to the Board of Governors of the IAEA by Article I.1(j)(iv) of the Revised Vienna Convention. However, this possibility is not provided for under the 1963 Vienna Convention or the CSC Annex. In this regard, the Explanatory Text of the Revised Vienna Convention notes that: "The fact that, unlike the 1960 Paris Convention, the 1963 Vienna Convention did not envisage the inclusion of other nuclear installations by a decision taken by a competent international body was in fact considered as precluding the possibility of taking into account recent or future developments by covering additional types of installations which may involve risks of a considerable magnitude, such as radioactive waste disposal facilities […]". See NEA (1990), Paris Convention: Decisions, Recommendations, Interpretations, OECD Publishing, Paris, www.oecd-nea.org/jcms/pl_79235/paris-convention-decisions-recommendations-interpretations-1990; and IAEA (2020), *The 1997 Vienna Convention on Civil Liability for Nuclear Damage and the 1997 Convention on Supplementary Compensation for Nuclear Damage – Explanatory Texts*, IAEA International Law Series No. 3 (Rev. 2), IAEA, Vienna, Section 2.2.2.

13. Paragraph 9 of the Explanatory Report by the Representatives of the Contracting Parties on the Revision of the Paris Convention and the Brussels Supplementary Convention, Annex IV to the Final Act of the Conference on the Revision of the Paris Convention and of the Brussels Supplementary Convention. See Paris Convention on Third Party Liability in the Field of Nuclear Energy, www.oecd-nea.org/law/paris-convention.html.

2.2.2. *Vienna Conventions and CSC*

The definitions of "nuclear installation" provided under the Vienna Convention [Article I(1)(j)], the Revised Vienna Convention [Article I(1)(j)] and the CSC Annex [Article 1(b)] include "any facility where nuclear material is stored, other than storage incidental to the carriage of such material". Since the definition of "nuclear material" includes radioactive products or waste, the conventions have been interpreted as applying to installations for the storage of radioactive waste.

As regards disposal facilities, the Vienna Conventions and the CSC do not include the term "installations used for the disposal of nuclear substances" as in the Paris Convention. The IAEA International Expert Group on Nuclear Liability (INLEX) discussed this issue on several occasions. In particular, at its 14th meeting held on 20-22 May 2014, the INLEX recalled the aforementioned 1984 decision taken by the Steering Committee (i.e. installations for the disposal of nuclear substances shall, for the pre-closure phase, be considered as "nuclear installations" within the meaning of Article 1(a)(ii) of the Paris Convention) and concluded that a similar interpretation should be followed under the Vienna Conventions and the CSC.[14] At its 16th meeting, held on 25-27 May 2016, the INLEX confirmed its interpretation of the Vienna Conventions and of the CSC. It also noted that the Paris Convention amended the definition of "nuclear installation" to include installations used for the disposal of nuclear substances and decided to keep this issue under review. The INLEX identified two areas of concern: (i) who, if anyone, would be the operator during the post-closure phase, and (ii) how could insurance or other financial security be guaranteed for such long-term time periods. At its 18th meeting, held on 15-17 May 2018, the INLEX decided to revisit this matter and reached the position that:

> … with specific reference to "long-term storage" or "disposal" facilities … the IAEA liability conventions would continue to apply during the period when the waste can be regarded as being in storage, institutional controls remain active and there is still an operator. Following the cessation of institutional controls, "the [INLEX] noted that, in the absence of an operator, the nuclear liability conventions cannot be applied and therefore the State which has agreed to the closure of the installation would implicitly be expected to assume the responsibility in case of any nuclear incident."[15]

However, as the INLEX is an advisory body established by the IAEA Director General, its conclusions are not binding on the Parties to the Vienna Conventions and the CSC. Therefore, a clarification of the scope of both the Vienna Conventions and the CSC could be relevant in the future to provide for increased legal certainty regarding their applicability to DGRs during the pre- and post-closure phases. For the Revised Vienna Convention, such clarification could be made through a decision of the IAEA Board of Governors in a format similar to that of the 1984 Steering Committee decision. For both the Vienna Convention and the CSC Annex, which do not provide the same flexibility to add nuclear installations to their scope of application through a subsequent decision, such clarification may require an amendment of those instruments. Meanwhile, those states parties to either Vienna Conventions or the CSC that are envisaging establishing DGRs may expressly provide in their national legislation that "installations used for the disposal of nuclear substances" are considered as "nuclear installations" covered by their nuclear liability law.

14. For more information on the INLEX positions on this matter, see IAEA (2020), *The 1997 Vienna Convention on Civil Liability for Nuclear Damage and the 1997 Convention on Supplementary Compensation for Nuclear Damage – Explanatory Texts*, IAEA International Law Series No. 3 (Rev. 2), IAEA, Vienna, Section 2.2.2.

15. *Ibid.* footnote 92.

2.3. Main challenges regarding the definition of nuclear installation

2.3.1. *The difference between “storage” and “disposal” of nuclear substances*

As mentioned above, the first challenge regarding the definition of “nuclear installation” under the nuclear liability conventions regards the difference between the “storage” and “disposal” of nuclear substances. These two terms find a commonly agreed definition in Article 2 of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the “Joint Convention”):[16]

> *(d) “disposal” means the emplacement of spent fuel or radioactive waste in an appropriate facility without the intention of retrieval [i.e. the final emplacement of disused material]; […]*
>
> *(t) “storage” means the holding of spent fuel or of radioactive waste in a facility that provides for its containment, with the intention of retrieval [i.e. limited in time].*

For many nuclear liability experts, the difference between “storage” and “disposal” is not relevant when considering whether those activities are covered by the nuclear liability regimes. In principle, nuclear liability applies whenever nuclear substances or nuclear material are present on site, unless the concerned nuclear liability convention allows its contracting parties to exclude the concerned nuclear installation for the storage or disposal of nuclear substances or material from the regime. However, such a distinction was made under the previously applicable Paris Convention (taking into account the 1984 decision of the Steering Committee) and the current Paris Convention, while the inclusion of disposal facilities into the scope of application of the Vienna Conventions and the CSC is not explicitly provided (see Section 2.2).

In conclusion, the most commonly agreed interpretation is that all nuclear liability conventions cover DGRs during their operational phase, but only the Paris Convention applies to the post-closure phase. An overall question of the applicability of the Vienna Conventions and the CSC remains open, particularly regarding the post-closure phase.

2.3.2. *Concept of “closure”*

If the Paris Convention explicitly covers the post-closure phase, that is not the case for the previously applicable Paris Convention, the Vienna Conventions and the CSC. It is therefore currently understood that under the latter conventions, the nuclear liability regimes may cease to apply upon the closure of the DGR, unless the decision is made to specifically include the post-closure phase into their scope of application. In this context, a clear definition of when the post-closure phase starts is necessary to know until when the nuclear liability regimes apply.

Two international or regional legal instruments in the field of nuclear safety provide for a definition of “closure”. Article 2(a) of the Joint Convention provides that “closure” means: “…the completion of all operations at some time after the emplacement of spent fuel or radioactive waste in a disposal facility. This includes the final engineering or other work required to bring the facility to a condition that will be safe in the long term.” At the EU level, Article 3(a) of the Council Directive 2011/70/Euratom of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste (the “Waste Directive”) also provides an almost identical definition of “closure”.[17]

16. Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (1997), IAEA Doc. INFCIRC/546, 2153 UNTS 357, entered into force 18 June 2001 (Joint Convention).

17. The Council Directive defined the term closure as follows “[…] the completion of all operations at some time after the emplacement of SF or radioactive waste in a disposal facility, including the final engineering or other work required to bring the facility to a condition that will be safe in the long term.”

From a technical perspective, the timeline of the licensing process for a DGR may be organised in three phases: pre-operational phase, operational phase, and post-operational (or post-closure) phase (Figure 3). The first two phases constitute the “pre-closure phase”. Regulatory frameworks and licensing processes vary between countries, but the main licensing stages (which are not reflected in Figure 3) are: (i) the construction licence for the DGR; (ii) the operation licence; and (iii) the termination of the licence, with each decision being informed by a long-term safety case for the installation, with increasing precision at each stage regarding the design configuration of the DGR at closure. Notwithstanding differences in regulatory practice between countries, the WPDGR considers that the termination of the licence is an appropriate reference point to define “closure” under the nuclear liability conventions, as it marks the time when the government recognises that requirements for closure are fulfilled, i.e. that no further work on the facility is required to ensure its long-term safety.

Process to close the DGR during the pre-closure phase

The different stages in the closure of a DGR may be summarised as follows, taking into consideration the ICRP Publication 122 (see Figure 3):[18]

(i) Decision to terminate waste emplacement operations at the DGR;

(ii) Submission of a final post-closure safety case, based on completed configuration and planned closure engineering;

(iii) Evaluation of the final safety case and a decision on final closure (may also be referred to as a decision to initiate closure) by the regulatory body or the responsible governmental body;

(iv) Closure activities, in accordance with the conditions and provisions provided in the determination of final closure, including the filling of the DGR, therefore leading to its physical (or technical) closure; and

(v) Termination of the licence, after having demonstrated that all conditions and provisions have been fulfilled, with a transfer of responsibility for the DGR from the operator to another institution more suited to long-term stewardship; at this stage, the installation is released from direct oversight.

The order of these stages may differ slightly from one country to another, but the experts agree that “closure” can be considered to have been completed once all of the above steps have been achieved, marking the start of the post-closure phase. From a regulator’s point of view, a decision on final closure means recognition that the operator has completed all disposals and is ready to backfill the access tunnels and complete all the necessary steps to bring the installation to a full closure. A number of experts have suggested that closure activities must be considered as a continuous process, rather than separate stages, but all agreed that they should in any case all be completed before termination of the licence, since no further action to ensure the safety of the facility should be required afterwards. Therefore, there cannot be termination of the licence for a DGR that would have been partially sealed to facilitate the potential reversibility of decisions or retrievability (or recoverability) of the waste.

For example, in the United States, the time span between the closing of the facility and the termination of licence may be measured in years: technical closure is when the facility is closed to future receipt of waste, following which all necessary closure activities are undertaken until the regulatory release is obtained with the issuance of the termination of licence. The decision on final closure indicated on Figure 3 corresponds in the United States to a licence amendment that the Department of Energy (DOE) will have to submit to the US Nuclear Regulatory Commission (NRC), which should lead to the latter approving the closure. In the United Kingdom, the regulators, i.e. the Office for Nuclear Regulation (ONR) and Environment Agency (EA), will assess the effectiveness of the technical (or engineered) closure and the safety cases

18. See ICRP (2013), *Radiological protection in Geological Disposal of Long-lived Solid Radioactive Waste*, ICRP Publication 122. Ann. ICRP 42(3).

to ensure that the installation will remain safe in the post-closure period. If the regulators are satisfied with the final safety cases and all closure activities have been completed safely, they will accept the operator's surrender of the site licence and disposal permit. The "period of responsibility" of the operator under the third party nuclear liability regime is a separate decision, and although the decision to end it often occurs simultaneously with licence/permit surrender, it may occur later. However, if the licence is surrendered before the period of responsibility is ended, the regulator has the power to regulate safety during the remainder of the period of responsibility by giving legally-enforceable directions to the operator.

Monitoring of the site

Two main stages may be distinguished in the post-closure phase of the DGR: (i) a period of *indirect oversight*, during which a competent organisation will conduct any agreed monitoring activities and will be responsible for the installation on behalf of the state, and regulatory, societal or administrative controls relating to use of the site and record keeping may continue; and (ii) a subsequent period of *no oversight*, when memory of the disposal facility is assumed to be lost, or insufficient to provide for any effective form of oversight.

Measures related to indirect oversight are expected to start once the DGR operating licence is terminated and will continue beyond "closure". It implies that the authorities continue institutional monitoring and control through a combination of passive and active measures.[19] Passive measures are mostly connected to record keeping and control of land usage, while active measures would correspond to the performance of continuous monitoring and surveillance over a defined time period. Indirect oversight has as its primary goal to maintain institutional memory, but it can also identify any need for remedial actions that was unforeseen in the final safety case. During this period, the distribution of responsibilities between the authorities and the organisation carrying out any required monitoring activity should be clear. From a nuclear liability perspective, the organisation bearing the nuclear liability should be clearly identified and will be considered as the operator for the purpose of compensating the victims in case a nuclear incident occurs at the DGR.

The start of the no-oversight period does not involve a specific decision point, but marks an assumed transition to when institutional memory of the DGR is no longer sufficient to provide a basis for effective control on land use or to attribute elevated environmental concentrations of radionuclides to the presence of the installation. In the ICRP publication entitled *Radiological Protection in Geological Disposal of Long-lived Solid Radioactive Waste*,[20] the no-oversight phase coincides with the loss of institutional memory. Once such memory is lost, it cannot be assumed that any monitoring focused on the facility as a potential source of radiological impact would occur. From a nuclear liability perspective, it marks a break in the transfer of information that is critical to demonstrating cause in the event of a claim for nuclear damage. An organisation should have been designated or recognised by the competent public authority as the operator of an installation in order to bear the nuclear liability in case of damage to the population or the environment during the post-closure phase.

Reversibility, retrievability and recoverability

From a nuclear liability perspective, the previously applicable Paris Convention, the Vienna Conventions and the CSC, which may be considered as applicable only until "closure", may also potentially be considered applicable after "closure" if a DGR in its final state is conceived to facilitate reversibility of decisions or retrievability (or recoverability) of the waste, at least during a specified timespan after closure. The fact that the installation may include design features

19. According to the IAEA Glossary, "*Institutional control* [means] the *control* of a *radioactive waste* site by an authority or institution designated under the laws of a State. This *control* may be active (*monitoring*, *surveillance*, remedial work) or passive (land use *control*) and may be a factor in the *design* of a *facility* (e.g. a *near surface disposal facility*)". IAEA (2022), IAEA Nuclear Safety and Security Glossary: 2022 (Interim) Edition, IAEA, Vienna, p. 43.

20. For more information, see ICRP (2013), *Radiological protection in Geological Disposal of Long-lived Solid Radioactive Waste*, ICRP Publication 122, Ann. ICRP 42(3).

that facilitate its re-opening or otherwise enable retrieval or recovery of the waste could bring into question whether "closure" of the installation has truly been achieved.

2.3.3. *Definition of "low-risk" nuclear installations*

As mentioned in Section 1.3.2, all nuclear liability conventions, except the Vienna Convention, provide for the possibility to set minimum liability amounts lower than those normally applicable for nuclear installations, where the nature of the installation is such that it entails a smaller risk of damage in case of a potential incident (see Table 1).[21] These installations are generally referred to as "low-risk installations" for the purpose of the nuclear liability regimes.

None of the liability conventions provide for a definition of low-risk installations or detailed criteria for selecting them. The Exposé des Motifs of the Paris Convention provides the example of small research reactors or laboratories and indicates that low-risk installations should not be considered "by [the concerned] Contracting Party as likely to cause great damage as compared to the other nuclear installations […] referred to in the Convention".[22] The determination of which installation is "low-risk" within the meaning of the nuclear liability regime is therefore left to the discretion of each contracting party. This determination entails a responsibility for the concerned state: under the modernised nuclear liability conventions (i.e. the Paris Convention, the Revised Vienna Convention and the CSC), the installation state is liable for compensating victims if damage caused by a nuclear incident at a low-risk installation exceeds the reduced amount, up to the liability amount applicable to "normal" nuclear installations.

Regarding the subject of the present report, a Contracting Party to any of the nuclear liability conventions, except the Vienna Convention, could decide to qualify a DGR as a low-risk installation under its national law. Such decision should, however, be made after a careful assessment of the risks associated with such an installation at the corresponding stage of its life cycle and the potential damage arising out of an accident, should it occur (see Chapter 5 of this report). Considering the "novel" nature of DGRs, it could be expected that the states hosting a DGR would give great consideration before making such a decision, as it will alleviate the insurance or financial security costs of the operator while imposing on the concerned state an obligation to assume liability should a nuclear incident at the DGR cause damage in excess of the reduced liability amount. In addition, states hosting a DGR would benefit from continuing information exchange in international fora concerning the potential classification of DGRs as "low-risk" installations, notably with a view to support their respective risk assessments and to identify appropriate liability amounts.

2.3.4. *Possibility to exclude certain nuclear installations from the application of the international nuclear liability conventions*

It is important to recall that the scope of international nuclear liability conventions is limited to risks of an exceptional character for which general tort law rules and practices are not suitable. Whenever risks, even those associated with nuclear activities, can properly be dealt with through existing legal processes, these should be left outside the scope of the nuclear liability conventions. For this reason, Article 1(b) of the previously applicable and current Paris Convention provides that "the Steering Committee may, if in its view the small extent of the risks involved so warrants, exclude any nuclear installation, nuclear fuel, or nuclear substances from the application of this Convention". Article I(2) of the Revised Vienna Convention and

21. See Article 7(b) of the previously applicable Paris Convention and current Paris Convention, Article V.2 of the Revised Vienna Convention and Article 4(2) of the CSC Annex. Also see Paris Convention on Third Party Liability in the Field of Nuclear Energy, www.oecd-nea.org/law/paris-convention.html and IAEA (2020), *The 1997 Vienna Convention on Civil Liability for Nuclear Damage and the 1997 Convention on Supplementary Compensation for Nuclear Damage – Explanatory Texts*, IAEA International Law Series No. 3 (Rev. 2), IAEA, Vienna, Section 2.2.2.

22. Paragraph 68 of the Exposé des Motifs of the Paris Convention (as revised by the Protocols of 1964, 1982 and 2004) (the "Paris Convention Exposé des Motifs"). See Paris Convention on Third Party Liability in the Field of Nuclear Energy, www.oecd-nea.org/law/paris-convention.html.

Article 1(2) of the CSC Annex also provide that an installation state may, if the small extent of the risks involved so warrants, exclude any nuclear installation from the application of the conventions, provided that, with respect to nuclear installations, criteria for such exclusion have been established by the IAEA Board of Governors and any exclusion by an installation state satisfies such criteria. However, the possibility of excluding a nuclear installation from nuclear liability is not provided for under the Vienna Convention, which only allows the potential exclusion of small quantities of nuclear substances.

To date, there has been no decision to exclude a nuclear installation from the scope of either the Revised Vienna Convention or the CSC. However, there are two currently applicable decisions providing for the possibility to exclude installations from the scope of the Paris Convention, namely the Decision on Exclusion of Nuclear Installations in the Process of Being Decommissioned and the Decision on Exclusion of Nuclear Installations for the Disposal of Certain Types of Low-Level Radioactive Waste.[23] These two decisions do not automatically exclude all concerned installations from the scope of application of the Paris Convention; instead, they provide the possibility for each Contracting Party to exclude a concerned installation on a case-by-case basis, subject to the fulfilment of technical criteria.[24] Both decisions provide for a two-step approach: first, an assessment against generic radioactivity concentration limits (to ensure an annual dose of no more than 10 mSv to a member of the public); followed by a comprehensive installation-specific safety assessment, to ensure that assessed scenarios would not result in an annual dose of more than 1 mSv to a member of the public living off-site. These two decisions could serve as examples, should Contracting Parties decide to investigate a similar approach for DGRs in the future, although discussions within the WPDGR indicate that technical criteria for DGRs may require a different approach to be defined.

Excluding a DGR from the scope of application of a nuclear liability convention will exempt its operator from having to meet any of the nuclear liability requirements. The main advantage of such option is that it would preclude the operator from having to secure financial security over an extended period of time, particularly during the post-closure phase. However, this would also mean that potential victims may – depending on the alternative applicable liability regime – lose the benefit of otherwise favourable provisions, such as the strict liability (i.e. no need to prove fault or wrongdoing) of the operator. As such, the DGR operator would not automatically be discharged of any liability in case of a nuclear incident, as the ordinary tort law or any other relevant liability regime would normally apply. Notwithstanding the above, excluding a DGR from nuclear liability requirements does not imply that it is not subject to regulatory oversight requirements.

Exclusions from the application of the international nuclear liability conventions require careful consideration on various aspects. For example, the conventions are not only important to address transboundary damage, but also allow the harmonisation of the national legislations of the contracting parties and contribute to increasing public acceptance of nuclear installation projects. A well-established nuclear liability system allows the public to better understand the legal process to be followed after an incident occurs and to be assured that a legal framework is in place to try to adequately compensate the victims. The experts expect future generations to decide, potentially as part of the decision-making process surrounding the termination of the DGR licence or at a later stage, on whether and under what conditions a DGR should be withdrawn from the nuclear liability regimes. At present, this possibility primarily appears to concern the Paris Convention, which is the only instrument that explicitly covers the post-closure phase. In addition, in those states where a specified timespan has been considered for

23. See the Exclusion of Nuclear Installations in the Process of Being Decommissioned from the Application of the Paris Convention [NEA/NE(2014)14/REV1] and the Exclusion of Nuclear Installations for the Disposal of Certain Types of Low-Level Radioactive Waste from the Application of the Paris Convention [NEA/NE(2016)7/FINAL]. See Paris Convention on Third Party Liability in the Field of Nuclear Energy, www.oecd-nea.org/law/paris-convention.html.

24. By way of example, the Netherlands have already decided to exclude two installations in the process of decommissioning from the scope of application of the Paris Convention.

the reversibility of decisions and/or retrievability or recoverability of the waste, the DGR should not be excluded from the nuclear liability regime until such a timespan has expired.

In light of the preceding, and as with the qualification of a DGR as a low-risk installation, excluding a DGR from the scope of application of the nuclear liability regime should require a sound assessment of the risks associated with such an installation in the post-closure phase. In-depth analyses could, if consensus is reached among the parties to a convention, lead to a decision by the competent body (either the Steering Committee or the IAEA Board of Governors) to allow the exclusion of DGRs from the nuclear liability regime at one point in time. If so, a detailed set of technical and regulatory criteria should be agreed to ensure the low level of risk involved. Furthermore, exclusions should only be pursued if there is confidence that the alternative legal framework would provide for the fair treatment and efficient compensation of victims in the event of a nuclear incident. In the absence of a specific liability regime, ordinary liability regimes, be it common tort law or administrative liability, would be applicable.

2.4. Recommendations

It would be beneficial to have a decision of the IAEA Board of Governors to provide additional legal certainty regarding the scope of application of the Revised Vienna Convention to installations for the disposal of radioactive waste, including DGRs.

In addition, states should provide for a clear definition of nuclear installation in their national legislation detailing whether and to which corresponding stages of their life cycle DGRs would be subject to the national nuclear liability regime, in accordance with the applicable convention, if any.

States considering to classify a DGR as a "low-risk" installation for the purpose of the nuclear liability regime or to exclude a DGR from the application of such regime should perform a careful assessment of the risks associated with such a facility at the corresponding stage of its life cycle. States would benefit from continuing information exchanges in international fora concerning the potential classification of DGRs as "low-risk" installations, notably to support their respective risk assessments and to identify appropriate liability amounts.

The risk assessment made in view of excluding a DGR from the nuclear liability regime should also include an assessment of an alternative liability regime that would best address the risk of damage arising out of a potential nuclear incident at the DGR.

Decisions to exclude a DGR from the application of the nuclear liability regime should be considered for the post-closure phase. If states have made the decision to facilitate the reversibility of decisions and/or the retrievability or recoverability of the waste during a specified timespan, a DGR should not be excluded from the nuclear liability regime until such timespan expires.

Chapter 3. The operator of deep geological repositories

3.1. Expected licensing process of a deep geological repository

The final disposal of spent fuel and radioactive waste is regulated through the entire life cycle of a DGR, i.e. from site preparation, construction and operation to facility decommissioning, closure and, finally, abandonment. The IAEA sets out the expectations of governments and regulators in the management of geological disposal of waste, noting the need to provide for a clear and staged licensing process, and the responsibilities of the regulator in establishing regulatory requirements for each step of the process.[25]

Licensing regimes vary from country to country.[26] Depending on the national legislation, a licensing process may involve multiple authorities to provide different aspects of regulatory oversight. Often there is a delineation between regulation of nuclear safety and regulation for environmental protection. The process may also involve multi-level concurrent regulatory processes. A 2013 NEA workshop noted that when multiple regulators are involved in assessing an application, designating a lead regulator to be in charge of the overall licensing decision can be a useful practice.[27]

The Swedish licensing process provides a good example of the potential complexities. In Sweden, the licence application for permission to develop a DGR for disposal of spent fuel is governed by two legislative acts: The Environmental Code and the Nuclear Activities Act. Separate licence applications have therefore been reviewed by the Environmental Court and the Swedish Radiation and Safety Authority (SSM), who then made separate recommendations ahead of the Swedish government's decision on both applications. A particular issue that arose in the licensing review process was the need for clarification and harmonisation in relation to how the underlying legislation governing the two cases addressed the question of long-term responsibility for the DGR after final closure.

During the licensing process, applicants are required to submit comprehensive information to demonstrate facility safety throughout the facility's lifetime. A central element is the safety case. This supports the licence application by presenting evidence, analyses and safety arguments that quantify and substantiate the safety of the DGR. The content of the safety case will vary as the DGR life cycle progresses. An initial safety case can be established early during a repository project to support concept development and identify research and development priorities. This then evolves into a more comprehensive and detailed case as a result of work carried out, incorporating experience gained and information obtained throughout the progression of the repository project.

Practical experience with the application of the licensing process provides an illustration of the responsibilities, key issues and challenges. The following subsections provide examples of the regulatory arrangements in Finland, Sweden and the United Sates.

25. IAEA (2011), *Geological Disposal Facilities for Radioactive Waste: Specific Safety Guide*, IAEA Safety Standards Series, No. SSG-14, IAEA, Vienna.

26. NEA (2013), *Preparing for Construction and Operation of Geological Repositories – Challenges to the Regulator and the Implementer: Proceedings of the Joint RF/IGSC Workshop Issy-les-Moulineaux, France, 25-27 January 2012*, OECD Publishing, Paris.

27. *Ibid*.

3.1.1. *Finland*

Finland has 40 years of licensing experience in the development of the country's DGR, Onkalo. Research and development (R&D) was undertaken from the late 1970s up to 2000, when a decision in principle was taken to develop a DGR at the Olkiluoto site. This was followed by a period of site characterisation, which concluded in 2015 with the granting of a construction licence. The operators of the DGR applied for an operating licence in 2021. Operation of the DGR is expected to start around mid-2020s.

As the Finnish DGR programme is among the most advanced internationally, it has been necessary to derive the licensing approach from that applied to other nuclear facilities, rather than benefit from the experience of other DGR programmes. Similar to the United States, Finland has also used a stepwise and staged regulatory process with regard to the development of the DGR. In the Finnish case, the key steps are:

- Decision-in-principle – based on a preliminary safety evaluation;
- Construction licence – on the basis of an updated safety evaluation;
- Operating licence – with reference to further updates to the safety evaluation.

The operating licence is required to authorise SF to be brought into the DGR. In Finland, this also includes encapsulation of SF, which is done at the DGR site.

At each step, there are three main submissions that are considered:

- the safety case;
- the operating phase safety assessment; and
- the long-term safety assessment (alternatively referred to as the safety assessment).

The long-term safety assessment is required to evaluate conservative scenarios and assumptions and demonstrate that a regulatory constraint of 0.1 mSv/year is met over long periods of time. Scenarios are required to examine the consequences of unlikely events (such as the rapid failure of barriers or human intrusion), as well as the "expected evolution" of the DGR. It is noted that, to date, the safety analysis has indicated that when it occurs in the far future, radioactive contamination will be limited to areas in the immediate vicinity of the facility's site (i.e. within a few km).

Under Finnish law, the DGR is only considered to be closed when the regulator has confirmed that the waste has been permanently disposed of in an approved manner. After closure, the responsibility for the waste is taken up by the state, provided the preceding steps have been approved by the regulator. The implementer is then required to pay a lump sum for the state to cover possible monitoring and control before it is finally released from its waste management obligations.

3.1.2. *Sweden*

The main legislative instruments regulating the management of spent fuel and nuclear waste in Sweden are:

- The Act on Nuclear Activities;
- The Radiation Protection Act;
- The Environmental Code;
- The Act on the Financing of the Residual Products of Nuclear Power.

According to the Act on Nuclear Activities, responsibility for managing the spent fuel and nuclear waste of an activity rests with the licence holder for the activity in question. The four utilities operating nuclear power reactors in Sweden have formed a special company, the Swedish Nuclear Fuel and Waste Management Company (SKB), to assist them in executing their responsibilities under the Act. SKB is also responsible for the planning and construction of facilities required for the management of spent nuclear fuel and radioactive waste outside the nuclear power plants, and for the research and development work required to provide such facilities.

The Act on Nuclear Activities provides a mechanism for regulatory and government oversight of the nuclear power utilities' programme for research and development in relation to DGR development. The Act on the Financing of the Residual Products of Nuclear Power is designed to ensure that sufficient funding is made available for the development and implementation of waste management solutions through the payment of fees to the Nuclear Waste Fund. The licensing process for establishing and operating the disposal facility follows that which applies to other nuclear installations, whereby all such facilities require a licence under both the Act on Nuclear Activities and the Environmental Code.

Following several decades of work on concept development and site selection, conducted within the framework of the nuclear utilities' research and development programme and involving a number of preliminary safety assessments, SKB submitted in 2011 its licence applications for an encapsulation plant in Oskarshamn and a DGR for spent fuel in Forsmark. The Land and Environment Court has examined SKB's application under the Environmental Code, whereas the Swedish Radiation Safety Authority (SSM) has reviewed SKB's applications under the Act on Nuclear Activities. Stakeholder perspectives were sought and received as a part of both review processes, while the development of the Environmental Impact Assessment prescribed by the Environmental Code entailed substantial public engagement, in particular with local and regional stakeholders as well as environmental organisations, prior to submission of the licence applications. The main safety case documentation for the DGR formed a part of the application documentation in both cases, but only the SSM received and examined the detailed supporting material. The SSM also participated as an expert witness in the Land and Environment Court's hearings, which took place in October 2017. In January 2018, both the SSM and the Court submitted final review statements to the Swedish government, as preparatory material for licensing decisions.

In April 2019, SKB submitted supplementary information requested by the government, including results from further experimental and theoretical studies relating to the integrity of the disposal canister, according to recommendations made by the Land and Environment Court. The SSM, in the role of statutory consultee, and after a thorough technical review of the new material, reiterated its earlier statement to the government that SKB's preferred site is suitable, the disposal concept is feasible and the safety case fulfils strict regulatory requirements. A further development that arose as a consequence of stakeholder engagement in the review of licence applications was that the host municipality demanded clarity regarding the legal allocation of responsibility for the DGR after final closure. This led to an amendment to the Act on Nuclear Activities and corresponding minor changes to other legislation, including the Environment Code, which came into force in November 2020. These amendments to primary legislation clarify the state's responsibility for the DGR after final closure and underline that the government is required to approve the application for closure.

On 27 January 2022, the government granted SKB a licence according to the Act on Nuclear Activities and gave its approval, according to the Environmental Code, to a final repository for spent nuclear fuel in Forsmark, in Östhammar Municipality, and an encapsulation plant in Oskarshamn. Shortly before this, on 22 December 2021, the government also decided to grant a licence and to give its approval to SKB to extend the existing final repository for short-lived radioactive waste (SFR) in Forsmark. Following the government decisions, the cases were handed over to the Land and Environmental Court and the SSM, which will set detailed conditions for future operations. This includes, first, an application from SKB to commence construction, based on an updated safety case that takes into account more precise plans for the repository's design and implementation. As part of the staged approval process, further updates of the safety case will be submitted for approval prior to commissioning and finally prior to routine operation. According to SSM regulations, SKB will also be responsible for keeping the safety case up to date throughout operation of the installation. Moreover, the SSM has the possibility, through licence conditions and as part of the implementation of periodic safety reviews, to require that during operation of the installation SKB regularly make an evaluation, based on gained experience and new knowledge, of the potential for improvements to design and operation.

Finally, as noted above, the government must approve an application for final closure of the DGR. If this application is approved, conditions will be established for the measures to be taken by SKB in connection with final closure. Confirmation by the regulator that these have been fulfilled is required before responsibility can be taken over by the state.

As part of its research and development programme, SKB has conducted inactive trials to demonstrate how a disposed canister could be retrieved, should this be required. SKB has also considered as part of its operational safety case the procedures involved in returning a damaged canister to the encapsulation plant, if such a need arose. There is, however, no general legal or regulatory requirement in Sweden relating to retrievability or recoverability of waste. Rather, SSM regulations state that any measures taken by the operator to facilitate monitoring or recovery must not adversely affect the facility's long-term safety.

*3.1.3. **United States***

The Nuclear Waste Policy Act of 1982 (NWPA) designates the responsibilities of the Department of Energy (DOE), Environmental Protection Agency (EPA) and Nuclear Regulatory Commission (NRC) in relation to geological disposal of radioactive waste. It also established a fund for waste management costs. Under the NWPA, the EPA is responsible for establishing "generally applicable" environmental standards for repositories managing spent fuel and high-level waste, while the NRC is responsible for developing regulations to implement the EPA's safety standards, and for licensing and overseeing the construction and operation of such repositories. The NRC is thus the lead regulator.[28]

The NWPA, as amended in 1987, designated Yucca Mountain in Nevada as the single candidate site for a repository within the United States. Following such designation, the Energy Policy Act of 1992 (EPAct) directed the EPA to establish site-specific standards for Yucca Mountain and the NRC to establish site-specific licensing requirements that incorporate EPA's site-specific standards. Therefore, while the site (Yucca Mountain) is designated in the NWPA, the roles of the regulatory agencies for that site are described in the EPAct. At present, EPA's standards and NRC's licensing requirements developed under the NWPA would apply to any repository site other than Yucca Mountain.

The DOE submitted an application to construct the facility in Yucca Mountain to the NRC in 2008. Federal funding for the site ended in 2011; however, due to a change in US government policy, the DOE is reviewing other options for high-level waste. NRC staff nevertheless completed and published their safety evaluation in 2015, but the adjudicatory hearing, which must be completed before a licensing decision can be made, remains suspended.

The NWPA defines the schedule for siting, construction and operation of DGRs, setting out the key licensing points. It specifies criteria to be satisfied at the following stages in the DGR life cycle:

- commencement of construction;
- receipt of waste;
- closure and decommissioning.

This differs from some other licensing processes which involve an initial site selection step. In the United States, the site was designated in the NWPA.

In regulating DGRs, the NRC recognises the need for flexibility to make decisions at logical times and therefore applies a staged licensing process. This takes account of the extent of information that can reasonably be gathered at each stage of the development of a DGR, and recognises that there can be further collection and analysis of information. A key consequence of this approach to licensing is that there is a requirement that waste be retrievable until a permanent closure decision is taken. This caveat ensures that there is no permanent commitment to disposal until all significant uncertainties in long-term safety performance are adequately addressed.

28. See NEA (2013), *Preparing for Construction and Operation of Geological Repositories – Challenges to the Regulator and the Implementer: Proceedings of the Joint RF/IGSC Workshop Issy-les-Moulineaux, France, 25-27 January 2012*, OECD Publishing, Paris.

Another key principle of the NRC's licensing approach is that of independent review and stakeholder participation. The NRC formally holds adjudicatory hearings to authorise construction and prior to licensing for the receipt of waste. Before the NRC authorises progress, it will examine the outcomes of these hearings to determine whether:

- there is any basis to doubt the repository will be constructed or operated safely;
- the NRC should take action to suspend or otherwise place conditions on the decision to address remaining issues.

The stepwise licensing process requires a continuous process of learning throughout the DGR life cycle. A "Performance Confirmation Program" is required to run from the initial steps of site characterisation to the closure of the facility. It provides the essential information for safety assessment analyses, which in turn underpin the safety case (see Chapter 5, Safety Cases for DGRs).

Initially, a site characterisation programme is necessary to provide sufficient evidence to underpin a decision to grant a licence for the construction of the DGR. Subsequently, construction information, gathered when the DGR is excavated, informs on the actual condition of the rock and the as-built engineering of the DGR. During the operational stage of the DGR, the Performance Confirmation Program will collect information on the waste emplaced and its specific characteristics. All this information is used to update the safety assessment, to confirm the continued suitability of the facility and its site.

After operations are completed, the decision to permanently close the DGR needs to be substantiated by all the information collected, the analysis of which is compiled in the safety assessment. Together these constitute the core of the safety case for the DGR. In addition, at closure, a plan is required for the post-closure management of the site, including monitoring and other institutional controls (e.g. access restrictions and markers). The satisfactory provision of this information and plans will enable the NRC to terminate the licence, although the DOE will have a continuing responsibility for the facility after its closure.

3.2. Definition of "operator" under the international nuclear liability conventions

Under the international nuclear liability conventions, the definition of "operator" is central, as the operator of the nuclear installation where the nuclear incident occurred is the only entity liable to compensate victims who suffered nuclear damage up to the amount provided under its national law.

The Paris Convention [Article 1(a)(vi)] defines the term "operator" as follows: "'Operator' in relation to a nuclear installation means the person designated or recognised by the competent public authority as the operator of that installation." The Vienna Conventions [Articles I(1)(c)] and the CSC Annex [Article 1(1)(d)] contain identical definitions.

The definition refers to the operator as a "person", which is only defined in Articles I(1)(a) of the Vienna Conventions as "any individual, partnership, any private or public body whether corporate or not, any international organisation enjoying legal personality under the law of the installation state, and any State or any of its constituent sub-divisions." Since the Paris and the Vienna Conventions, as well as the CSC, are more or less identical in their substance and since this definition conforms to the generally used understanding of the term "person", it may be also used for the purposes of the other nuclear liability conventions.

As mentioned in the Paris Convention Exposé des Motifs,[29] in states where there is a system of licensing or authorisation, the holder of the licence or authorisation will usually be designated or recognised as the operator. However, a state may designate or recognise another

29. Paragraph 24 of the Paris Convention Exposé des Motifs. The Revised Vienna Convention and CSC Explanatory Texts, p. 11, footnote 28, provide an almost identical explanation.

entity, such as its parent company, as the operator for the purpose of nuclear liability.[30] Where an action for compensation for nuclear damage is brought, the court is bound to consider the person deemed to be the operator by the competent public authority of the country where the relevant nuclear installation is situated as the operator of that installation. In any event, the entity designated as the "operator" needs to have effective influence on the operation of the installation or any other determining link with the installation. The operator is defined "in relation to a nuclear installation" and thus linked to a nuclear installation.

International nuclear safety conventions, such as the Convention on Nuclear Safety[31] and the Joint Convention, do not contain the same definition of "operator" as in the nuclear liability conventions. They use instead the term "licence holder", who is primarily responsible for ensuring safety of the installation. This concept calls to mind the "operator of a nuclear installation" under the liability conventions, but the licence holder is not necessarily the nuclear liability operator.

3.3. Corporate and organisational structures for DGR operators

As part of its activities, the WPDGR considered the corporate and organisational arrangements set in place by several NEA member countries regarding the current or future operators of their respective DGRs. While the nuclear liability conventions are expected to apply similarly to the operators of a DGR regardless of their legal structure, some choices in the establishment of the DGR operator may entail specificities regarding nuclear liability.

It is apparent from the review performed by the WPDGR that most countries opt for a straightforward structure, where a single entity both owns and operates the DGR. DGRs are not, in most countries, expected to be operated on the basis of an operate and manage (O&M) contract, although some countries pointed out that subcontractors may be used to perform activities as part of operating their DGRs. This should result in a situation where the identification of the operator of the DGR for the purpose of the nuclear liability regime would not raise difficulties. However, it is interesting to note that in certain countries the parent company of the operator may be held jointly liable in case of nuclear damage, which would expand the financial capacity to compensate the victims.

Regarding the legal nature of the DGR operator, it appears that in most NEA member countries the operator is expected to be a public entity, whether a government agency or ministry/department. Some countries, however, reported hybrid structures, where the operator of the DGR would be a wholly state-owned private company or a body with the specific status of public enterprise. Finally, in a limited number of countries, arrangements have been made for the DGR operator to be established as a fully private company, with capital jointly held by waste generators. It is important to note that if the operator is a company (whether public or private), several issues may arise for which a mechanism should be provided in the national law:

(i) For those countries providing unlimited nuclear liability, it is important to note that the financial capacity of companies is limited by the size of their assets. Therefore, if the nuclear incident causes extensive nuclear damage, the company might not be in a position to compensate the victims in full.

30. For example, during test operation when a reactor, for the initial trial period, is normally operated by the supplier before being handed over to the person for whom the reactor was supplied, the person liable will be appropriately designated by the competent public authority. Paragraph 15 of the Exposé des Motifs of the previously applicable Paris Convention (the "previously applicable Paris Convention Exposé des Motifs"). See Paris Convention on Third Party Liability in the Field of Nuclear Energy, www.oecd-nea.org/law/paris-convention.html.

31. Convention on Nuclear Safety (1994), IAEA Doc. INFCIRC/449, 1963 UNTS 293, entered into force 24 October 1996 (CNS).

(ii) Should the company go bankrupt, the victims of a potential nuclear incident might not be duly compensated, as other creditors of the company may be paid first (i.e. the preferred creditors), and may have to wait until the end of the bankruptcy process to be compensated.

(iii) The shareholders of the company may decide to dissolve it.

In theory, the public nature of a DGR operator may also influence the choice of financial security to meet its requirement under the nuclear liability regimes, as states are capable of self-insuring.[32] However, for various reasons it appears that most countries actively planning a DGR programme consider using similar financial security mechanisms, primarily through the insurance market.

3.4. Changing operators and keeping institutional memory

When examining key issues in waste disposal, the NEA identified change of ownership and transfer of responsibilities as an important factor in the safe management of the waste. If poorly managed, such changes could lead to a loss of important knowledge and information. Many regulatory frameworks only cover this issue in a basic way. The NEA has therefore convened an expert working group and published the Report on Preservation of Records, Knowledge and Memory (RK&M) Across Generations, with a view to helping improve the institutional memory of DGRs.[33]

The subject of institutional memory and how to maintain it is important to allow future generations to establish the presence of a DGR and the causal link between the potential damage suffered and the DGR; to identify the liable person in case of potential contamination; and to apply, if still relevant, the nuclear liability regimes. The RK&M guidance is therefore important to this report.

During the DGR life cycle, a large amount of potentially important information will be produced over many decades. As noted in the brief presentation of the US regulatory framework, it is essential that information and knowledge is effectively managed, as understanding the potential hazards associated with the DGR is critical. Furthermore, the context of information can change with time. For example, the overarching legal and regulatory framework is likely to evolve over periods of decades, and as the DGR moves through its life cycle there will be changes in people and potentially in organisations.

There are also particular information needs at each stage of the DGR life cycle. For example, information may be needed:

- for planning the appropriate management of waste and facilities (e.g. waste acceptance criteria);
- to demonstrate compliance, such as showing that the DGR is designed as specified to receive the appropriate waste;
- to provide a suitable degree of confidence that the long-term impacts are within accepted criteria (noting that the degree of uncertainty in such estimates should gradually decrease with time, as information is gathered); and
- to help future generations take informed decisions about the management and characteristics of the facility, including in the unlikely event of a nuclear incident causing nuclear damage to third parties who would be entitled to compensation if the nuclear liability regime still applies.

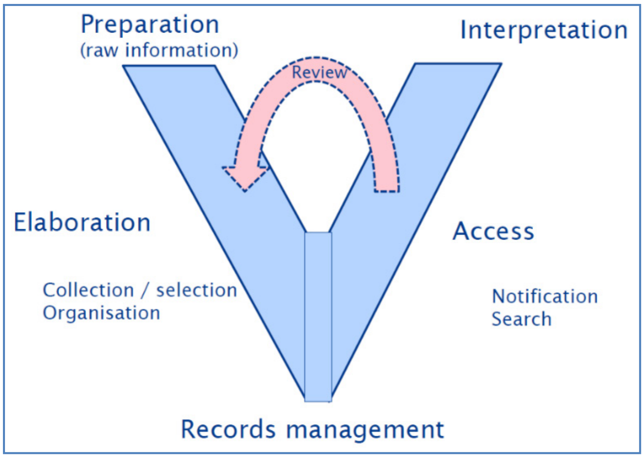
32. Under paragraph 2 of Article VII of the Vienna Convention, Revised Vienna Convention, and paragraph 2 of Article 5 of the CSC Annex: "Nothing [….] shall require a Contracting Party or any of its constituent sub-divisions, such as States or Republics, to maintain insurance or other financial security to cover their liability as operators."

33 NEA (2019), *Preservation of Records, Knowledge and Memory Across Generations: Final Report*, OECD Publishing, Paris.

Addressing these needs requires a robust process to ensure that information is collected, managed, preserved, transferred and understood. This also needs to ensure continuity of information and guarantee that records remain understandable in the future. The information management process needs to be suitably managed and funded to ensure that it is continued, and there should be no loss of authenticity, integrity, availability or confidentiality over time.

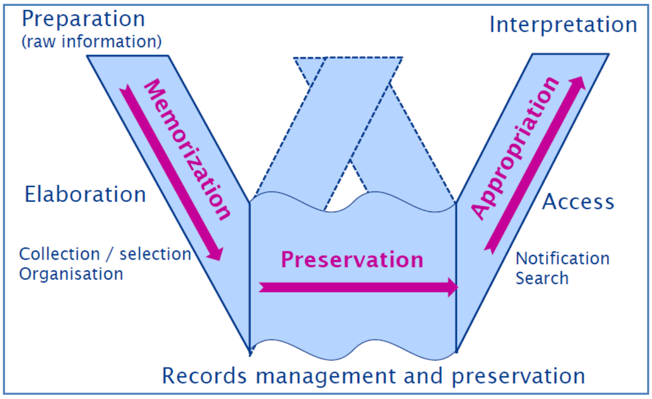
The management of information from its raw state to a form in which it is readily accessible and interpreted is illustrated in Figure 4. Within this process, periodic reviews ensure that the information is always in a suitable form for interpretation. Over longer periods of time, successive reviews will be needed to ensure the information remains available in a relevant form (see Figure 5).

Figure 4. **The process of information transmission**



Source: Dumont, J.-N. (2016) "Main challenges due to the time perspective: changing operators and keeping institutional memory", presented at the 1st Workshop on Deep Geological Repositories and Nuclear Liability, Paris, November 2016. Courtesy of Andra.

Figure 5. **Information transmission with time perspective**



Source: Dumont, J.-N. (2016) "Main challenges due to the time perspective: changing operators and keeping institutional memory", presented at the 1st Workshop on Deep Geological Repositories and Nuclear Liability, Paris, November 2016. Courtesy of Andra.

During the elaboration stage, the challenge is to collect information likely to be useful in the future, based on experience at the time. The real information needs may not be clear when the information is collected, which is likely to motivate operators to collect more information than might appear to be needed at the time. This makes it important for the context of the information, and the basis of its selection, to be properly recorded. A clear process and associated standards and regulations can help guide operators.

The key challenge in information preservation is selecting durable formats and media for records[34]. These should ensure the authenticity, integrity, availability and confidentiality of information (especially when transferred). Periodic reviews and updates of the information are essential. Archiving and backups are also essential, and might be undertaken by a central archive function.

Accessing information will always be a challenge due to its quantity and diversity. An effective access provision firstly requires awareness of the information available and its context. The next challenge is being able to find the relevant information among very large quantities of data. For example, even in the preliminary phase of the Cigéo project in France there are around 15 000 documents produced per year. Achieving effective access to this large quantity of documents requires well organised information repositories, notably making use of information technology techniques for searching.

The final step is the interpretation of the information that has been retrieved. Over long timescales, the context within which the information is used is likely to change or evolve from that within which it was collected. It is therefore essential that contextual information be retained, for example with technical glossaries.

In addition to information management and knowledge preservation, other organisational issues that are equally critical in DGR development are staff management and training. This is especially the case because the workforces of both nuclear regulators and radioactive waste management organisations are ageing. For workforce planning, organisations are examining the capabilities and competencies that will be required in the next decade, identifying potential risk areas and developing strategies to address the issues. The issue of long-term sustainability of expertise may be especially acute for regulatory bodies, as regulators need to maintain scientific and technical knowledge for independent assessments.

3.5. Main challenges

3.5.1. *The ultimate liability of the state in the post-closure phase*

As explained in Chapter 2, a DGR is expected, during its operational phase, to be considered as a nuclear installation under the international nuclear liability conventions.[35] These conventions should therefore apply as long as the country where the DGR is situated is a party to at least one of them. After closure, there is a planned period of indirect oversight (see Figure 3), during which a competent organisation may be tasked with the responsibility to monitor the DGR and confirm that it continues to function as expected. Indirect oversight also includes the prolonged preservation of institutional memory of the DGR and use of planning controls to restrict development at the site. It is typically assumed that memory will be preserved and the potential for other oversight measures thereby enabled for a period of several hundred years. However, the function of any organisation tasked with such responsibilities would primarily be “oversight” rather than operation, so the degree to which they would be liable for any potential incident may differ from the conventional interpretation of an “operator”.

34. NEA (2019), *Preservation of Records, Knowledge and Memory Across Generations: Final Report*, OECD Publishing, Paris, www.oecd-nea.org/rkm-2019, p. 66.

35. As explained in Section 2.2.2 above, contrary to the Paris Convention, the Vienna Conventions and the CSC do not explicitly cover installations for the disposal of radioactive waste.

It cannot be precluded that the memory of the disposal facility will gradually decrease over time, up to a time when it may be lost or become insufficient to provide for any form of indirect oversight. There is a common understanding within the nuclear safety and waste management technical community that any deficiency in performance during the "no-oversight" period is the legal responsibility of the state and/or government, even if it is a result of actions by others much earlier in the life cycle of the DGR.

Indeed, should an incident occur that leads to unanticipated exposure, it might be difficult to determine which organisation is responsible and/or liable for the situation. Causality could be very difficult to establish and it might also be impossible to hold any organisation accountable, as the incident may occur long after the DGR is closed and, in the far future, when there is no direct responsibility of any particular organisation.

This common understanding is confirmed by the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, which provides for the subsidiary responsibility of the state in the absence of a licence holder:

> *Article 21.1: Each Contracting Party shall ensure that prime responsibility for the safety of spent fuel or radioactive waste management rests with the holder of the relevant licence and shall take the appropriate steps to ensure that each such licence holder meets its responsibility.*
>
> *Article 21.2: If there is no such licence holder or other responsible party, the responsibility rests with the Contracting Party which has jurisdiction over the spent fuel or over the radioactive waste.*

Regarding nuclear liability, it is considered that, should the nuclear liability regime continue to apply to the DGR once there is no holder of licence or authorisation to operate the DGR, the competent public authority of the installation state would have to designate or recognise a "person" to be the operator of that installation (and therefore compensate the victims in case of a nuclear incident). As noted above in this report, such a "person" could be "any individual, partnership, any private or public body whether corporate or not, any international organisation enjoying legal personality under the law of the installation state, and any State or any of its constituent sub-divisions" (see Section 3.2).

Following an approach similar to that of the Joint Convention, some experts consider that in the absence of a licence holder, the role of operator under the nuclear liability regimes should be expressly transferred by law or regulation to the state during the post-closure phase, thereby providing more visibility to stakeholders in respect of legal liability. Some countries already appear to provide for similar mechanisms in their national legal frameworks. In the United States, during the post-closure phase of repositories for low-level radioactive waste, the government takes over the ownership of the land and bears the nuclear liability. In Belgium, when the initial owner of the radioactive waste does not exist anymore (e.g. in case of bankruptcy), the cost related to the disposal of the waste is borne by the state.

It should be noted that the INLEX held a slightly different position regarding this matter, as it held at its 18th meeting that "in the absence of an operator, the nuclear liability conventions cannot be applied…".[36] However, that group reached a similar conclusion to the approach described above, as it noted that "the State which has agreed to the closure of the installation would implicitly be expected to assume the responsibility in case of any nuclear incident."[37]

There are various benefits of a transfer of liability to the state: (i) States have in principle a longer lifetime than private entities; (ii) as provided under the Joint Convention, if there is no more licence holder, the state must take over responsibility with regard to the installation; (iii) public

36 See IAEA (2020), *The 1997 Vienna Convention on Civil Liability for Nuclear Damage and the 1997 Convention on Supplementary Compensation for Nuclear Damage – Explanatory Texts*, IAEA International Law Series No. 3 (Rev. 2), IAEA, Vienna, Section 2.2.2, footnote 92.

37 *Ibid*.

acceptance of DGRs may be enhanced if it is made clear that the state takes over responsibility; (iv) international nuclear liability conventions already establish a residual responsibility of the state to provide the necessary funds to compensate victims to the extent that the insurance or other financial security is not available or sufficient to satisfy such claims.[38]

Against this background, one consideration is that such an eventual transfer would require the payment of an adequate fee to the state by the initial waste generators to meet the requirements of the polluter-pays principle. It may be possible that such a fee be initially paid by the waste generator to the operator of the DGR, or collected in amounts transferred to a central Waste Management Fund, and subsequently paid by the latter to the state when liability is transferred to the state. As part of its work, the WPDGR noted that several countries already provide for arrangements according to which the state formally takes over liability for the DGR at a suitable point after final closure.[39] In the case of Finland, this explicitly includes a financial provision made by the operator, whereas in Sweden there are currently only general provisions regarding the potential to attach conditions to the transfer of responsibility. To implement such an approach, it is important to define in the applicable legal framework the terms and conditions of the transfer to the state to enable the financial implications to be taken into account when calculating the fees to be paid by the initial waste generators. However, it is also conceivable that the perspective on such matters will evolve over the many decades during which a repository is in operation and that stakeholders other than the state (including even the host community) may have a legitimate interest and potential influence on the nature of such terms and conditions.

*3.5.2. **Multiple operators***

Operational time frames of many decades must be envisaged for DGRs. It is possible, and even expected, that the operator will change during this period due to organisational developments. Consequently, there needs to be a clear mechanism by which liabilities can be established, assigned and the provisions transferred through the operational phase.

According to the nuclear liability conventions, the only entity liable for nuclear damage would be the one operating the nuclear installation at the time of the nuclear incident, notwithstanding the fact that the responsibility to operate and manage the DGR has been transferred from one entity to another in the past. Ultimately, it is assumed that at any given time the operator that has the responsibility for the safety of the DGR will be liable in case of nuclear damage, as is the case with any other type of nuclear installation. The operator(s) having operated the DGR before such a nuclear incident would therefore bear no liability for nuclear damage whatsoever.

If radioactive waste is transported from the operator of a nuclear power plant to the operator of a DGR, there will be only one liable operator, which will be the one designated by the applicable nuclear liability convention at the time of the nuclear incident.

It is also important to note that the ownership of the radioactive waste or spent fuel placed in the DGR has no consequence for the identity of the liable person under the nuclear liability regimes. Insofar as the liability conventions are considered to apply, the operator of a DGR will always be liable for any accident caused by the waste stored therein, even if the waste was generated or is owned by another entity.

*3.5.3. **Multinational deep geological repository projects***

As part of its activities, the WPDGR briefly discussed the legal status of potential DGRs that may operate under an international co-operation arrangement. It was noted that such a case would raise specific challenges with regard to nuclear liability and would most likely require a special solution that needs to be addressed separately, taking into account the specificities of the projects. Multinational DGR projects are therefore not included within the scope of the present report.

38. Article 10(c) of the Paris Convention, Article VII.1 of the Vienna Conventions and Article 5.1 of the CSC Annex.

39. This is, for example, the case in Finland and Sweden.

3.6. Recommendations

For the purpose of nuclear liability, states should provide for legal frameworks that clearly identify the DGR operator throughout the life cycle of the installation, including after potential changes in operator.

In addition, to the extent possible, states should consider including in their legal frameworks the terms and conditions of a possible transfer of the nuclear liability to the state at some stage in the DGR's post-closure phase, acknowledging that such a decision should be made by future generations and that stakeholders other than the state (including but not limited to the host community) may have a legitimate interest in such a decision.

Chapter 4. Nuclear liability coverage for deep geological repositories

4.1. Nuclear liability insurance and other financial security required by the international nuclear liability conventions

Under all the nuclear liability conventions, operators are required to financially secure their potential liability. To do so, they are obliged to have and maintain insurance or other financial security, up to the liability amount provided in the installation state's national law (which cannot be less than the amount of liability provided in the international nuclear liability convention to which the installation state is a party to). The insurance or financial security must be of such type and terms as the competent public authority shall specify. In case the installation state provides for unlimited liability, the operator must cover its nuclear liability up to the limit of financial security provided in its national law (provided that such limit shall not be less than the amount of liability provided in the nuclear liability convention to which the installation state is a party to). Under the Paris Convention, the Vienna Conventions and the CSC, such financial security cannot be suspended or cancelled without giving prior written notice of at least two months to the competent public authority.[40] Where the financial security covers the operator's liability for nuclear damage arising from nuclear incidents occurring during the carriage of nuclear substances, it shall not be suspended or cancelled during the period of the carriage in question. The sums provided as financial security may be drawn upon only for compensation for nuclear damage caused by a nuclear incident. It is important to note that proof of the existence of the insurance or financial security to cover third party nuclear liability is usually one of the pre-conditions to obtain or renew an operating licence or authorisation.

As explained in Section 3.5.1, the Paris Convention, the Vienna Conventions and the CSC provide that the installation state must ensure the payment of nuclear damage compensation claims by providing the necessary funds where the insurance or other financial security is not available or not sufficient, up to an amount not less than the nuclear liability amount provided by the applicable convention.[41]

The most commonly used financial security is private insurance, which is described in detail in this Chapter. It is important to note that the insurance market has a limited capacity, which requires insurers to have a sound understanding of which risks are covered, and that insurers are subject to certain requirements to mitigate financial risks, such as those set up under the EU Solvency II Directive.[42] As a result, there are certain types of nuclear damage provided under the Paris Convention, the Revised Vienna Convention and the CSC that some insurers are reluctant to cover as of today (such as personal injury after the first ten years following the nuclear incident).

40. Article 10(b) of the previously applicable Paris Convention, Article 10(d) of the Paris Convention, Article VII.4 of the Vienna Conventions and Article 5.4 of the CSC Annex.

41. Article 10(c) of the Paris Convention, Article VII.1 of the Vienna Conventions and Article 5.1 of the CSC Annex.

42. The Solvency II regime (Directive 2009/138/EC of the European Parliament and of the Council of 25 November 2009 on the taking-up and pursuit of the business of Insurance and Reinsurance) introduces a harmonised prudential framework for insurance firms in the EU. It is based on the risk profile of each individual insurance company and is intended to promote comparability, transparency and competitiveness. Solvency II (Directive 2009/138/EC) – as amended by Directive 2014/51/EU ("Omnibus II") - replaces 14 existing directives commonly known as "Solvency I".

There are also other financial securities provided by the public and private sectors. A combination of insurance, other financial security and state guarantee may be accepted by the competent public authority. An operator may change the insurance or other financial security, provided that the maximum amount is maintained and that it is acceptable to the competent public authority. Whatever their nature, the alternative mechanisms need to provide:

- confidence and certainty: funds should be as secure and as predictable as those currently provided by private insurers, so that the victims can easily access compensation, and should continuously meet rigorous assessment criteria, such as credit rating and ready response capacity, and
- a financially reasonable alternative to both governments and the nuclear industry: assessment and monitoring functions must be cost-effective and their costs may be fully or partially borne by the operators.

Some national insurance markets do not yet cover certain risks such as nuclear incidents caused by terrorism, emissions in the normal course of operation or certain major natural disasters, or the prescription period with respect to loss of life and personal injury which was extended from 10 to 30 years from the date of the nuclear incident. The public and private alternative mechanisms will then become crucial to the operators in order to comply with their national laws.

To fill these gaps, governments may sometimes provide financial securities themselves, such as state and/or government guarantees, insurance, re-insurance or indemnity. However, they tend to try to avoid providing such financial securities, preferring that the risks relating to nuclear energy activities be taken by the private sector. It may be considered that the public sector mechanisms have certain advantages: they may be less costly, are financially strong and stable, and enable inspection and loss prevention programmes to be implemented. Even though some may consider that providing these public financial securities derogates the "polluter-pays" principle and state aid rules, and/or that states lack the expertise of the traditional insurance market (e.g. capability and experience in risk assessment, premium pricing or claims handling), the states will in fact be complying with their obligations under the international nuclear liability conventions to ensure the payment of nuclear damage compensation claims by providing the necessary funds where the insurance or other financial security is not available or not sufficient (see Section 3.5.1 above).[43]

There are a number of private sector alternatives:

- <u>Mutuals</u>: a mutual is an insurance company that is collectively owned and controlled by its members, and therefore acts in their best interest. The member-owners, who are generally treated with equality, share any profit the mutual insurance may make and collectively make up for any shortfall it may have. They are both individually insured parties and collective insurers.
- <u>Operators' pooling arrangements</u>: these arrangements have mainly been used for decades at the national level in two NEA member countries, Germany and the United States. In these systems, the operators participating in the pooling arrangement collectively provide coverage when one of them is due to pay compensation for nuclear damage beyond the amount covered by the insurance. Moreover, in Germany, the liable operator is entitled to trigger the pooling arrangement mechanism only if it is not able to provide funds up to the

43. After the 2016 workshop, the EC confirmed on 14 July 2017 that the Belgian state guarantee scheme for nuclear operators that do not find sufficient civil liability coverage on private insurance markets does not constitute state aid. The EC found that, in the case of the scheme notified by Belgium, the premium to be paid by the nuclear operators to benefit from the state guarantee was set at such a level that it will not give them an economic advantage. The Commission also found that the premium is expensive enough to avoid crowding out the private insurance market – there are sufficient incentives for private players to develop competitive offers to replace the need for the state guarantee. The decision was published in the Official Journal of the EU, C 380, 10 November 2017, Aid number SA.46602 (2017/N).

financial security limit required under the national law (i.e. EUR 2.5 billion maximum). International operator pooling arrangements (not mutuals) have been much debated but never agreed. This is primarily because the shareholders have been reluctant to pay for nuclear damage caused by an operator in a country that has no connection with the other operators in question. In addition, an operator subject to a national regulatory regime does not want to contribute funds to compensate nuclear damage for an operator in another country and subject to a potentially very different regulatory and liability regime (i.e. with regard to compensation criteria and amounts).[44]

- Other alternative private sector mechanisms include cash instruments and letters of credit, bank or corporate guarantees, self-insurance (especially for government-owned facilities[45]), captive insurance (insurance company established by the parent company of an operator), securitisation (converts existing assets/future cash flows into marketable securities) and increased operator revenue (e.g. tariff increase).

  If these mechanisms provide some advantages (e.g. large amount of funds readily available, respecting the "polluter-pays" principle, possibility of ensuring inspection prevention programmes and of co-insuring the risk with insurance), they may have some disadvantages (e.g. a higher cost, requirement for an assessment and monitoring costs mechanism, potential lack of claims handling capability for major events such a nuclear incident, potential public distrust). The alternative private sector mechanisms that have been mostly used by operators are mutuals, operators' pooling arrangements, self-insurance and captive insurance.

4.2. Potential challenges to cover deep geological repositories

As mentioned in Section 4.1, the most common way to cover the operator's nuclear liability is to take and maintain third party nuclear liability insurance. The transfer of financial risks to the private insurance market is one of the available risk management options if the risk cannot be avoided, controlled or retained; the other options are the alternative financial security mechanisms such as the sharing with peers (industry mutuals and operators' pools) and the transfer to the state (state/government financial securities). The insurers accept to bear the risk as long as it relates to an unknown event (i.e. future, unpredictable and external) and it is quantifiable.

During the first years of nuclear energy development, insurance markets excluded from all their policies radioactive contamination that could cause widespread damage in order to protect their solvency. Nuclear incidents were unknown and poorly perceived, as the market had in mind the consequences of the nuclear bombs of 1945. In addition, there was a low frequency outlook: there is a very limited base of evidence from nuclear incidents to support the use of actuarial techniques by insurers to calculate the frequency, cost and other consequences of such events. This has made it difficult to work out the likelihood and severity of nuclear incidents to calculate the compensation for nuclear damage that could be payable and the

44. On operators' pooling arrangements, see NEA (2007), "International Pooling of Operators' Funds: An Option to Increase the Amount of Financial Security to Cover Nuclear Liability?", article by N. Pelzer, *Nuclear Law Bulletin*, No. 79, OECD Publishing, Paris, p. 37; NEA. (2008), "Perspective on the Pros and Cons of a Pooling-type Approach to Nuclear Third Party Liability", article by S. Carroll, *Nuclear Law Bulletin*, No. 81, OECD Publishing, Paris, p. 75; Pelzer, N. (2013), "Operators' pooling arrangement: a national and international perspective", paper presented at the OECD/NEA Workshop on Nuclear damages, liability issues and compensation schemes, 10–11 December 2013 (www.oecd-nea.org/jcms/pl_30323/liability-workshop-12-operators-pooling-arrangement-a-national-and-international-perspective).

45. This is clearly allowed under Article VII.2 of the Vienna Conventions, which provide that "Nothing in paragraph 1 of this Article [i.e. operator's obligation to maintain insurance or other financial security covering his liability for nuclear damage] shall require a Contracting Party or any of its constituent sub-divisions, such as States or Republics, to maintain insurance or other financial security to cover the liability as operators."

premium that should be charged to the operators for third party nuclear liability insurance. In the mid to late 1950s, the insurers agreed to establish nuclear insurance pools to mutualise the risk at the national level. However, given the increase in the nuclear liability amounts over time, some national nuclear insurance pools did not have the financial capacity to cover all the national nuclear power plants. This led the national pools to re-insure each other by reciprocating risk to provide greater market capacity for nuclear insurance and thereby enable them to provide the required coverage.[46]

The nuclear insurance pools issue third party nuclear liability insurance policies to cover off-site nuclear damage caused by a nuclear installation or during transport of nuclear substances or materials to any person, whether s/he is a third party inside or outside the installation or an employee of the operator of the installation in question. Such policies are drafted on the assumption that the installation state has adopted the nuclear liability principles set forth in the international nuclear liability conventions (see Section 1.3.2). On-site damage is not covered by these policies, as explained in paragraph 55 of the Paris Convention Exposé des Motifs:

> With respect to property, there is no right of compensation under the Convention for damage to the nuclear installation itself, to any other nuclear installation, including one under construction, on that same site, which is used or to be used in connection with any such installation. The purpose of this exclusion is to avoid the financial security constituted by the operator from being used principally to compensate damage to such installations or such property to the detriment of third parties.[47]

However, this exclusion does not affect the personal property of any person employed on the site.[48] On-site damage is covered by another type of insurance: the material damage insurance policy.

Third party nuclear liability insurance policies for nuclear installations are typically issued on an annual basis, covering damage caused by an incident taking place during the year of coverage, as long as claims are filed within the applicable prescription period. Accordingly, operators of a nuclear installation are required to secure an insurance policy each year, as long as the nuclear liability regime applies to their installation. The price and/or availability of insurance policies may fluctuate over the life cycle of the nuclear installation to which the nuclear liability regime applies.

DGRs raise specific insurance challenges in light of their potential risks and long life cycle. According to the technical experts invited by the WPDGR, nuclear incidents related to DGRs would not be of the same type as for other nuclear installations, and more specifically nuclear power plants. Nuclear damage, were a "nuclear incident" to occur at a DGR, would most probably be related to the gradual and continuous release of radionuclides over a long period, which might, for example, contaminate groundwater (see Chapter 5). In such circumstances, it is difficult for nuclear insurers to determine the scope of the damage to be covered by the insurance and to quantify its magnitude and likelihood. In addition, establishing a causal link between these kinds of nuclear incidents occurring at a DGR and the identified nuclear damage would be technically difficult and may lead to costly and time-consuming claims handling and judiciary processes.[49] In addition, DGRs may have the potential to attract malicious or terrorist acts. Finally, pursuant to the nuclear liability conventions, financial security must be maintained throughout the life of a

46. For more information on nuclear insurance, see NEA (2022), "Insurance of Nuclear Risks", article by Reitsma, S.M.S and M.G Tetley in *Principles and Practice of International Nuclear Law*, OECD Publishing, Paris, pp. 445-465.

47. Article 3(a) of the previously applicable and current Paris Convention, Article IV.5 of the Vienna Conventions and Article 3.7 of the CSC Annex.

48. Paragraph 27(c) of the Paris Convention Exposé des Motifs.

49. According to Article 7(g) of the previously applicable Paris Convention, Article 7(h) of the Paris Convention, Article V.2 of the Vienna Convention, Article V.A.1 of the Revised Vienna Convention and Article III paragraph 4 of the CSC, any interest and costs awarded by a court in actions for compensation of nuclear damage shall be payable by the operator in addition to the sums for which it is liable for compensation of nuclear damage under the conventions and its national law.

nuclear installation for which the conventions apply.[50] This creates challenges as it may not be possible to ensure the availability of insurance policies or to accurately assess the pricing of such instruments far into the future. In particular, if financial securities are exhausted by a nuclear incident at such an installation, it may be difficult to attract the insurance market to reinstate the required insurance, as required under the nuclear liability conventions. If insurance policies or other types of financial security mechanisms become unavailable, the state will have the obligation to take action to ensure that there are the necessary funds to compensate victims in the event of another nuclear incident at the same nuclear installation (see Section 4.1 above).

Table 2. **Insurance structure summary**

Timeline:	Years	Decades		Centuries	Millenia
DGR phases:	*Pre-op phase*	*NM emplacement*	*Observation*	*Oversight*	*No oversight*
Insurance:	Construction insurance	Nuclear physical damage Nuclear liability	Limited phys.dge. Nuclear liability	Nuclear liability	Non-nuclear liability?
Comment:	Easily insured for both physical damage & liability by NON-NUCLEAR markets	Physical damage likely to be required for material amount until final closure; it includes decont. Nuclear liability required once 1st nuclear material arrives on site. Operator to be site, not NM originator?	Limited phys.dge may be required, to provide for any event that requires repair. Nuclear liability required for operating entity.	Phys.dge cover not required. Nuclear liability only for nuclear damage arising from seepage from DGR	With insiginificant public risk, it is assumed no nuclear liability cover will be required.
Risk profile:	Low; non-nuclear	High; nuclear	Medium; nuclear	Low - very low: nuclear	Insignificant
NTPL FS amount	None	As for HLW facility	As for LLW facility	As LLW initially	None: tort law?
To note:	*Construction policy: contract length; designer E&O exposure? Nuclear covers either annual or up to 5 years? Consider longer cover options from capital markets.*				

Note: NTPL: nuclear third party liability; FS: financial security.

Source: Tetley, M.G. (2016) "DGRs – Specific insurance considerations", presented at the 1st Workshop on Deep Geological Repositories and Nuclear Liability, Paris, November 2016.

From an insurer's perspective, the risks related to DGRs may be categorised as follows when determining the premium and the necessary financial reserves:

- Pre-operational phase: only usual construction insurance policies would be required at this stage, which does not raise any particularities.
- Operational phase – emplacement of radioactive waste: this stage raises the most concerns in relation to potential incidents associated with the emplacement of the radioactive waste in the DGR and the transportation of the radioactive waste packages. While the maximum nuclear liability amount may be applicable during waste emplacement, the amount may decrease once emplacement operations cease, due to the lower nuclear risk posed by the DGR. The operator should be able to access the standard third party nuclear liability insurance policies available to nuclear installations to cover this phase.
- Post-operational phase – indirect oversight and no oversight: whether there is a need to take and maintain nuclear liability insurance for this phase needs to be discussed. From a technical point of view, the nuclear risk would be significantly decreased. During this phase, the application of the nuclear liability regimes may seem impractical due to the very long life cycle of the DGRs and the reserves necessary to cover the costs associated with the nuclear liability financial coverage (insurance premium, investigation and claims handling). Where there would not even be oversight activities, the insurance market may not be the right place to transfer the risks to.

50. Article 10 of the previously applicable and current Paris Convention; Article VII.1 of the Vienna Conventions, and Article 5.1 of the CSC.

DGRs also involve challenges with regard to the funding of their operation and maintenance activities, which also include the cost of insurance. In many countries, decommissioning funds exist, which are financed by the waste producers and used for the design and construction of the DGRs, emplacement of the radioactive waste and final closure activities. These funds could also cover the costs of nuclear insurance policies or other necessary financial securities to cover the DGR operator's nuclear liability. The possible premiums or guarantees are commonly not considered in estimates of the costs of financing radioactive waste management programmes; nor are the potential costs that would be related to institutional surveillance after closure. Alternative funding mechanisms, such as involving the capital market (pension funds), could be examined, particularly for the post-closure phase. Since claims handling after a nuclear incident in the post-operational phase could represent costly and time-consuming processes, as mentioned above, another mandatory fund might need to be established in advance to cover such costs.

In order for DGRs to operate in an economically viable manner, appropriate nuclear liability regimes should be identified for each phase of the DGRs' life cycle, taking into account the nature and extent of the potential risks inherent to each phase. In addition, it would be necessary to adequately distribute the risks among private and public entities.

4.3. Challenges regarding the funding of the nuclear liability coverage

Among the challenges related to financial security mechanisms and insurance, the issues regarding funding were of particular interest to the WPDGR participants and were the subject of substantial discussions. In most, if not all, countries with a nuclear power programme, DGRs are financed via funds that waste generators are required by law to set aside. These funds are subsequently transferred to the operator of the DGR to take over the waste to be disposed of, via various mechanisms, depending on the country. In some countries, the transfer is made through commercial contracts between the waste generator and the operator of the DGR; in other countries, waste generators are expected to pay a lump sum to the operator of the DGR; in a limited number of countries, the DGR operator may be a joint venture of the waste generators, potentially providing for other funding avenues. Regardless of these different mechanisms, the core principle is similar: funds set aside by waste generators are expected to cover the whole life cycle of the DGR and no public funds are expected to be paid for the concerned DGR programme, in accordance with the polluter-pays principle.

Since DGR operators are not expected to generate revenue besides the funds set aside by waste generators, such funds will likely be called to cover the costs associated with nuclear liability for the concerned DGR programmes. Such costs include the maintenance of the required financial security throughout the life cycle of the installation to which the nuclear liability regime will apply, but also potentially costs associated with claims handling or litigation in the event of an accident. For countries that provide for the unlimited liability of the operator of a nuclear installation, costs associated with nuclear liability may also include the compensation of victims beyond the coverage provided by financial security mechanisms, in the event of a large-scale incident. The costs that the DGR operator would also be expected to cover include any funds that the operator may be required to transfer to the state when the latter takes over responsibility and liability for the DGR in the post-closure phase.

The overall life cycle nuclear liability-related costs for a DGR are difficult to assess in advance, notably due to the significant uncertainties regarding the applicable legal frameworks in the future, whether DGRs will be subject to nuclear liability during the post-closure phase (and, if so, for how long), the availability of certain types of financial security and their pricing. For example, the price of insurance coverage may significantly increase in the event of a large-scale nuclear incident, following which the operator would be required to reconstitute its financial security. Nevertheless, it was considered by some insurance experts within the WPDGR that the total nuclear liability-related costs, as discussed in the previous paragraph, would likely only amount to a fraction of the otherwise considerable funds collected from waste generators for the development and implementation of the DGR programmes.

In light of the preceding discussion, it appears important to enhance understanding of the applicable legal framework regarding nuclear liability and DGRs, with a view to better assess the related costs and ensure that the necessary arrangements are in place from the outset to secure their funding. Future generations should not bear an undue burden regarding such funding. A mechanism could be put in place for the initial waste generators to contribute beyond their fees, if such entities still exist at the time of the nuclear incident and are financially viable.

4.4. Recommendation

States, DGR implementers and national nuclear insurance pools should give priority to identifying the potential gaps in the insurance coverage for the national DGR, with a view to organising appropriate private or public alternative financial security mechanisms. To this effect, potential providers of financial security should be given the information necessary to assess the technical risks of the DGR to be covered and the applicable legal framework, so that they can provide the appropriate financial security.

Chapter 5. Nuclear incidents at deep geological repositories

5.1. Safety cases for deep geological repositories

5.1.1. *Overview*

An essential component of any DGR programme is the "safety case". The concept of the safety case was largely elaborated by the NEA Expert Group on Integrated Performance Assessment (IPAG).[51] The NEA defines a safety case as a formal compilation of evidence, analyses and arguments that quantify and substantiate a claim that the repository will be safe.[52] It may be used:

- to support a decision;
- to help review a project's status;
- to test safety assessment methods; or
- to prioritise R&D activities.

Various international guidance documents (e.g. by the NEA Integration Group for the Safety Case, IGSC,[53] established in 2000) have been developed to advise on the scope, structure and content of a safety case. In 2011, the IAEA noted that a safety case submission is required for each phase of the DGR life cycle, and in each phase it must provide relevant information needed for regulatory decisions.[54]

A comprehensive DGR safety case will typically cover both operational and post-closure issues. The operational safety case for a DGR will be broadly similar in scope to that for other simple nuclear installations. The post-closure safety case is different. This is because the analysis of safety performance in the post-operational phase is based on projections, over long timescales, of the performance of the passive barriers provided by the engineered system and geological environment. There is, however, an interface between the operational safety case and post-closure safety case, as post-closure safety relies upon achieving operational safety to deliver a "reference state" at the start of the post-closure period.

51. The management of radioactive waste and, in particular, the safety assessment of radioactive waste disposal systems are areas of high priority for the NEA. The Working Group on Integrated Performance Assessments of Deep Repositories (IPAG) was set up in 1994 to provide a forum for informed discussion on the performance assessment (PA) of proposed deep repositories for radioactive waste. The group ended the third phase of its work in 2002. A common object of all IPAG studies is the collection of detailed information from national programmes through a questionnaire; the compilation and rationalisation of the information into a synthesis; and the identification of the lessons to be learnt. For publications related to IPAG, see www.oecd-nea.org/rwm/ipag.html.

52. NEA (1999), *Confidence in the Long-term Safety of Deep Geological Repositories: Its Development and Communication*, OECD Publishing, Paris.

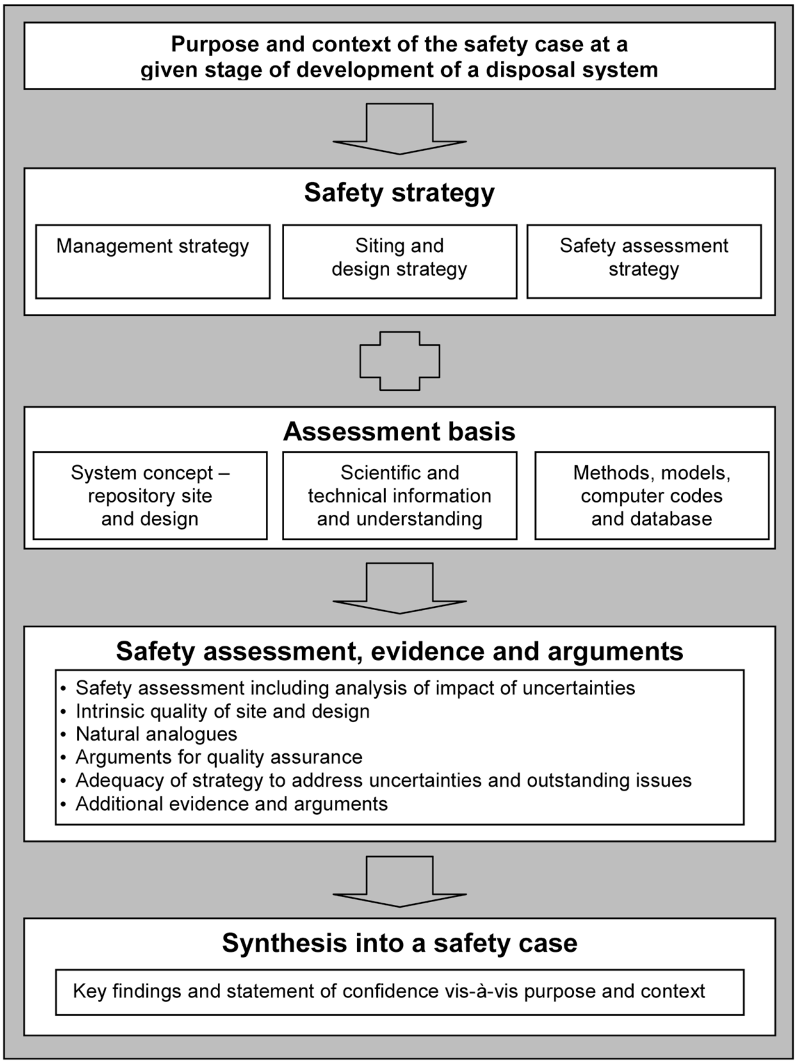
53. The mission of the IGSC is to assist member countries to develop effective safety cases supported by robust scientific technical basis. In addition to the technical aspects in all developmental stages of repository implementation, the group also provides a platform for international dialogues between safety experts to address strategic and policy aspects of repository development. For publications related to the IGSC, see www.oecd-nea.org/igsc.

54. IAEA (2011), *Disposal of Radioactive Waste: Specific Safety Requirements*, IAEA Safety Standards Series, No. SSR-5, IAEA, Vienna, p. 19.

The safety case itself needs to contain a description of the key aspects of the disposal system (the site, facility and its management) that contribute to its safety. It needs to provide assurance to regulators and other stakeholders regarding the capability of the DGR to provide the required level of protection of people and the environment. To do this, it needs to demonstrate that the operator has an adequate knowledge of the key features and factors of the disposal system that influence safety. This information is in turn used in a quantitative safety assessment, which uses computer models of the DGR and its environment, and all the processes relevant to their long-term evolution, to provide estimates of barrier degradation, radionuclide release and transport, and the potential radiological impacts from the facility. The safety case, safety assessment and supporting information need to be documented clearly and comprehensively so as to enable independent review and, where appropriate, verification.

The detailed structure and format of the safety case for a DGR needs to reflect the specific project, but the NEA notes that it is generally accepted to have the main components shown in Figure 6.

Figure 6. **NEA guidance on safety case structure**



Source: NEA (2013), *The Nature and Purpose of the Post-closure Safety Cases for Geological Repositories,* , OECD Publishing, Paris, www.oecd-nea.org/post-closure-safety-cases.

The first part is a **statement of purpose**. Clear definition of the context of the safety case (for example the stage in the DGR life cycle, what decision points need to be addressed, and the information and level of detail needed) is an important guide to scope the expectations for its content.

The next element is the **safety strategy**. This describes in general terms how the management of the DGR project, its siting and design will provide a reliable and robust safety performance. It includes, for example, an account of the key barriers in the disposal system and their functions over different phases of its anticipated evolution. Finally, it needs to describe the strategy used for the safety assessment and analysis, for example with respect to the identification and management of key sources of uncertainty, as well as the development of safety arguments using multiple lines of evidence.

The **assessment basis** describes how the safety performance of the system can be evaluated in terms of analysis of the identified barrier functions. To do this, the system itself can be described in terms of features, events and processes (FEPs) that can affect safety performance. These FEPs can then be used to support the development of conceptual models for the disposal system, which can then be analysed using numerical models and computer codes. This process provides opportunities to understand the dominant sources of uncertainty and their significance.

As highlighted previously, the **safety assessment** is central to the safety case. It provides a quantitative measure of the DGR system performance over long timescales, exploring the implications of uncertainties and testing sensitivity to key assumptions. Although there is no fixed approach for safety assessments, there is international consensus that the analysis should use a systematic process for determining scenarios to be represented, the models to be used and calculation cases to be explored, as well as for analysing their outcomes and handling uncertainty.

*5.1.2. **Scenarios in safety cases***

Scenarios are descriptions of the potential evolution of the DGR system and its environment. The selection of scenarios for assessment is a particularly important element of the safety assessment process. The set of scenarios must encompass the range of conditions that can reasonably be expected to occur in the future as well as less likely conditions that might adversely affect the performance of the DGR. It is also essential that the assessment results for each scenario be viewed in context (for example, highly unlikely scenarios may provide relevant insights if they give rise to significant impacts, but care should be taken to present estimated radiological consequences in the light of pessimistic assumptions inherent in the definition of the scenario).

Scenarios are identified in a formalised and structured way by systematically analysing FEPs and determining those that could impact the safety functions assigned to different components of the disposal system. Those scenarios that are highly likely and those that might have high consequence (even if unlikely) are generally selected for further analysis. There are typically several types of scenario that are assessed as part of a DGR safety case:

- the "expected evolution" scenario, which represents the range of conditions relevant to the probable development of the DGR;
- scenarios that represent the less likely situations in which there are adverse effects on the performance of a DGR, including
  - natural disruptive events, such as earthquakes, and
  - future human actions that might inadvertently affect the DGR, most notably inadvertent intrusion (e.g. a borehole) into the facility;
- highly improbable or residual scenarios, not for comparison against safety criteria, but which can be useful in exploring the consequences of extreme situations or the safety role played by individual components of the barrier system. These are sometimes referred to as "what if" scenarios.

The scenario and respective calculation cases that describe the expected evolution of the DGR provide a baseline for its performance over time and can be considered as approximately equivalent to the "normal operation" of a nuclear facility. This scenario should demonstrate that, for a range of plausible evolutions of the system and its surroundings, the estimated radiological exposures of people and the environment are sufficiently small so as not to cause any harm.

Just as with other nuclear installations, the safety case for a DGR needs also to consider unlikely situations that could lead to more significant consequences. In safety assessment studies these are typically characterised as deviations from the expected evolution of the disposal system due to an unexpected set of conditions or events. These scenarios examine the robustness of the disposal system in the face of uncertainty regarding the future, thereby exploring the limits of performance. Such scenarios are characterised by an analysis of the likelihood and potential consequence of relevant events or combinations of unexpected conditions. These could be of natural origin (e.g. an earthquake) or resulting from human activities (e.g. a site investigation borehole).

Siting principles for DGRs stress the importance of reducing the likelihood of adverse natural events by siting the facility in a way that minimises the likelihood of such events or their consequences for its performance. For example, geological characterisation can identify regions of rock that have been stable for very long periods of time, minimising risks related to seismic activity. Geological records may be used to provide evidence of the low probability of such natural events.

The likelihood of inadvertent human intrusion into a DGR (e.g. due to a deep borehole) will be very low in any given year. Set against this, however, is the potential for significant harm to any person exposed to the waste, even if intrusion were to occur far into the future, so this is an important scenario to consider in terms of characterising the residual hazard posed by the waste stored in the repository as a function of time. Human actions might also affect the performance of the disposal system even if they do not directly disturb the waste itself. However, the precise likelihood of human actions that could affect the disposal system is difficult to establish. The pace of human development means that any estimate of the probability that human actions might disturb the DGR in hundreds or thousands of years is speculative. Suitable siting (away from areas of interest in terms of resources) will reduce, but cannot completely remove, the possibility of inadvertent human disturbance of the DGR. Actions aimed at retaining memory of the DGR (see Section 3.4) and enabling the persistence of indirect oversight after its final closure will also contribute to reducing further the potential for inadvertent intrusion.

Having established a suitable set of scenarios, quantitative models of the disposal system and its evolution need to be built to represent them. Results calculated with such models are not intended to be predictions of actual consequences in terms of release and radiological impact, because of the uncertainties in parameters used to characterise processes and the need to adopt assumptions relating to the evolution of the system, particularly the biosphere. However, they illustrate the safety functions and performance of the system and contribute to its understanding. Models can deal with uncertainties in various ways, but often through making conservative assumptions for relevant data. If the uncertainty is sufficiently significant, it may be explicitly represented by using a range of assumptions to capture the breadth of uncertainty. This could include undertaking calculations with best estimate and conservative values for a given parameter. Alternatively, the range of parameter values might be represented using a probability distribution.

Safety assessment calculations yield a substantial body of information, which needs to be examined as part of the synthesis of the safety case. Such an examination might involve, for example, an exploration of the adequacy of the models against the background of the assessment or consideration of whether all relevant data have been considered. Any limitations need to be identified and addressed by revisiting the assessment or the design of the DGR system.

Experience of developing safety cases has shown that it is valuable to begin to prepare the case in the early stages of the DGR life cycle. It can then develop progressively and provide a basis for key licensing steps and inform research and development priorities and site investigations. The safety case will become more detailed and based on more precise information regarding the disposal system and its surroundings as the DGR programme proceeds.

5.2. **Definition of "nuclear incident" under the international nuclear liability conventions**

The international nuclear liability conventions provide for more or less similar definitions of "nuclear incident",[55] some being more specific than others:

- previously applicable Paris Convention: any occurrence or succession of occurrences having the same origin which causes damage, provided that such occurrence or succession of occurrences, or any of the damage caused, arises out of or results either from the radioactive properties, or a combination of radioactive properties with toxic, explosive, or other hazardous properties of nuclear fuel or radioactive products or waste or with any of them, or from ionising radiations emitted by any source of radiation inside a nuclear installation;

- Paris Convention and Vienna Convention: any occurrence or series of occurrences having the same origin which causes nuclear damage;[56]

- Revised Vienna Convention and CSC: any occurrence or series of occurrences having the same origin which causes nuclear damage or, but only with respect to preventive measures, creates a grave and imminent threat of causing such damage.

An "occurrence" can be an ordinary, running, repetitive and even foreseeable event, which does not need to be sudden, nor serious or even significant. It is important to note that this definition covers both the "incidents" and "accidents" defined under the INES scale,[57] to the extent that they comply with the legal definition of "nuclear incident". "Series of occurrences" is understood as occurrences that happen within a certain period of time, such as an uncontrolled release of radiation extending over a certain period of time that causes nuclear damage.[58] For many countries, this would imply that there is a nuclear incident even where the level of the emission is within the limits prescribed by national law for the normal course of operation, if it causes nuclear damage and a causal link is confirmed. In the case of DGRs, the main risk is quite likely not the occurrence of a sudden nuclear incident with direct release to and dispersion in the atmosphere, but gradual pollution over a long period of time associated with larger than anticipated releases of radionuclides from the engineered disposal system, leading to the gradual build-up of significant radioactive contamination in groundwater and/or soils and thereby causing damage to the environment and human health. Such gradual and long-term occurrence could be considered as a "series of occurrences" and therefore a nuclear incident: however, it might be difficult for victims to demonstrate the causal link, to technically prove that a nuclear damage is caused by a leak from a DGR during the post-closure phase. It might also be difficult to determine with any certainty the applicable prescription period according to the liability conventions, as there will likely be very limited information on which to determine when the nuclear incident actually started to occur. The prescription period to claim compensation under the international nuclear liability conventions is 10 years from the date of the nuclear incident but it has been extended to 30 years for personal injury and death under the Paris Convention [Article 8(a)(i)] and the Revised Vienna Convention [Article VI(1)(a)(i)].[59] In addition, victims need to comply with a discovery period, which is set by the international conventions at two or three years from the date

55. Article 1(a)(i) of the previously applicable and current Paris Convention, Article I.1(l) of the Vienna Conventions and Article I(i) of the CSC.
56. It is important to note that the Paris Convention also covers preventive measures, but this is referred to in the definition of "nuclear damage" under the Paris Convention.
57. The international nuclear liability conventions do not follow the International Nuclear and Radiological Event Scale (INES scale), which makes a distinction between "incidents" and "accidents" depending on the severity of the events. For more information, see IAEA (2013), *INES: The International Nuclear and Radiological Event Scale User's Manual*, Non-serial Publications, IAEA, Vienna, Section 1, pp. 1-4.
58. Paragraph 15(a) of the Paris Convention Exposé des Motifs, and Revised Vienna Convention and CSC Explanatory Texts, page 7.
59. Article 8(a)(i) of the previously applicable and current Paris Convention, Article VI.1 of the Vienna Conventions and Article 9.1 of the CSC Annex.

on which the person suffering nuclear damage had knowledge or should have had knowledge of the damage and of the operator liable for the damage, provided that the above-mentioned prescription period is not reached.[60]

Table 3. **Prescription and discovery periods**

Nuclear liability convention	Prescription and discovery periods
Previously applicable Paris Convention	- **Prescription period**: right of compensation shall be subject to prescription if an action is not brought within 10 years from the date of the nuclear incident. - **Discovery period**: actions must be brought no less than 2 years from the date at which the person suffering damage has knowledge or ought reasonably to have had known of both the damage and the operator liable, provided that the period does not exceed the prescription period.
Vienna Convention and CSC	- **Prescription period**: 10 years - **Discovery period**: not less than 3 years
Paris Convention and Revised Vienna Convention	- **Prescription period**: * for loss of life and personal injury: 30 years * for other nuclear damage: 10 years - **Discovery period**: not less than 3 years

Source: Overview of the international nuclear liability regimes, presentation by the NEA Secretariat.

A "nuclear incident" only exists if it causes "nuclear damage". The definition of "nuclear damage" has evolved in time:

- previously applicable Paris Convention and Vienna Convention:[61] "nuclear damage" means damage to or loss of life and property;
- Paris Convention, Revised Vienna Convention and CSC[62] have further detailed the heads of damage that may be compensated under their respective regimes to cover:
    1. *loss of life or personal injury;*
    2. *loss of or damage to property;*

  and each of the following to the extent determined by the law of the competent court,

    3. *economic loss;*
    4. *the costs of measures of reinstatement of impaired environment;*
    5. *loss of income deriving from a direct economic interest in any use or enjoyment of the environment (Paris Convention) or loss of income deriving from an economic interest in any use or enjoyment of the environment (Revised Vienna Convention and CSC);*
    6. *the costs of preventive measures, and further loss or damage caused by such measures;*
    7. *any other economic loss, other than any caused by the impairment of the environment, if permitted by the general law on civil liability of the competent court (Revised Vienna Convention and CSC).*

60. Article 8(c) of the previously applicable Paris Convention, Article 8(d) of the Paris Convention, Article VI.3 of the Vienna Conventions and Article 9.3 of the CSC Annex.
61. Article 3(a) of the previously applicable Paris Convention and Article I.1(k) of the Vienna Convention.
62. Article 1(a)(vii) of the Paris Convention, Article I.1(k) of the Revised Vienna Convention and Article I(f) of the CSC.

With regard to "preventive measures", it is important to note that the "threat of causing nuclear damage" is not considered a nuclear incident by itself. Preventive measures may be compensated if taken after a nuclear incident occurred or an event creating a grave and imminent threat of nuclear damage. In the absence of an actual release of radiation, preventive measures may be taken in response to a grave and imminent threat of a release of radiation that could cause other types of nuclear damage. The use of the phrase "grave and imminent" makes it clear that preventive measures can be taken if there is a credible basis for believing that a release of radiation with severe consequences may occur in the future. Preventive measures (as well as measures of reinstatement relating to impairment of the environment) must be reasonable and taken by any person after a nuclear incident or an event creating a grave and imminent threat of nuclear damage to prevent or minimise nuclear damage, subject to any approval of the competent authorities required by the law of the state where the measures were taken. The terms "preventive measures" and "reasonable measures" are defined in the Paris Convention, Revised Vienna Convention and the CSC. Preventive measures may range anywhere from taking iodine pills to the evacuation of the population in a given area.

The heads of damage listed in 1-5 above are linked to the following key concepts:

- Radioactivity: the loss or damage must arise out of or result from ionising radiation emitted by any source of radiation inside a nuclear installation or emitted by nuclear fuel or radioactive products or waste in a nuclear installation, whether so arising from the radioactive properties of such matter or from a combination of radioactive properties with toxic, explosive or other hazardous properties of such matter.
- Nuclear substances: the loss or damage must arise out of nuclear substances coming from, originating in, or sent to a nuclear installation, whether so arising from the radioactive properties of such matter or from a combination of radioactive properties with toxic, explosive or other hazardous properties of such matter.
- Nuclear installation: the conventions will only be applicable if the nuclear incident either occurred at a nuclear installation or in the course of carriage from or to a nuclear installation.

Damage to the nuclear installation itself, or to any other nuclear installation (including a nuclear installation under construction) or property used or to be used in connection with any such installation that is located on the same site as the nuclear installation itself will not be compensated under the nuclear liability conventions (see Section 4.2 above).

5.3. Radiological protection perspectives on nuclear incidents

The system of radiological protection developed by the International Commission on Radiological Protection[63] centres on three principles:

- Principle of justification: any decision that alters the radiation exposure situation should do more good than harm;
- Principle of optimisation of protection: the likelihood of incurring exposure, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable (ALARA principle), taking into account economic and societal factors;
- Principle of application of dose limits: the total dose to any individual from regulated sources in planned exposure situations other than medical exposure of patients should not exceed the appropriate limits specified by the ICRP.

63. ICRP (2007), *The 2007 Recommendations of the International Commission on Radiological Protection*, ICRP Publication 103. Ann. ICRP 37 (2-4).

The application of the last principle is conditional on the situation. Dose limits are applicable in "planned" situations but not in "emergency" situations or those where there is an existing source of exposure to radiation. These are defined as follows:

- Planned exposure situations are situations involving the deliberate introduction and operation of sources of radioactivity. Planned exposure situations may give rise both to exposures that are anticipated to occur (normal exposures) and to exposures that are not anticipated to occur;[64]
- Emergency exposure situations are situations that may occur during the operation of a planned situation, or from a malicious act, or from any other unexpected situation, and require urgent action in order to avoid or reduce undesirable consequences; [65]
- Existing exposure situations are exposure situations that already exist when a decision on the need for control needs to be taken, including prolonged exposure situations after emergencies.[66]

Specific recommendations for the interpretation of the ICRP's system of radiological protection are made in relation to the geological disposal of solid radioactive waste.[67] They take account of the particular challenges of providing radiation protection over extended timescales with passive controls. The ICRP's guidance has evolved over time to take account of experience, and of evolving understanding. The guidance recognises the need to protect future generations and adopts a precautionary approach in relation to the potential health effects from possible radiation exposures in the future. The ICRP recommends that individuals and populations in the future should be afforded at least the same level of protection as the current generation. This includes using current-day assessment criteria for possible future doses, and extends to transferring knowledge and any resources necessary to maintain safety.

The ICRP's guidance on the application of the three primary principles of radiological protection in relation to the post-operational phase of a DGR (see Figure 3) is summarised below.[68]

Justification for geological disposal is considered to be an issue for national policy decisions, as the existence of HLW and SF and need for their safe long-term management are direct consequences of the justification for a programme of nuclear power generation. For application of the justification principle, waste management and disposal operations have to be considered as an integral part of the practice generating the waste. This justification should be reviewed over the lifetime of that practice whenever new and important information becomes available.

Optimisation of protection is the central element of the stepwise design, construction and operation of a DGR.[69] Optimisation has to be understood in the broadest sense as an iterative, systematic and transparent evaluation of protective options, including "Best Available Techniques" for enhancing the protective capabilities of the system and reducing its potential impacts (radiological and others). In application of the optimisation principle, the radiological criterion for the design of a waste disposal facility recommended by the ICRP is an annual dose constraint for the general population of 0.3 mSv per year, and below the annual dose limit of 20 mSv per year or 100 mSv in 5 years for occupationally exposed workers. A risk constraint for the general population of 1×10^{-5} per year is recommended when applying an aggregated approach combining probability of the exposure scenario and the associated dose.

64. *Ibid*.
65. *Ibid*.
66. IAEA et al. (2014), *Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards*, IAEA Safety Standards Series, General Safety Requirements, No. GSR Part 3, IAEA, Vienna, p. 9, paragraph 1.20(c).
67. See ICRP (2013), *Radiological protection in Geological Disposal of Long-lived Solid Radioactive Waste*, ICRP Publication 122. Ann. ICRP 42(3).
68. *Ibid*.
69. *Ibid*.

The ICRP recommends that the ***public protection criteria*** be applied to the "expected evolution" scenario for the DGR, treating it as being equivalent to a planned exposure situation, even if the exposure is projected to rise during the period of no oversight. This is in recognition that the passive controls that are built into the design of the disposal system at closure should provide an equivalent level of protection to individuals in the future. Safety assessment techniques provide a mechanism for assessing the exposures and thus form the basis of the safety case for this period. However, the ICRP also recognises that over very long timescales the uncertainties in exposure scenarios, and the uncertainties in the response of far-future life to exposures, become so large as to render assessments to be no more than indicative. On very long timescales, therefore, assessed doses and risks should be used to compare between options rather than as a measure of expected health effects.

Because the future is uncertain, protecting people in the future also requires a demonstration that less likely situations would not result in exposures that would be judged unacceptable today. It is for this reason that safety assessments need to assess scenarios such as inadvertent intrusion in the DGR by humans, or a severe natural disruptive event. For severe natural disruptive events or human intrusion situations after memory of the disposal facility has been lost, the dose/risk constraint is not applied in some countries. Such scenarios are considered to be equivalent to an emergency exposure situation (at the time of the event) or as an existing exposure situation (should the event give rise to the spread of contamination).

Considerable experience is available from the analysis of post-closure safety of DGRs and indicates that the most significant potential nuclear incident in terms of the consequences for individual exposure is human intrusion. This is because siting and engineering can only mitigate the risk to a degree. By contrast, many natural disruptive events can be effectively precluded by siting in areas where they are not a threat, e.g. away from seismically active zones.

The main features of nuclear incidents for a DGR are as follows:

- the most significant potential exposure is associated with human intrusion, and the primary consequences are experienced by the intruder(s);
- the nature of the disposal system is such that major discharges of radionuclides to the surface environment following a disruptive event are not credible (the vast majority of the inventory will remain isolated and confined);
- although there might be some localised long-term contamination in the event of an intrusion (e.g. from material brought to the surface as a result of borehole drilling), the quantities of radioactivity involved will be relatively limited.

During the period of indirect oversight, administrative controls should prevent inadvertent intrusion. If it were to occur, the main focus would be the immediate vicinity of the DGR. So long as memory of the facility is retained, any required evacuation could be planned and readily applied, as could controls on the use of groundwater if there is leakage to the biosphere.

If, for whatever reason, an incident were to occur that resulted in gradual and long-lasting contamination of the environment, it would be considered according to ICRP principles as an "existing exposure" situation. The actions taken would depend on the scale of exposures for the potentially affected population. The type of countermeasures would depend on the type of releases, which would be specific to DGRs. In the longer term, any need for decontamination would depend on the extent of contamination in the geosphere, although it could in principle extend to dismantling of the DGR and recovery of its contents.

In conclusion, the capability to prevent, or respond to, a nuclear incident at a DGR would largely depend on the degree of oversight, which is related to the preservation of institutional memory regarding the existence and nature of the facility. Oversight cannot be maintained indefinitely, however. For DGRs the most important type of nuclear incident to consider in the no-oversight period is that of human intrusion. The main consequences would probably be the exposure of a very small number of people to potentially high levels of radiation, and possibly some very localised, long-term contamination.

5.4. Main challenges

In assessing nuclear liability, the potential for damage or harm is primarily evaluated on the basis of the possible consequences of incidents or unplanned situations that could lead to exposures of people.

The nature of the hazard presented by a DGR, especially after final closure, is very different from that associated with other nuclear installations, in particular nuclear power plants. As discussed, a DGR is intentionally designed to provide a stable, isolated and contained environment. This means there is an implicit limit to the scale of any incident, or uncontrolled release of radioactivity, that could occur. By contrast, the same material (nuclear fuel) is present within a nuclear power plant but in a highly energetic environment that could, under accident conditions, disperse high concentrations of radioactivity widely. Of particular concern to nuclear liability are such "beyond design basis" situations.

In order to understand how nuclear liability applies to DGRs, equivalent scenarios must be considered. Furthermore, in evaluating the accident risk posed by a DGR, it is necessary to distinguish the various phases of the life cycle of this type of facility, as different hazards will be present at different times. Safety case development and safety assessment methods include systematic, transparent and rigorous processes to identify such situations for the period of pre-operations, operations and afterwards.

During the period of waste emplacement, normal operations will ensure that waste is contained and exposures are controlled. The need to handle and emplace the waste does, however, mean that there is the possibility of an accident. The types of incidents that might occur are broadly analogous to those that could occur at any waste management facility or in an underground mine. Conventional mining hazards require effective controls against, for example, rock fall, fire and flooding. Radiological hazards are mainly concerned with events during handling and emplacement of the waste that could breach the waste container and disperse its contents. Such situations will routinely be assessed in the development and maintenance of an operational safety case for the DGR. The worst-case scenario could potentially result in exposures to nearby members of the public if radionuclides released from damaged waste containers were carried to the surface, for example via the DGR's ventilation systems. Nevertheless, the total quantity of radioactivity involved and its potential for dispersal from a DGR is very much lower than could be the case for a major accident at a nuclear power plant.

There will be no such activities that could give rise to such an accident during the post-closure phase, as the DGR will be sealed. Because geological environments are predictable over very long timescales, it is possible to quantitatively assess the impact from the expected evolution of the disposal system with a degree of confidence, and conservative assumptions can be made to set bounds on the estimated maximum impact. However, there remains the possibility that, despite best endeavours, the disposal system might not function as planned. Over very long timescales, natural disruptive events could compromise the engineered and natural barriers, or the barriers might perform substantially worse than planned (perhaps due to undetected defects during manufacture or construction). Such scenarios are examined with safety assessment calculations. It is this latter category of situations that are most relevant to consider in forming a view on liabilities, as they are equivalent to "beyond design basis" situations for nuclear power plants, rather than those that are normally central to the compliance evaluation undertaken in a safety case (the "expected evolution" of the disposal system).

Because of the multiple barrier approach to the design of DGRs, it is unlikely that health impacts will rise very substantially, even if individual barriers do not perform as planned. Safety analysis, as part of the safety case, provides evidence to quantify the level of health impact and thus determines the potential scale of any liability issues. This can refer to internationally recommended safety targets for geological disposal, which are set below the public dose limit and so have an intrinsic safety margin.

However, in the post-closure phase there is a situation that could give rise to exposures exceeding the dose limit. Human activities, specifically geological investigation and characterisation, have the potential to inadvertently bypass the barriers of the DGR and could bring waste directly to the surface (e.g. in drilling mud or as a core sample) or result in a more direct pathway to the surface for the radionuclides in the DGR. The high concentrations of long-lived radionuclides in HLW and SF mean that there is a risk of serious health effects in relation to such a situation, even if it occurred in the far future. Once again, established safety assessment processes can quantify the associated impacts as part of the development of a safety case.

One reason for isolating the waste through disposal at depth is to minimise the likelihood of such a situation. Inadvertent human intrusion can also be effectively prevented while there is some oversight of the DGR through the maintenance of land-use controls in the vicinity of the DGR. Records management is also a valuable tool in reducing the likelihood of human intrusion by maintaining knowledge of the presence of the radiological hazards represented by the waste in the DGR. However, the possibility of intrusion cannot be discounted over very long timescales because future human societies are not predictable, and the retention of land controls and knowledge cannot be guaranteed. This also means that the likelihood of inadvertent human intrusion cannot be meaningfully established (although it can reasonably be considered to be a remote possibility in any one year, given the relative infrequency of geological exploration to depths of several hundred metres).

Throughout the DGR life cycle, and in particular upon its closure, national regulators will evaluate projections of safety on the basis of the assessed impacts from all such scenarios. It is only when a sufficiently robust final safety case has been made, closure engineering has been installed and verified, and the impacts from a DGR are judged to be acceptable that the termination of the licence will be permitted. As explained in Chapter 2, the demonstration of a sufficiently low impact could also potentially form the basis for exclusion from the application of the international nuclear liability conventions after final closure. However, this might require analysis of a wider range of scenarios than might conventionally be considered relevant for safety case purposes for regulatory compliance. In particular, there may be a need for assessment of a wider range of scenarios that correspond to “beyond design basis” situations.

Over time, it is possible that the safety standards against which the DGR is assessed might change. However, radiation dosimetry and radiological protection knowledge is now mature and major changes to the current understanding are considered unlikely. Furthermore, the impact criteria applied are equivalent to or lower than those applied to other environmental and human health risks (e.g. chemical contaminants) and so more stringent controls are considered unlikely.

In relation to nuclear liability, the key issue that remains is the interpretation of risks from DGRs, and especially those that result from human intrusion and other “beyond design basis” scenarios. While proper siting and design can reduce to insignificant levels the probability of natural events leading to possibly high exposures, it is difficult for the likelihood of human intrusion to be quantified meaningfully. The interpretation of such situations in the context of liability is therefore a key challenge.

Also regarding nuclear liability, it was noted that some of the potential accident scenarios for DGRs, combined with the very long time frame for such installations, could make the application of the nuclear liability regimes very complicated. In the event of a gradual pollution taking place well into the post-closure phase (especially when there is no oversight) at a level significantly higher than anticipated in the safety case, e.g. owing to major unforeseen defects in barrier performance, damage could be caused to the environment and possibly to human health. However, it might prove very difficult for victims to demonstrate the causal link between the damage suffered and the alleged nuclear incident, to technically prove the reality of a nuclear damage caused by a leak occurring at a DGR and to determine with certainty the applicable prescription period, as it will be difficult to determine when the nuclear incident actually started to occur. These difficulties are therefore not specific to the nuclear liability regime: it appears that, in many cases, applying ordinary tort law would only provide for additional difficulties, without solving any of the aforementioned problems. For this reason, it may be relevant to discuss, in due time, potential alternative liability regimes that would ensure that the rights of victims are duly ensured.

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Deep Geological Repositories and Nuclear Liability

The disposal of long-lived radioactive waste in a deep geological repository (DGR) is a scientifically and technically credible solution that meets the need for long-term safety without reliance on active monitoring and management. Nevertheless, it is important to assess the potential risks that may be associated with such a nuclear installation and to ensure that an appropriate regime is in place to adequately compensate third parties in case they suffer nuclear damage caused by a DGR. Therefore, countries developing or intending to develop DGRs must take into account nuclear third party liability regime(s) as long as they apply to the disposal facilities. Those regimes establish a specific legal system that deviates from general tort law principles, including strict and exclusive liability of the operator of a nuclear installation, which will have to maintain a compulsory financial security to cover its liability.

Given the unusually long life cycles of such installations, this report discusses issues that concern future generations against the background of the currently applicable legal frameworks for the operation of nuclear installations, and existing technical knowledge, conscious that both will evolve. Nevertheless, it is important to identify and address potential issues regarding nuclear liability with the currently applicable legal frameworks and to set a clear framework for the applicable nuclear liability regime(s) during the different phases of operation of the DGR.

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