Timetable for Decision Making

Domain Insight 1.1.2

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Overview

This Domain Insight covers the development and maintenance of broad timescales and schedules for implementing the radioactive waste management activities leading to geological disposal, using a stepwise decision-making process (in short, the 'timetable for decision making').

The ability to set and maintain a time schedule for all the activities that are needed to meet the requirements of the disposal programme is critical with respect to ensuring the eventual safe achievement of disposal and to managing the technical and human resources, as well as the funds that are required to complete the programme.

The core elements of time scheduling are the identification of the sequence of steps that need to be taken, the appropriate time at which they need to be taken, the organisations involved and their respective roles, and the information and resources needed to move from one step to the next. Taking each step requires identification and assessment of the options available (optioneering) and an efficient and transparent procedure for taking effective decisions (decision-making).

Keywords

steps, staging, timeframe, schedule, requirement, decision, decision-making, option, optioneering

Key Acronyms

DBDF	Deep borehole disposal facility
DGR	Deep geological repository
MNR	Multinational repository
NPP	Nuclear power plant
QC	Quality control
RWM	Radioactive waste management
URCF	Underground rock characterisation facility
WMO	Waste management organisation

1. Typical overall goals and activities in the domain of the Timetable for Decision Making

Effective management of a national inventory of radioactive wastes requires a defined time framework and stepped schedule within which the necessary activities can be planned and carried out. A generic example of repository development stages produced by the IAEA and applicable to all types of disposal facility is shown in Figure 1.

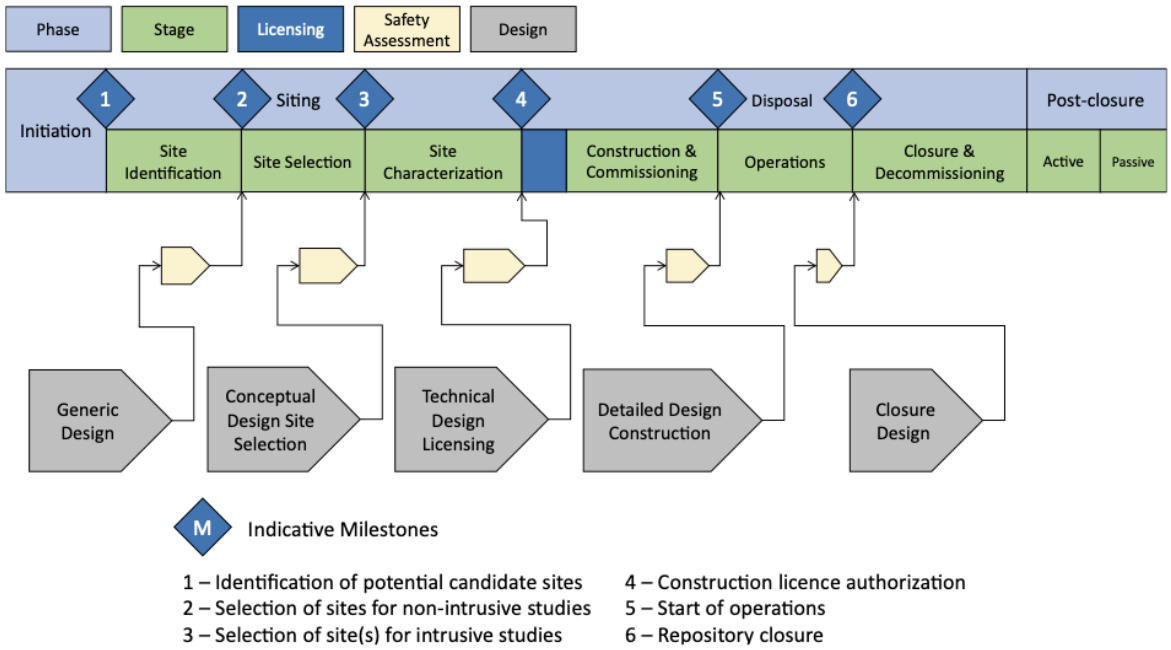


Figure 1: Generic repository lifecycle and associated design stages aligned with indicative project milestones (from IAEA, NW-T-1.27, 2020)

Whilst there are recognised common steps in deep geological repository (DGR) development, such as those shown above (and the EURAD Roadmap is based on five generic phases, themselves based on a further IAEA, DGR-specific, roadmap), there is no specific, widely recognised radioactive waste management (RWM) *timeframe* set out in international guidance, as it is acknowledged that there are many technical, political and societal drivers that will affect the duration of steps and the order and possible time overlapping of sub-steps, and most of these will reflect national policy and preferences. In some cases, national RWM policy (see Domain Insight 1.1.1) might establish broad time requirements or even target dates for the achievement of various steps in the process, but it is normally up to the waste management organisation (WMO) to develop a detailed schedule that matches all the requirements that it must address, within the framework of national policy. Experience of over 40 years of programme development in the EU is that target dates set for completion of RWM activities have seldom been met, and allowance must thus be made in the time scheduling of activities for delays in some key steps. The most serious delays to time schedules have occurred in the siting of DGRs and in the legal, political and regulatory steps involved in permissioning and licensing. When programme steps become extended it can cause significant problems in the planning and management of staff and resource allocations, with impacts on programme costs and even on viability. Generally, the clear definition of roles, responsibilities and requirements of the organisations involved in decision-making, and of the detailed process itself, can go a long way towards avoiding problems.

Schedules and timescales need to be built up in detail from the identified major programme steps (EURAD Roadmap Phases), each of which is likely to require some form of choice or decision before moving on to the next stage. Additional steps will be identified within each Phase and will need to be

included in the time schedule estimates. Typically, each major stage of the RWM process (and many of the minor steps) will be faced with a number of options for how, when or where to carry out activities. These options will have arisen from application of a requirements management system, where an optioneering process will have identified the alternative approaches for how to manage a step in the RWM process and meet the requirements placed on (or generated by) the WMO. At the end of each step, decisions are required on how to move forward to the next step, based on the practical experience and results of carrying out the work to date. This focusing point, before moving on, is sometimes referred to as a 'stage gate', and several WMOs use gated procedures to progress with their schedules.

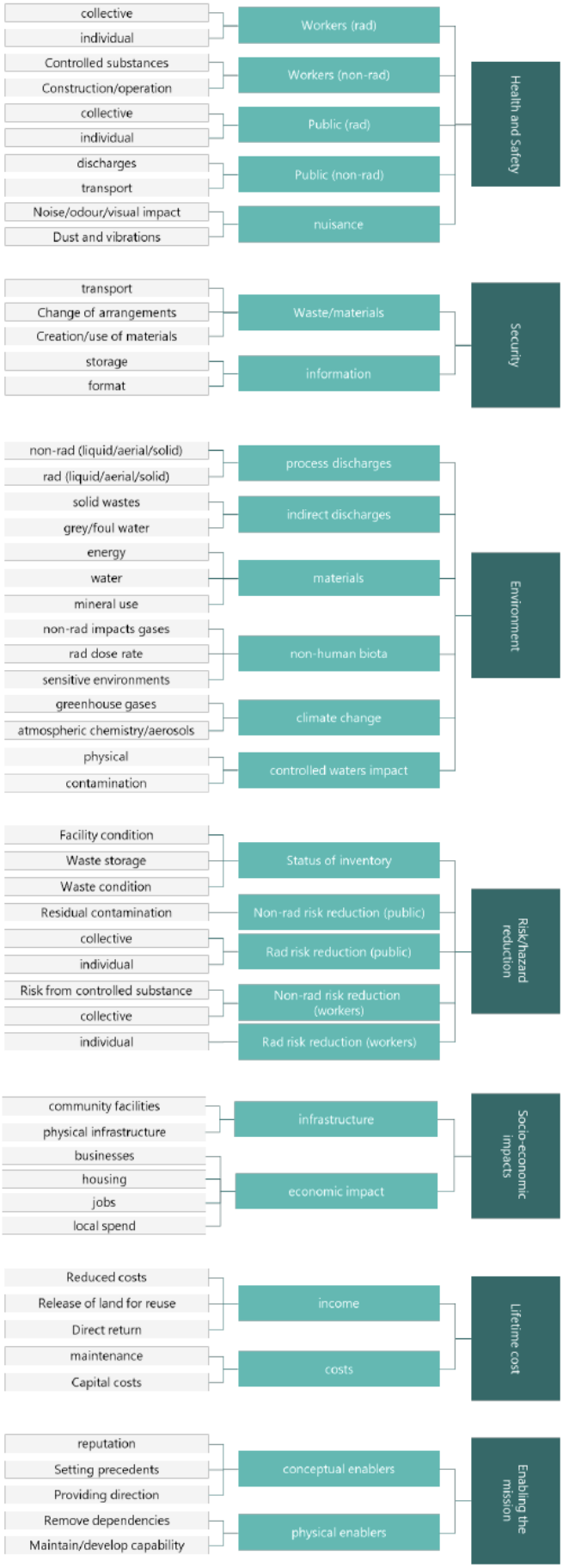
An essential consideration for a new DGR development programme is to establish broad agreement among key stakeholders as to which organisations and groups will be involved in decision-making. While some roles are generally clear (for example, those of government and the national authorities involved in making regulatory licensing decisions), other decisions can be managed in various ways and an initial process of consultation may be helpful in establishing organisational relationships. Where consultations have taken place, they have usually been led or initiated by the national government. Section 2 gives examples of how stakeholders might typically be involved in making key decisions at various programme stages.

1.1 Optioneering and decision-making

The most critical decisions in a DGR programme are those that involve siting, design and scheduling. As shown in the tabulated example in Section 2, some decisions, especially some of the earliest strategic decisions that will frame the programme and its timetable, are entirely the responsibility of government, or the DGR owners or end-users. As the programme develops, decisions will begin to involve other stakeholders, and gathering and organising the information required, and assembling the options to be considered, is generally the role taken by the WMO. Here, the WMO needs to have a clear understanding of the constraints and drivers affecting other stakeholders and how each stakeholder will process information, become involved in the process, and make its own, internal decisions.

For design and siting work in particular, a WMO would be expected to develop and apply a formal process of decision-making, which needs to be transparent, professionally managed and well-recorded, as the rationale and data used for decisions could well need to be revisited, perhaps many years in the future, as project boundary conditions respond to inevitable change. The decision-making procedure will be used many times in the lifetime of a RWM programme and needs to be able to accommodate a wide range of decisions, from broad, multi-stakeholder matters such as the choice of a DGR site, to detailed technical issues such as the choice of a waste container lining material.

The nature of the procedure can be different for different types of decision, reflecting their relative importance, priority and complexity. As observed in the UK NDA Value Framework (NDA, 2021): *"Consideration should be given to including the decision-maker(s), internal stakeholders... and external stakeholders, in addition to technical experts within the relevant assessment panel. When decision-makers are not part of the assessment panel, they should at least be aware of and supportive of the assessment approach. In general, wider stakeholder engagement is encouraged."* There are several established techniques for assessing options and using analyses to guide and underpin decisions, with varying degrees of formality. Decision analysis is used widely in manufacturing industries and other engineering sectors. Typically, attributes will be assigned that cover the requirements, functions and characteristics of options, and these are assessed either qualitatively (e.g., in simple pair-wise comparison methods) or quantitatively, by scoring the utility of an option for each attribute and weighting attribute scores according to preferred outcomes (e.g., in multi-attribute decision analysis), allowing options to be ranked. An example of a high-level set of attributes that could be evaluated in comparing disposal concepts and/or siting options is included in the NDA Value Framework mentioned above, and is shown below.


collective
individual
Controlled substances
Construction/operation
collective
individual
discharges
transport
Noise/odour/visual impact
Dust and vibrations
Workers (rad)
Workers (non-rad)
Public (rad)
Public (non-rad)
nuisance
Health and Safety
transport
Change of arrangements
Creation/use of materials
storage
format
Waste/materials
information
Security
non-rad (liquid/aerial/solid)
rad (liquid/aerial/solid)
solid wastes
grey/foul water
energy
water
mineral use
non-rad impacts gases
rad dose rate
sensitive environments
greenhouse gases
atmospheric chemistry/aerosols
physical
contamination
process discharges
indirect discharges
materials
non-human biota
climate change
controlled waters impact
Environment
Facility condition
Waste storage
Waste condition
Residual contamination
collective
individual
Risk from controlled substance
collective
individual
Status of inventory
Non-rad risk reduction (public)
Rad risk reduction (public)
Non-rad risk reduction (workers)
Rad risk reduction (workers)
Risk/hazard reduction
community facilities
physical infrastructure
businesses
housing
jobs
local spend
infrastructure
economic impact
Socio-economic impacts
Reduced costs
Release of land for reuse
Direct return
maintenance
Capital costs
income
costs
Lifetime cost
reputation
Setting precedents
Providing direction
Remove dependencies
Maintain/develop capability
conceptual enablers
physical enablers
Enabling the mission

The attributes shown could be treated using qualitative methods or broken down in more detail to enable quantitative scoring of options.

All methods of decision analysis involve applying expert judgement. As with decision analysis itself, there are also formal methods for managing the inputs of experts so that the process and outcomes are transparent. For critical, high-profile decisions (e.g., siting choices) it can be appropriate to have independent management of the procedure by skilled facilitators.

The power of any form of properly structured decision analysis is that it:

- requires comprehensive identification and treatment of options so that all feasible solutions are dealt with equally;
- assembles relevant information in a structured manner so that the baseline data underpinning decisions is recorded and can be evaluated by others, perhaps at a later date;
- can incorporate uncertainties in the data used in making a decision;
- highlights the key reasons (i.e., attributes) that lead to certain options being preferred and, where weightings are applied to selected attributes, records the preferences and reasoning of the group that makes a decision;
- facilitates subsequent adaptation within a disposal system if boundary conditions change or new options come available ('change control');
- forces clarity in the justification of a decision.

Establishing options identification and evaluation (optioneering) procedures and a decision-making framework, closely linked to a requirements management system, is a high priority for a WMO embarking on a DGR programme. As discussed earlier, this needs to be embedded within a nationally adapted roadmap that identifies the key development steps, the roles of, and the actions needed by different stakeholders, and how decision making within different stakeholders interacts and can be integrated with the progress of the technical waste management programme. The overall framework can be expected to adapt as experience is gained and as the programme becomes broader and deeper.

1.2 Policy and strategic drivers affecting programme steps

The principal **policy and strategic drivers** affecting the stepped structure of a DGR programme and the timescales for these steps include:

- Any national policy or legal requirements, for example:
  - the time of completion of the RWM programme, or elements of it;
  - the numbers and locations of RWM facilities or alternative sites that must be considered;
  - the way in which a DGR is to be managed once waste has been emplaced (e.g., to allow prolonged access or to facilitate reversibility);
  - the way in which public stakeholders must be involved in decision-making;
  - whether to recycle or reprocess SNF (this could equally be a waste-producer decision).
- Supra-national legal requirements placed on the WMO, such as EU Directives requiring environmental submissions to be submitted and approved; agreements with neighbouring countries on review of licensing materials; nuclear safeguards surveillance requirements.
- The planned lifetime of the waste-generating facilities (nuclear power plants (NPPs), waste processing plants etc.).
- The availability of the necessary funds to proceed with each stage of the project and the decisions involved in optimal economic management of any public or private waste management fund.
- National or waste-generator plans for future NPPs (and advanced NPP technologies) whose wastes might need to be accommodated.
- The rate of generation of wastes destined for geological disposal.

- The planned lifetimes of storage facilities, affecting the times at which waste needs to be removed and/or the strategy for additional storage.
- The number and nature of the licensing and approval stages for RWM facilities, and their information requirements, that are defined in national policy or by regulatory agencies.
- Any agreements made with communities on the duration of RWM activities or the end-state of (e.g., storage) facilities.

For the development of shared, multinational solutions, such as a multinational repository (MNR), all of these drivers would need to be considered for each user-country contributing waste to the scheme. Producing an integrated timetable for an MNR will thus be a complex undertaking and will involve more organisational actors (with possibly a wider set of requirements) than would a purely national DGR programme.

It should be recognised that many of the policy and strategic drivers listed above could change during the long lifetime of a DGR programme. Some national DGR schedules envisage a programme lifetime of well over 100 years. In this period, strategic change is inevitable, so a well-structured programme being established today would endeavour to be as robust as possible to changes in order to respond effectively to, and accommodate, potential changes. Ensuring robustness implies deferring some critical decisions to the latest possible time without impacting on safety or utility, or resulting in unacceptable costs.

1.3 Technical and societal drivers affecting programme steps

In addition to strategic drivers, there will be a range of **technical and societal drivers** that will have major influences on schedule development. These include:

- Whether established processes are to be used for RWM activities, using available technology and/or established suppliers.
- Any requirement for concept, material, design or process development that will necessitate RD&D work.
- The extent to which shared technology development activities or shared pre-disposal facilities can reduce RWM times.
- The time required for heat-generating wastes to be sufficiently cool to be managed.
- The time required to establish, legitimise and carry out site-selection programmes for disposal facilities, which today would be expected to use a volunteer engagement approach to identify potential communities and locations.
- The approach to be used for characterising disposal sites.
- The approach to be used for repository concept and safety case development, which will depend on the suitability of the sites considered and the technical maturity of the stakeholders involved.
- Any WMO or regulatory requirement for pilot or demonstration underground rock characterisation facility (URCF) stage in DGR development.
- Construction times for facilities.
- Expected or planned operational rates of waste throughput or emplacement.
- The advent of new and more efficient waste handling/packaging or construction technologies.

There is now sufficient experience internationally to be able to make reasonable estimates of the times required to address each of these two groups of drivers (policy/strategic and technical/societal). The initial task of a WMO is to develop a stepped programme that includes work and/or time allowances to address them.

1.4 Other geological disposal options

Deep borehole disposal

Several countries are currently considering the possibility of disposing of some parts of their waste inventory in deep boreholes, with the disposal zone located at considerably greater depths than a DGR

(deep borehole disposal – DBD – in a deep borehole disposal facility – DBDF). Effective work on this technology, along with the development of supporting safety cases, has only begun in the last few years and the concept is consequently less developed, with some key aspects of the technology requiring testing and demonstration. However, it is clear that many of the steps in siting, design, safety assessment and licensing would be equivalent to those for a DGR, with similar types of requirement and similar decisions needing to be managed. The roles of stakeholders are also likely to be parallel to those experienced in existing DGR programmes.

National programmes that intend to develop a DBD approach could also require access to a DGR for other wastes in their national inventory and might need to develop both types of facility, with a consequent need to bring the decision-making required for both types of facility into an integrated framework.

Multinational disposal

Some countries have a 'dual-track' RWM policy, whereby their national DGR programmes run in parallel to exploration of possible geological disposal of some or all of their higher-activity wastes in a common, multinational repository (MNR). An MNR might be a joint enterprise by countries that will share the development and use of the facility, or it could be developed as a commercial enterprise by one country, with services offered to others.

A dual-track policy introduces additional decisions into a national RWM programme that focusses on geological disposal, with significant changes in the roles of, and requirements on, most of the stakeholders involved. While the strategic and technical nature of the decisions will be similar to those for a national DGR, WMOs, regulators and waste producers from multiple countries will have the additional and complex task of integrating their requirements. For example, while the MNR host country is likely to follow a similar technical development path to that needed for a national DGR programme, it will also need to incorporate requirements and decisions made by each of the user countries – on issues such as inventory, design, scheduling, licensing and costs.

1.5 Building a stepped schedule for disposal

Identifying at a coarse level the major steps in a RWM programme is a starting point for developing a time schedule and identifying the decisions that are likely to be needed. Here, we consider the management of a national waste inventory destined for geological disposal.

Domain Goal	
1.1.2 Develop and maintain broad timescales and schedule for implementing radioactive waste management activities using a stepwise decision-making process (Timetable for decision making).	
Domain Activities	
Phase 1: Programme Initiation	Establish a **broad timeframe for achieving an operational DGR**. This will involve negotiation between national policy makers, DGR end-users, the WMO and the organisations funding the project. Key factors will include: • the planned inventory (e.g., whether limited to specific waste producing facilities/users; whether limited or open-ended in operating time) • the time at which funds are made available by or to the project owners • the status of existing and planned waste processing and storage facilities (including, e.g., SNF reprocessing and HLW transfer schedules; time-limited storage facilities; cost-optimised storage arrangements) • the nature and estimated timescales of any dual-track RWM programme that might lead to development of an MNR in the national area, or transfer of wastes abroad. Establish a **framework for decision-making** that assigns decision responsibilities to the various actors. It is critical to know which organisation will take which major decisions and the information that will be needed for them to do so. The WMO will have the most decisions to manage and will need to establish a **formal approach to optioneering** and decision-making that covers both major and minor option selections.
Phase 2: DGR Site Identification	Ensuring transparency and credibility of the decision-making process used in identifying one or more preferred sites is a critical part of any DGR programme. The process and criteria need to be clearly established before the site identification phase begins. Define the **technical and societal approach** to be taken to DGR siting. This might be specified in national policy or law. Most programmes would now be based on attracting volunteer communities to host a DGR. The schedule needs to include agreeing the procedures and consultation periods for engaging with communities nationally, and for narrowing down to those that have characteristics that offer mutual benefits and possibilities to both the WMO and the community. Part of this process is likely to involve regional evaluations to locate areas of interest and/or remove technically (and, possibly, non-technically) **excluded areas**. Define the approach to be taken to DGR development, including the **time required for assessment of alternative disposal concepts and selection of preferred concepts**. This will allow a **stepped siting programme** to be developed, along with estimates of the time required for each step.

Phase 3: DGR Site Characterisation	This might involve work at more than one location. It might also involve progressing with more than one DGR concept in more than one geological environment. The time schedule must take account of the likely durations of the following possible steps: • remote and surface-based investigations • narrow down to one site before going to underground investigations • underground investigations involving excavations • a possible URCF demonstration facility During these steps, the WMO will need to take many decisions that respond to the developing findings of the characterisation work. Fitting conceptual designs to the actual site properties and adapting the concept to become a practical DGR **design basis** linked to a **site-specific safety case** that includes performance targets for the DGR system and components will be important steps. Interspersed with these steps will be the time required for the relevant local **community engagement and approvals** and the regulatory **approval and licensing** steps. An important decision 'gate' at the end of Phase 3 is likely to be application for and approval of a **license to construct** the DGR. Depending on national policy and legal stipulations, there may be requirements for **government approval** of decisions made by other agencies, with time schedule implications.
Phase 4: DGR Construction	In some programmes, it is planned that some parts of the DGR, such as some access shafts/tunnels and caverns would be constructed as part of Phase 3 Site Characterisation underground activities but, in others, the step of going underground is seen as the first phase of repository construction. The subsequent **construction time schedule** will begin with initial extension into the disposal areas. The schedule will be determined by factors such as whether all of the DGR is to be constructed before operations begin, or whether construction and disposal are to progress in parallel, and time/cost optimisation (as the main stage of construction is the most resource-intensive stage of the DGR lifecycle). Construction factors that can impact on the time schedule include the procedures to be used for **quality control of excavations and approval for use** of excavated caverns, tunnels and boreholes. The decision-making procedure needs to be clearly established and auditable. The WMO will need to have **testing procedures linked to finalised design specifications** for accepting volumes of rock as being fit for purpose for waste emplacement. Allowance needs to be made for a certain amount of construction being rejected, with consequent time and cost implications. Depending on agreed national policy, this Phase might conclude with a step that converts a construction license to a **license to operate** the DGR (i.e., to emplace waste). This might require an updated operational and/or post-closure **safety case**, based on information obtained during DGR construction. Alternatively, national policy might be to combined construction and operating licensing at the end of Phase 3, but it is likely that a regulator would still require some form of further approval based on construction experience before the first waste is emplaced.
Phase 5: DGR Operation and Closure	The operational time period will be determined by the **rate of waste delivery** to the DGR, which will depend on many factors, including pre-disposal processing and storage arrangements, the lifetime of waste generating facilities and the optimised rate of waste emplacement. In its decision-making procedures, the WMO needs to allow for the possibility of **lifetime extension** of a DGR resulting from changes in inventory, perhaps caused by an evolving national nuclear power programme. This implies a procedure that keeps operational options open for as long as is reasonable without affecting safety or the efficient use of available funds. Although sections of the DGR will be closed during operations, the time schedule for final closure will depend on arrangements made to facilitate **reversibility**: e.g., policy might require a protracted open period after final waste emplacement. Following closure, the time schedule may need to include arrangements for **long-term monitoring** of the DGR site for environmental, security and safeguards purposes.

2. A generic example of a Timetable for Decision Making based on international experience

Every active national DGR programme in Europe has its origins more than 40 years ago and most project DGR operations continue past the end of this century. The time schedules that have been involved so far and are currently envisaged for the future are consequently over 100 years long. In response to the widespread delays, redirection and cancellations that were prevalent in 20th century RWM programmes, there has been enormous change in approach over the last 25 years, and analysis of much of the prior international experience of the durations of Phase 1 and Phase 2 steps, activity durations and decision-making procedures is unedifying. Today, the majority of European RWM programmes are established more firmly and, with the advent of improved stakeholder definition and engagement, consent-based facility siting and modern systems engineering approaches to design, optioneering and decision-making, it is feasible to identify and integrate the best international experiences and time schedules to provide a generic model.

The table below provides such a model, giving indicative durations for the major programme steps and the typical key decisions that will be encountered in each. The intention is to show how these might develop in a new national DGR programme. The list is not exhaustive and will not necessarily be applicable to every new RWM programme, as national preferences and requirements will shape programmes differently. The links between programme steps and the EURAD Roadmap Themes and Sub-Themes are indicated.

Phase	**Typical Steps affecting project timetable**	**Typical Duration (years)** Note that these may overlap	**Key decisions and main organisations involved** G = government R = regulator W = WMO E = end-user O = DGR owner C = host community
Phase 1: Programme Initiation	Define national policy and programme framework for geological disposal and ensure organisations and initial resources are in place and operational *Roadmap Theme 1, Sub-Themes 1.1 to 1.4*	2 to 5	Roles and responsibilities (G) Inventory to be disposed (G, E, O) Time and cost boundary conditions (G, E, O) Framework for project decision-making (W) Approach to optioneering (W)
Phase 2: DGR Site Identification	Define technical and societal approach and implement stepped siting programme up to point of identifying preferred site, including community involvement *Roadmap Theme 6, Sub-Themes 6.1 and 6.2*	3 to 5	Consultation and agreement on approach (G, W, C) Nature of benefits programme (W, O) Agreement to participate (C, W) Technical siting guidelines (W, R) Procedure for site comparison and selection (W, C, R)
	Regional evaluations to locate areas of interest and/or remove technically (and/or non-technically) excluded areas *Roadmap Theme 4, Sub-Theme 4.2*	2 to 3	Exclusion/inclusion criteria (W, R)

	Identify and select appropriate disposal routes, options and concepts for national radioactive waste inventory *Roadmap Theme 1, Sub-Theme 1.5; Theme 2, Sub-Themes 2.1 and 2.2; Theme 5, Sub-Themes 5.1 and 5.2*	2 to 3	Identify disposal concept(s) for DGR, DBD etc. (W, O) Procedure for option and concept selection (W, R)
	Initial evaluation of site suitability and performance in an initial safety case *Roadmap Theme 4, Sub-Themes 4.1 to 4.3*	2 to 3	Approval in principle of site suitability to proceed to site characterisation (W, R, O, G)
Phase 3: DGR Site Characterisation	Characterisation steps: • remote and surface based investigations • narrow down to one site before going to underground investigations • underground investigations involving excavations (some programmes would consider these to be in Phase 4) • possible URCF demonstration facility *Roadmap Theme 6, Sub-Theme 6.2*	5 to 10	Selection of preferred site from a group that have been assessed (W, R, C, G, O) Consider inclusion of a URCF stage and, if yes, its goals (W, C)
	Development of design basis and site-specific safety case *Roadmap Theme 5, Sub-Theme 5.4; Theme 7, Sub-Themes 7.1 – 7.3; Theme 3*	2 to 3	Identify preferred concept and design for preferred site (W, O)
	Community engagement *Roadmap Theme 6, Sub-Theme 6.3*	ongoing	Agreement to proceed with the site (W, C) Agreements on design factors affecting community (W, C)
	Produce site-specific safety case and submit application for license to construct *Roadmap Theme 6, Sub-Theme 6.3*	3 to 5	License approval and conditions (R)
Phase 4: DGR Construction	Initial construction stages of first disposal areas	2 to 4	Rate and staging of construction: time-cost optimisation (W, E, O) Management procedures of classified areas of DGR (W, R)
	Develop and test procedures for quality control (QC) of excavations and approval for use *Roadmap Theme 5, Sub-Theme 5.2*	2 to 4	Approval of testing to meet design specifications (W, R)
	Updated design basis and safety case, and submit application for license to operate	2 to 5	Final design specifications to move to operation (W, E) License approval and conditions (R)

	Roadmap Theme 5, Sub-Theme 5.4; Theme 7, Sub-Themes 7.1 – 7.3; Theme 3		
Phase 5: DGR Operation and Closure	Demonstration emplacement of first waste, followed by routine emplacement	15 to >100	Define waste emplacement schedule (E, O, W) Possible lifetime extension or inventory extension (O, E, W, R, G, C)
	Closure of completed sections of DGR	ongoing	Decision to close a DGR section (W, R)
	Possible management of open DGR after final emplacement, before final closure ('reversibility period') *Roadmap Theme 5, Sub-Themes 5.3 and 5.6*	0 to 100	Duration of reversibility period (W, O, C) Reversibility triggers and objectives (R, W, O, C, G)
	Implement adapted monitoring programme evolving from Phase 3-5 monitoring to post-closure monitoring *Roadmap Theme 5, Sub-Theme 5.5*	open-ended	Design and objectives of post-closure monitoring (W, O, R, C)
	Final closure	3 to 5	Decision to close (O, W, R) End-state of site (O, W, C)

3. Further reading

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