1. PROGRAMME MANAGEMENT; THEME OVERVIEW

Implementing a National RWM Programme leading to Geological Disposal

Geological disposal is the preferred solution for some of the radioactive wastes (RW) in almost every national inventory, with all EU Member States eventually requiring access to some form of deep geological repository (DGR), unless all their present and future arisings of higher activity wastes can be returned to their country of origin. Implementing a DGR is thus the endpoint of many national programmes and is also the most complex and difficult activity that they will have to undertake. Getting to an effective solution has to be done within the framework of a broadly-based and comprehensive national programme that addresses all aspects of radioactive waste management (RWM) for all of the wastes in the national inventory and all of the RWM facilities that will be needed. This Theme looks at how geological disposal can be implemented within the framework of a national RWM programme. It focuses on some of the practical experiences of more advanced programmes as they move through the phases of work that lead to a DGR. A national RWM programme requires a strong foundation of national policy that defines overall objectives, a schedule and the legal framework for implementing waste management, transport, storage and disposal solutions. The legal framework should include provisions stipulating the responsibilities of waste producers, waste owners and the national regulatory authorities. It should identify the mechanisms for funding the national RWM programme. The national RWM programme should operate inside a strong infrastructure of effective organisations with sound management systems and clear interaction procedures. There should be a clear policy of involving relevant external stakeholders in decision-making processes. In the early phase of establishing national policy or developing a RWM programme there is documentary and advisory support available from the IAEA, along with decades of experience encapsulated in EU-wide good practice.

KEYWORDS: policy, law, responsibility, regulation, schedule, interaction, resources, requirements, stakeholder

KEY ACRONYMS: RW – radioactive waste; RWM – radioactive waste management; DGR – deep geological repository; WMO – waste management organisation; MS – Member State; RMS – requirements management system; WBS – work breakdown structure; MIR - medical, industrial and research wastes; IAEA – International Atomic Energy Agency; ERDO – European Repository Development Organisation.

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TYPICAL PROGRAMME MANAGEMENT GOALS PURSUED BY NATIONAL RWM PROGRAMMES

This section provides a goals breakdown structure (GBS) for the EURAD roadmap theme 1 on programme management. It is organised in a hierarchy of three levels according to theme > sub-themes > domains.

Theme (Level 1)	
1. Implement a national programme for the management of spent fuel and radioactive waste, covering all types of spent fuel and radioactive waste under its jurisdiction and all stages of spent fuel and radioactive waste management from generation to disposal (National Programme Mgt.)	
Sub-themes (Level 2)	**Domains (Level 3)**
1.1 Establish the national policy and plan for radioactive waste and spent fuel management activities, from generation to disposal (Programme Planning)	1.1.1 Establish and maintain a national plan for radioactive waste management, including a nuclear fuel cycle strategy (e.g., open or closed cycle) for those countries with, or intending to use, nuclear power (National RWM Policy).
	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)
	1.1.3 Ensure that public information on radioactive waste and spent fuel and a process for public participation are available (Public information and participation)
	1.1.4 Establish a process for progressive development and optimization of the plan (safety, security, use of resources)
1.2 Establish and maintain a national regulatory and organisational framework for the timely implementation of all steps of spent fuel and radioactive waste management, from generation to disposal (Programme Organisation)	1.2.1 Establish and maintain a competent and independent regulatory body and system for licensing (Licensing framework)
	1.2.2 Establish regulatory criteria for waste management facilities, based on international standards (Licensing criteria)
	1.2.3 Establish and maintain organizational structures or license holder(s) having overall clear responsibility for any activity or facility related to the management of spent fuel and radioactive waste (Allocate responsibilities)
	1.2.4 Implement a system of appropriate oversight, a management system, regulatory inspections, documentation and reporting obligations for radioactive waste and spent fuel management activities (Waste management System)
	1.2.5 Establish and implement a research, development and demonstration strategy with activities clearly related to timeframes, concepts, plans, and milestones defined in the national programme (RD&D Strategy)

1.3 Ensure that adequate financial and human resources (core capability and supply chain support) are available, and can be adapted to the changing needs of the programme over many tens of years, from generation to disposal (Programme Resources)	1.3.1 Specify a funding mechanism to ensure that adequate financial resources are available when needed for the implementation of the national radioactive waste programme (Financing Scheme)
	1.3.2 Develop and maintain a technical and management skill base within the programme (core capability), meeting national regulatory competence requirements (Skills and Competence Management)
	1.3.3 Use the knowledge, technology and experience gained internationally and co-develop RD+D where possible to improve and consolidate confidence in the scientific and technical data base, to help reduce risks to successful programme implementation and to avoid unnecessary costs (International Cooperation)
	1.3.4 Work collaboratively with delivery and specialist organisations nationally and internationally to obtain value for money (Procurement & Supply Chain Arrangements)
1.4 Establish and maintain a national inventory of radioactive wastes (National inventory)	1.4.1 Develop and maintain an inventory of all spent fuel and radioactive wastes from all sources and activities, together with estimates for future quantities arising, including the characteristics, location, ownership (responsible organisation) and amounts, in accordance with an appropriate classification scheme (National radioactive waste inventory)
1.5 Identify and select appropriate disposal routes and concepts for the national radioactive waste inventory (Management Solutions)	1.5.1 Identify and evaluate potentially available concepts and technical solutions for spent fuel and radioactive waste management, taking account of national or local conditions, such as available predisposal and storage options, geological environments, national technical and economic resources and expertise etc. (Integrated waste management routes and strategic options)
	1.5.2 Perform iterative evaluation of options and concepts at each stage of programme development taking account of international technological advances (Options and Concept selection)

CORE ACTIVITIES IN THE NATIONAL PROGRAMME

This section describes broadly the typical RWM activities that are required to successfully achieve generic goals in theme 1 on programme management.

Establish the national policy and plan for radioactive waste and spent fuel management, from generation to disposal (Programme Planning)

- All EU Member States are subject to the requirements of Council Directive EURATOM 2011/70 (EC, 2011), requiring them to have a programme and a schedule for responsible and safe management of spent fuel and radioactive waste. All Member States (and EURATOM) are also parties to the IAEA Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, requiring them to demonstrate commitment to apply stringent safety measures, to prepare a national report on the applied measures and to submit it for review by all other Contracting Parties. It is sound practice to align national RWM policy with the international requirements of the Directive and the Joint Convention and to encapsulate that policy into law. See, for example, the national laws in France relating to the management of radioactive waste (Légifrance, 1991 and 2006)
- The national plan needs to be comprehensive of all radioactive wastes arisings in the country, accounting for potential changes in the use of nuclear energy and should ensure that mechanisms and pathways exist for their safe collection, storage, transport and disposal. Thus it must address issues such as the construction of interim storage facilities for all types of RW and final repositories for medical, industrial and research (MIR) wastes, as well as defining a route to an eventual DGR.
- A key aspect of a national legal framework is the identification of responsibilities, assurance of a means of funding RWM and the establishment of objectives, safety criteria and a schedule. In the first instance, responsibilities for implementing and funding RWM typically lie with the waste producers, who must act within a framework of national policy, which may be enshrined in laws, overseen by government, and regulations, overseen by regulatory authorities and agencies.
- An important issue in national policy is the definition of a time schedule in phase with the potentially multigenerational character of disposal program implementation. National law might stipulate target dates for certain milestone goals to be achieved. Without appropriate schedule ambitions, national programmes can fail to make progress and this is particularly problematic for DGRs, whose implementation dates can appear vague or arbitrary if they are many decades into the future.

Establish and maintain a national regulatory and organisational framework for the timely implementation of all steps of spent fuel and radioactive waste management, from generation to disposal (Programme Organisation)

- Many national programmes have opted to establish a dedicated waste management organisation (WMO), funded by the waste producers, or by government, where there is a significant legacy of wastes from past national activities. Any new WMO created can benefit from the multi-decadal experience of others, represented within the EDRAM group (EDRAM, 2019). Clarity on which wastes the WMO is responsible for is important. In some countries a national WMO is responsible for all RW in the national inventory; in others, the WMO is only responsible for an eventual DGR. If there is to be more than one organisation with responsibility for RWM, then ensuring consistency of regulatory requirements, time schedules and objectives is vital. As time schedules and objectives can change, potential impacts on responsibilities need to be recognized in planning.

- Regulatory authorities have the power to assess compliance with and enforce the legal framework for safe management of RW and can do this by establishing their own guidelines and requirements (for example for ensuring acceptable public health impacts of RWM activities). There is a well-accepted international basis for such requirements in IAEA and ICRP (see, ICRP, 2013) documentation and European nuclear regulators share experience in their own group (ENSREG, 2021). Regulatory functions for RWM typically lie within organisations that have wider responsibilities for nuclear power or general environmental quality regulation.
- Effective interaction between implementers (WMOs) and regulators is the key to efficient progress in achieving a trustworthy and transparent national policy. In any project, including the very long-term activities required in DGR development, early and regular interactions promote understanding before problems might arise. Implementing procedures for identifying and resolving issues from the outset can prove helpful in avoiding difficulties at the eventual licensing stages of major projects.
- A key activity of the WMO is the establishment of a more detailed schedule of activities within the national framework. A systems engineering approach, involving the use of a requirements management system (RMS) linked to a work breakdown structure (WBS), can be helpful to identify and organise activities, ensuring the timely delivery of outputs against project milestones. Advice on this approach is available from the IAEA (IAEA, 2021). The role of the RMS is to define and assemble all the external (e.g., legal, procedural, regulatory, societal) and internal (e.g., budgetary, technical, systems engineering) requirements that drive a programme, the means for addressing them, the targets that show each requirement to have been met, and the group responsible for dealing with it. The WBS is a means of representing the total plan for the RWM programme. It organises the activities required to address the requirements into work streams, projects and critical paths.
- All organisations involved in the RWM programme need to operate transparently and take into account the views of relevant stakeholders who are external to statutory legal and regulatory interactions. This is important at all stages of the programme and in particular at the points where critical decisions have to be made. The procedures and ground-rules for stakeholder interactions need to be considered and agreed early, both within the overall programme and, perhaps, separately, within each major project. External stakeholders might be statutory consultees, local or national groups and organisations, or representatives of neighbouring countries. Guidance on stakeholder interactions in developing a disposal facility, is available from a number of sources, including the OECD-NEA (NEA, 2015).

Ensure that adequate financial and human resources (core capability and supply chain support) are available, and can be adapted to the changing needs of the programme over many tens of years, from generation to disposal (Programme Resources)

- The WBS that defines the structure and content (plan) of the RWM programme (and major projects within it, such as a DGR) needs to be populated with organisations and individual with the appropriate skills and resources to carry out the required work. Each activity requires trained and experienced engineers, scientists and managers. In a new programme, many of these people will have to become familiar with the context of RWM. Both the WMO and the regulatory authorities will need to identify competent organisations and individuals to work inside their organisations or as contractors. For transparency of decision making and to avoid conflicts of interest, regulators and WMOs often agree tacitly to segregate expert contractors.
- Neither WMOs nor regulatory agencies can incorporate all the necessary skills to implement and assure a comprehensive RWM programme. A supply chain of competent advisers and contractors should be established and nurtured so that it will function reliably over decades. This can be encouraged if WMOs actively involve organisations in the programme planning process and support mechanisms for training and knowledge transfer within contractors and across the whole educational

sector. The WMO (and other key stakeholders) should possess sufficient internal knowledge to guide a project to a successful conclusion but will require expert assistance from its supply chain for project implementation.

- Some RWM projects, especially those leading to a DGR, will extend over decades and several generations. As projects evolve from concepts to implementation and conclusion, organisational structures and expertise requirements will change significantly, and organisations need to plan and be prepared to make these important transitions.
- Similarly, technology and scientific understanding will continue to develop over multi-decadal programmes. While the technology exists today to implement most aspects of a RWM programme, future development will require WMOs actively to keep abreast of change and to be prepared to take advantage of advances in materials, processes, understanding and techniques. The WMO needs to have the knowledge and resources to identify and, where necessary, support relevant and forward-looking RD&D externally. The IGD-TP provides guidance on identifying RD&D programme requirements (IGD-TP, 2021). The regulator needs to evolve accordingly to remain capable of qualified oversight.
- The long multigenerational duration of DGR projects until repository closure requires a well organised knowledge transfer within WMO and regulators. This needs to be organized well in advance before key personal retires.
- Estimation of the costs involved in all aspects of managing radioactive wastes is an important responsibility of the organisation(s) responsible for the wastes. Cost information is needed not only for programme planning but also to ensure that adequate funds can be made available when required (see below). Cost estimates for a DGR present problems owing to the potentially long lifecycle of such facilities. While there are substantial up-front costs involved in the initial construction activities, the annual operational costs over a multi-decadal operational period add up. Also, closure costs can be substantial, but might not arise for many decades. Both total and annual cost estimates need to allow for the multiple uncertainties associated with the value of money in the distant future. Experience shows that there is a tendency to underestimate costs, which means that it is important to have agreed and transparent frameworks and procedures for carrying out cost estimates and making regular updates. Guidance on this issue is provided by (IAEA, 2020).
- The funding of the RWM programme is most appropriately laid down in national legislation, but responsibility for the collection, management and disbursement of the funds needs to be assigned to a competent organisation or handled by the waste producers, subject to legal process and procedures: both cases need to be subject to both fiscal and technical oversight. The policy and rules directing the development of a waste management fund must ensure that adequate funding is collected from waste producers, sufficient for the whole duration of the programme, which might be many decades. It is also essential that clear procedures exist to allow this funding to be spent in a timely manner to ensure that operational RWM solutions are available when required. In some countries, this role is taken by regulatory authorities, while others have established a specific organisation with a legally mandated function. Guidance on the economic aspects and funding of RWM is available from the NEA (NEA, 2013) and the IAEA (IAEA, 2007 and 2020).

Establish and maintain a national inventory of radioactive wastes (National Inventory)

- Knowledge of the wastes present and arising from all national sectors (energy production, medicine, industry, research) and its temporal evolution with the national nuclear energy programme and policy is a fundamental requirement for a comprehensive RWM programme. The responsibility for establishing and maintaining the national RW inventory should be assigned to a competent organisation, such as the national WMO or a regulatory agency.

- The national inventory should be a unified, accessible data base, reviewed and updated regularly, as it is the basis for planning and adapting the national RWM programme. Updates can be based on submissions by waste producers, audited by the competent organisation.
- A typical inventory, see for example (NDA, 2021) or (Andra, 2021), will contain information on the source of wastes, the amounts, the waste producer, the physical and chemical characteristics of the material, the content of radionuclides, any conditioning measures applied to the waste, packaging information, the location of the waste and the proposed further handling and disposal route.
- Understand uncertainties in the inventory. For programme planning it will be important to judge whether it would be more optimal to develop waste management solutions that would accommodate the uncertainties in the inventory or whether resources are better spent on reducing the uncertainties to produce more optimised, waste-specific solutions.

Identify and select appropriate disposal routes and concepts for the national radioactive waste inventory (Management Solutions)

- A national inventory is likely to include all categories of radioactive wastes arising from all sources. While some of the lowest categories of waste might be managed using decay storage and existing municipal waste disposal facilities, the RWM programme is likely to be focussed on the need for specialised disposal facilities for higher categories of waste, especially those arising from the nuclear power industry. The national RWM plan needs to consider appropriate concepts and actual technical solutions for each category.
- Identification of waste management routes and disposal concepts should be done in close cooperation and communication between the waste generator, different organizations managing the waste (as applicable) and the organization responsible for implementing disposal. Frequent, structured and organised exchange between waste producer and WMO, as well as interface with the regulator, is necessary.
- Early in a national RWM programme, the WMO will need to balance the national inventory against potential disposal options and consider solutions that can feasibly be implemented nationally, or in collaboration with other countries. In the latter case, the WMO would be expected to adopt a 'dual-track' approach (seeking both national and shared options until one solution is identified) and work with the ERDO group of countries (ERDO, 2021). A range of disposal solutions, from near-surface disposal, through the use of boreholes, existing caverns, shallow constructed caverns, or DGRs or boreholes might need to be evaluated, with special reference to the environmental and geological conditions of the country. The geological environment of any DGR offers the potential to implement a range of engineered disposal concepts and waste emplacement schemes.
- The choice of possible solutions will depend on the size, radiological and physical/chemical states of the inventory and the geological characteristics of potentially available sites for a DRG. A range of specific guidance on options is available in IAEA documents, both in terms of general technical repository concepts and specific solutions for countries with small inventories. Optimising the routing of specific waste streams to specific facilities will depend upon the interplay between the development and operational schedules, locations, waste acceptance criteria (WAC) and costs of each facility.

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RECOMMENDED PROGRAMME MANAGEMENT ACTIONS OVER PHASES OF IMPLEMENTATION

This section provides examples of typical actions completed in programme management, based on the experience of advanced programmes, over different phases of implementation.

Programme Initiation (Phase 1)

Programme Implementation (integrated actions in theme 1 on programme management linked to activities in other themes)

- The WMO should apply a systems engineering approach, involving the use of a requirements management system (RMS) linked to a work breakdown structure (WBS), to identify and organise activities, ensuring the timely delivery of outputs against project milestones (*See, RMS activities in 5.1.1 Design Specification*). In the early stages of the overall RWM programme, only quite general requirements can be established. As specific projects/facilities are identified, formulation of detailed requirements will develop iteratively, based on feedback from, for example, safety case development (*See, 7 Safety Case*) and engineering (*See, 5 Design*).
- Regulators should start developing applicable regulatory requirements in accordance with well-accepted international bases and initiate interactions with the WMO (*See, 6.3 Licensing*).
- Both WMO and regulator should identify relevant stakeholders who are external to statutory legal and regulatory interactions and initiate a dialogue on the procedures and ground-rules for stakeholder interactions (*See, 6.3.1 Stakeholder Involvement*).

Programme Planning

Formulation of a national radioactive waste management policy that:

- Defines overall objectives.
- Includes provisions stipulating the responsibilities of waste producers, waste owners and the national regulatory authorities.
- Identifies the mechanisms for funding the national RWM programme.
- Provides a schedule and the legal framework for implementing waste management, transport, storage and disposal solutions. The WMO should plan a more detailed schedule of activities within the national framework, see e.g. SKB (1986).
- Includes a preliminary programme risk management plan.

Programme Organisation

- Establish a national regulatory and organisational framework for the timely implementation of all steps of spent fuel and radioactive waste management from generation to disposal or other handling.
- Identify which organisations are responsible for which wastes and for which RWM facilities, and which of these is responsible for reporting the national programme to the EC and to the Joint Convention (where the IAEA provides the secretariat).
- Identify the competent regulatory authorities.
- Establish a dedicated waste management organisation (WMO) for developing and later implementing specific components of the national RWM programme (e.g., and typically, a DGR).

- Establish the fund management organisation and the (separate) organisation responsible for cost estimates: this could be the WMO or another body.
- The WMO, regulatory authorities and other key organisations establish and later develops the management system needed to meet its objectives.

Programme Resources

- The organisation(s) responsible for developing costs estimates, should develop a procedure and a cost estimate tool, and make a first estimate of the total programme costs, see e.g. SKB (1990).
- Both WMO and regulator should establish a core team that could plan future recruitment needs and prepare for the use of a supply chain of competent advisers and contractors to be used in the different stages of the programme.
- Develop procurement procedures and a hiring programme and assess the need for training, both of staff and of key contractors.
- Establish international contacts, both through the international organisations and bilaterally with organisation judged to have relevant experiences in building and managing a RWM programme.
- Assess availability of relevant scientific and engineering experiences in existing disposal programmes and establish means for collaboration or procurement.

National Inventory

- Establish a national inventory of radioactive wastes present and arising from all national sectors, see further Theme 2. Since the inventory is a fundamental requirement for a RWM programme, the ambition level should be high from the outset, to ensure that all types of wastes are identified and that a clear picture is established, especially of where there might be large uncertainties in the inventory.
- For programme planning, assess whether to develop waste management solutions that would accommodate the uncertainties in the inventory or whether resources are better spent on reducing the uncertainties to produce more optimised, waste specific solutions.

Management Solutions

- Establish feasible options compatible (either directly or with modification) with each category within the national radioactive waste inventory, see for example Baldwin et al (2008). Assess the scale of the waste management challenges (e.g., to define the national inventory) and assess viable options for meeting these challenges.
- Conduct a review of concepts and technology solutions for managing each category of waste that are available internationally, as well as past national approaches.
- Assess the full range of feasible management options, up to and including geological disposal, and identify appropriate options for each waste category.
- For the waste categories considered for geological disposal, if any, assess potentially suitable repository concepts considering the range of potential facility siting environments (see further Theme 6).
- For potential DGR concepts – the focus of the remainder of this Theme perform a basic assessment of key Design and Safety aspects of these concepts. See further Theme 5 and 7.

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Site identification and selection for a DGR (Phase 2)

Programme Implementation (integrated actions in theme 1 on programme management linked to activities in other themes)

- For the waste categories where a DGR is judged to be an option the key activity is for the WMO to plan and later implement a programme for site investigation and site selection (*See, Theme 6 Siting and Licensing*).
- The WMO should update the RMS based on the knowledge gained from the initial assessment of key Design and Safety aspects from Phase 1 (*See, 5.1.1 Design Specification*).
- The WMO, regulator and other stakeholders, should identify and agree the activities involved in the different steps in the site identification, site investigation and final site selection: it is critical that this includes a stakeholder engagement plan that addresses the roles of local communities in decision-making (*See, Theme 6 Siting and Licensing*).
- WMO to prepare plans for site investigations followed by the DGR concept development and safety assessment that will be conducted during the site characterisation phase (*See, Theme 6 Siting and Licensing*).
- In dialogue with the nuclear regulatory bodies and other planning, environmental and security regulation agencies, the WMO should clarify the legal requirements, including security, safeguards, occupational, safety, health and environmental regulations, that are involved in these different steps (*See, 5.3.1 Safeguards, 5.3.2 Security and Physical Protection, 5.4 Operational Safety, 6.3.2 Regulatory licensing*).
- Continue the dialogue with other relevant stakeholders to explore their interests/concerns and to solicit their input to the site and repository concept selection process (*See, 6.3.1 Stakeholder Involvement*).
- WMO to carry out the activities and produce the documented evidence needed to satisfy regulatory requirements and meet the legal permits to start site investigations, provided the site identification would evolve into a site characterisation phase (*See, 6 Siting and Licensing, 7 Safety Case*).
- Regulatory agencies to evaluate submissions of the WMO and issue any requisite approvals to move to the next phase of work.

Programme Planning

Update the overall national RWM-programme to include:

- The specific steps and requirements that will lead to implementation of a DGR siting programme.
  - Plans for implementing waste management options other than geological disposal (*see further Sub-theme 2.2 Predipsal Implementation*).
  - An update of the national WBS, programme schedule and risk management plan.

- Government, regulatory authorities and WMO to agree and develop a cybersecurity and facilities protection programme.

(DGR) Programme Organisation

- The organisation of the WMO and the regulator will remain the same as for the initial stage but updated and reinforced by the needs of the DGR site investigation and site selection phase.

Programme Resources

- The responsible organisation(s) to update total programme costs regularly and the WMO to develop a more detailed costing and budgeting of the site investigation phase.
- Maintain and expand the WMO and regulatory core teams to ensure transmission of relevant knowledge, focusing on the needs of geoscientific as well as field investigation expertise during the site investigation phase, but also on the need for active communication with different stakeholders.
- Each organisation to expand and further develop their supply chain of competent advisers and contractors.
- All organisations: maintain and expand international contacts.
- All organisations: continue their training programme.
- WMO to seek collaboration with organisations having experience in site investigations or in developing repository concepts similar to what is envisaged in the programme.

National Inventory

- The responsible organisation to update the initial waste inventory analysis, including projections of future waste generation, focusing on resolving uncertainties of importance for safety and design. see further Theme 2.

Management Solutions

- From the concept options judged feasible for geological disposal in Phase 1, WMO to develop a set of reference DGR concepts generally adapted to potential siting environments and assess their design and safety aspects, see further Theme 3, 5 and 7.
- WMO, regulators and waste producers begin to scope out possible waste acceptance criteria (WAC) for the DGR concepts and environments being evaluated.
- WMO to assess what would be required and what would be favourable conditions on the geological environment for these concepts, see e.g. Andersson et al. (2000).
- WMO initiates actions to develop additional concepts in case existing ones are judged impractical or non-optimal.
- Waste producers and national policy owners to ensure that, in parallel to DGR development, work is in hand to develop disposal routes for all categories of waste scheduled for DGR (See, 2 Predisposal).

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Site characterisation (Phase 3)

Programme Implementation (integrated actions in theme 1 on programme management linked to activities in other themes)

- WMO implements the programme for DGR site investigation, final site selection and repository concept development, leading to a construction license application (*See, 6 Design, 6 Siting and Licensing*).
- Regulatory agencies to define procedures and requirements for any programme of review and inspection that will be carried out during the DGR site characterisation phase.
- WMO updates the RMS for the DGR, based on the knowledge gained from the assessment of key Design and Safety aspects from Phase 2 (*See, 5.1.1 Design specification*).
- WMO to develop repository designs adapted to the site(s) (*See, 5 Design*).
- Waste producers and WMO to develop agreed approach to pre-disposal management of wastes to ensure eventual disposability in the emerging DGR design
- WMO to develop a safety case supporting the construction license (*See, 7 Safety Case*).
- WMO to develop (and agree with the regulatory agencies) plans for the qualification and quality control needed to ensure that the repository construction of the manufacturing of the EBS meet these requirements (*See, 5.2 Constructability, demonstration and verification testing*).
- WMO to develop (and agree with the regulatory agencies) a monitoring strategy and programme to be applied during the construction and operational phases, considering health, operational and post closure nuclear safety and environmental aspects (*See, 5.5.2 Monitoring during construction and operations)*.
- Continue the dialogue between WMO, regulatory agencies and other relevant stakeholders to explore stakeholders concerns and to solicit their input to the licensing process (*See, 6.3.1 Stakeholder Involvement*).
- WMO to develop plans for repository construction as well as plans for detailed underground investigations (*See, 6.2.2 Site Characterisation*).
- WMO to carry out all activities needed for the application for final site selection and repository construction and prepare the necessary documents (*See, 6.3.2 Regulatory Licensing*)
- Regulatory agencies to receive construction license application, review and, if approved, issue a license, with any conditions considered necessary (*See, 1.2.1 Licensing Framework*).

Programme Planning

- If necessary, update the national RWM-programme with special emphasis on how to implement the DGR site characterisation programme and the eventual final site selection and application for repository construction.
- Update the national WBS, programme schedule and risk management plan as needed.
- Update and maintain a cybersecurity and facilities protection programme.

Programme Organisation

- The organisation of the WMO and the regulator will remain the same as for the initial stage but updated and reinforced by the needs of the site characterisation programme, final site selection and application for repository construction.

Programme Resources

- The requirements for updates on costing will continue as the DGR project focuses on a specific site and concept and the eventual disposal inventory is clarified.

- Maintain and expand the programme core team to ensure transmission of relevant knowledge, focusing on the needs of assessing the site investigation data and its further use in repository design and safety assessment as well as on the need for active communication with different stakeholders.
- Towards the end of this phase, skills requirements will transition from site characterisation, conceptual design, feasibility demonstration and licensing towards construction engineering, with a need to adapt the supply chain of the WMO towards civil and nuclear engineering.
- Training and collaboration activities will continue in all organisations.

National Inventory

- No specific new requirements: continued update and refinement will continue, *see further Theme 2*.

Management Solutions

- WMO to select DGR concepts and design, preliminary WAC and construction methodology and schedule, including scheme for identifying and selecting suitable volumes of rock for disposal.
- Assess implications for construction and safety, see further Theme 3, 5 and 7.
- Formulate detailed requirements for the license application and further development and construction of the repository, including the EBS, see e.g. Posiva SKB (2017).

References

Posiva; SKB (2017), Safety functions, performance targets and technical design requirements for a KBS-3V repository. Conclusions and recommendations from a joint SKB and Posiva working group, Posiva SKB Report 01 (available at www.skb.se)

IAEA (2014), Monitoring and Surveillance of Radioactive Waste Disposal Facilities, Disposal Facilities IAEA Safety Standards Series No. SSG-31. International Atomic Energy Agency, Vienna.

Construction (Phase 4)

After an initial stage of construction of access, underground service areas and the first disposal sections of a DGR, in many concepts underground construction activities continue during repository operation, as disposal vaults are excavated progressively, as needed. Furthermore, disposal vaults may be backfilled, i.e., closed, soon after they are filled with waste, as part of the disposal activities. In many cases, repository operation also starts with a pilot phase. For clarity, in this document, Phase 4 “Construction” generally concerns the construction of the repository access and the underground spaces and installations needed for subsequent repository expansion, disposal activities and closure. However, actions discussed under this phase may also be applicable to the operational phase discussed under “Phase 5” in this document.

Programme Implementation (integrated actions in theme 1 on programme management linked to activities in other themes)

- If applicable, WMO to define and update a plan for progressive development of repository construction, operation and closure; and the possibility of a fist pilot phase.

- WMO to carry out the DGR construction and prepare for repository operation, including any test and demonstration activities considered necessary.
- WMO to update the RMS for the DGR based on the knowledge gained from the assessment of key Design and Safety aspects from Phase 3 (*See, 5.1.1 Design specification*).
- Finalise repository design, including the engineered barrier and waste emplacement systems, and further adapt it to the site conditions found as construction progresses. This further design development would be especially important if the repository operational phase includes further construction of the repository (See, 5 Design).
- WMO and regulatory agencies to agree and WMO to implement the underground monitoring programme, see Phase 3, and further update it to cover monitoring needs during the operational phase (*See, 5.1.1 Baseline Monitoring, 5.5.2 Monitoring during construction and operations*).
- Continue dialogue between WMO, the regulator and with other relevant stakeholders. At this stage, the scope and nature of this dialogue might be formalised in stipulations from the construction license (*See, 6.3.1 Stakeholder Involvement*).
- WMO to carry out all activities needed for the application for repository operation and prepare the necessary documents (*See, 6 Siting and Licensing, 7 Safety Case*).
- Regulatory agencies to implement an inspection programme during construction.
- Regulatory agencies to prepare for, receive and review an application from the WMO for an operating license when sufficient construction work has been completed, leading to issuance of license with any conditions considered necessary

Programme Planning

- At this stage, the national programme should be firmly established and only require updating with respect to any additional requirements that might arise from new sources of waste.
- Regulatory agencies and WMO, in collaboration with IAEA and EURATOM, to agree a nuclear safeguards plan to support the DGR safety case for operation.

Programme Organisation

- The internal organisation of the WMO will need to evolve from the site characterisation stage to reflect the industrial phase of the project and might change significantly, possibly with a new operational group or organisation being established. The management system should reflect sufficient procedures and identification of different functions for the quality control and qualification of repository construction and manufacturing of the EBS.
- The regulatory agencies might also need to adapt their internal organisational structure to facilitate inspection of construction activities taking place over many years.

Programme Resources

- Continued updates of total programme costs, with WMO to make a more detailed costing and budgeting of operational and repository closure phase.
- Maintain both the programme core team and the supply chain but evolve from the site characterisation stage to reflect the industrial phase of the project.
- Make a dedicated effort to maintain the core competence of the safety case, geoscience and waste properties, since these competences may otherwise be lost when the programme transforms to an industrial project, and to increase competences in other scientific and technological domains relevant to construction and operating, including future optimization.

National Inventory

- Maintenance and updates.

Management Solutions

Develop the DGR repository plans and procedures to a stage where operation can be implemented.

- Qualify constructions and procedures
- Develop QC plans
- Carry out commissioning tests
- Explore possibilities to optimise the concept while maintaining the basic safety.

References

POSIVA (2017), Safety Case Plan for the Operating Licence Application, POSIVA Report 2017-2, Posiva Oy.

Operations & Closure (Phase 5)

Programme Implementation (integrated actions in theme 1 on programme management linked to activities in other themes)

- WMO to carry out the DGR operation including deposition activities and further underground construction in a quality-controlled manner (See, 5.2 Constructability, demonstration and verification testing).
- WMO to update the RMS on a regular basis considering experiences from the operation and repeated safety assessments (See, 5.1.1 Design specification).
- WMO to revise repository design specifications, based on updates to the RMS, if judged necessary or beneficial (See, 5.1 Design).
- WMO and regulatory agencies to agree and WMO to implement the monitoring programme for the operational phase and update when judged needed (See, 5.5.2 Monitoring during Construction and Operations).
- WMO to update the safety case periodically and in accordance with any stipulations in the operational license (See, 7 Safety Case).
- WMO to carry out all activities needed for the application for final repository closure and prepare the necessary documents. It is noted that many disposal concepts involve progressive backfilling of disposal vaults as a part of the operation (See, 6 Siting and Licensing).
- Regulatory agencies to review and agree proposals from WMO for closure and any post-closure actions, and issue closure license.

Programme Planning

- As DGR closure approaches, the government needs to agree and establish in law, requirements and responsibilities for the post-closure ownership and management of the site.

Programme Organisation

- Further develop the organisation for industrial operation. Maintain and update the management system regarding quality control of repository construction, EBS manufacturing and deposition activities.
- The role of the WMO will need to be revised to reflect a legally agreed definition of 'closure' and agreed legal responsibilities of the WMO, government and other parties: after DGR closure the WMO might cease to exist and any residual responsibilities would need to be reassigned.

Programme Resources

- Update estimates of total programme costs regularly and make a more detailed costing and budgeting of the remaining operational and repository closure phase.
- The requirements on and the nature of both the WMO programme core team and supply chain will change considerably as operation becomes routine, but closure is likely to require similar skills as those in Phase 3 – possibly several generations later.
- Both regulator and WMO to continue with the dedicated efforts to maintain the core competence of the safety case, geoscience and waste properties – this is likely to become increasingly demanding over a multi-decade operational period.
- Sharing of operational experience among international counterpart organisations with DGRs should focus on means of maintaining the competencies mentioned above.

National Inventory

- Updates to continue: it is likely that long-term changes in national and global energy policies could significantly impact the inventory over timescales of several decades (*See, 2 Predisposal*).

Management Solutions

- WMO to revise the DGR design based on the updated RMS, if judged needed or judged beneficial during the long operational period (*See, 5.1.1 Design Specification*).
- WMO to develop and qualify technical solution for final repository closure in time for the application for repository closure (*See, 5.1.2 Design Qualification*).
- Government and regulatory agencies to put in place requirements for post-closure ownership and management of the DGR site.

References

To be added.

AVAILABLE CAPABILITIES: STATUS AND OUTLOOK

This section describes programme capability needs (including infrastructure) that are required to successfully complete the activities and actions recommended to achieve generic goals on programme management.

Knowledge and understanding

The need to respond formally to Directive 2011/70/EURATOM places a responsibility on each MS to have the basic elements of a programme in place and to continue with developing an effective RWM programme. While all of the core capabilities for establishing a RWM programme that are discussed above exist across the EU and globally, some MS may not have all the capabilities required and might require assistance in evolving their programmes. This is particularly the case for a national programme that currently only has the resources needed to manage storage facilities for MIR wastes but wishes to establish the early stages of a credible DGR programme whose endpoint might be late in the present century.

A MS at the early stages of establishing an RWM programme can take advantage of the experience built up over decades in other MSs. While there are multiple opportunities for interacting in shared EU research projects, there is at present no central mechanism for sharing strategic knowledge and assisting programme development in less advanced MSs. This gap needs to be filled. Because all aspects of programme development discussed above are covered in detail in a range of IAEA publications, such a mechanism would form a key resource for less advanced RWM programmes.

While national core capability exists in the more advanced programmes, it needs to be maintained and sustained inter-generationally by continuous programmes of knowledge management, training and interaction with partner organisations. Mechanisms for doing this exist within EU programmes. There is also a continuous need to inform the public and key stakeholders about the evolving RWM programme, which requires continual outreach to the media by responsible organisations.

European programmes on RWM began in earnest in the 1970s, almost fifty year ago. This period has seen two generations of experts come and go. It is evident that future DGR development projects, with newly involved experts, might tend to 'reinvent the wheel' if the decision-making deliberations of earlier work have not been adequately recorded. Efforts are required to maintain not only knowledge, but information on how knowledge has been used and how decisions have been made. While much of this critical decision-making involved technical choices (e.g., materials), there is also a need to record and pass on the basis and drivers for strategic decisions over programme options, and the mechanisms used to make them. This is likely to become increasingly demanding as DGR programmes enter routine, multi-decade operations and some of the skills involved in initially implementing them are no longer needed by the operators. As closure approaches, these skills and the thinking behind early decisions on design and post-closure safety will be needed again.

Current knowledge management projects are addressing this problem and should be aimed not only at information management and transmission, but also at capturing strategic programme drivers and decision-making experience. This becomes particularly important when experts from outside the field of radioactive waste management are involved in programme development. As an example, economic analysts and advisers are a key component of programme optimisation as planning moves closer to implementation and major investment but they are likely to come from outside the nuclear sector. They need to work along with other experts within a multidisciplinary environment where the key decision

drivers and optimisation trade-offs (between costs, schedule, flexibility, practicality etc) are widely understood. This requires the propagation of knowledge and past experience throughout a programme team.

At present, there is no shortage of advice, experience or management expertise at a European level, although newer radioactive waste management programmes are likely to find gaps at a national level as they improve and integrate their pre-disposal activities and begin to implement disposal solutions. Mechanisms for such programmes to make best use of the available knowledge do, however, need to be developed or improved quite urgently.

Experts and practical skills

- National nuclear legislation and regulation
- Planning, implementation and cost estimation for major infrastructure projects
- Community and partnership engagement
- Professional services (project management, procurement, finance, information technology, human resources)
- Radioactive waste inventory management
- Value frameworks and strategic decision making at government or regional levels
- Strategic overview of national nuclear infrastructure

Laboratories and centres of excellence

- Nuclear fuel and materials testing
- Generic underground research facilities

Equipment, tools and technology

- Database services and arching

Industrial manufacturing

- Nuclear industry
- Metallurgical industry
- Mining and tunnel construction industry

Contractors and human / material resources

Owing to the advanced nature of a number of European RWM programmes there are established supply chains of competent organisations, both at national levels and internationally, with many contractors

supporting programmes worldwide. A new and developing programme is encouraged to make use of its own national expertise (e.g., national surveys and the academic sector) where appropriate, assisted by the many opportunities for experience-building and guidance outlined above.

End of document.