Roadmap goals breakdown structure (GBS)

A generic roadmap for implementing radioactive waste management, leading to geological disposal:

A generic roadmap for implementing radioactive waste management, leading to geological disposal:

1: National Programme Management		
Theme	Sub-theme	Domain
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.)	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 policy for spent fuel and radioactive waste management (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 opportunities for public participation are available (Public information and participation)
		1.1.4 Establish a process for progressive optimization of the plan (safety, security, use of resources)
		1.1.5 Establish and maintain a national nuclear fuel cycle strategy (open or closed cycle, contribution to national energy mix etc.)
	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 help reduce programme risks and unnecessary cost (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 and amounts, in accordance with an appropriate classification scheme (National radioactive waste inventory)
	1.5 Identify and select appropriate disposal 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)
2: Predisposal		
Theme	Sub-theme	Domain
2. In conjunction with waste producers, identify and deliver solutions to optimise the management of radioactive waste throughout the predisposal phases of the radioactive waste management programme (Predisposal)	2.1 Perform predisposal management of radioactive waste to support key risk and hazard reduction, and to help reduce costs and save space at interim storage and disposal facilities (Predisposal Mgt.)	2.1.1 Characterise, classify and quantify radioactive waste in accordance with requirements established or approved by the regulatory body (Waste generation)
		2.1.2 Stabilise and minimise the quantity and volume of radioactive waste through processing (Processing)
		2.1.3 Conduct storage of radioactive waste (Storage)
		2.1.4 Transport radioactive wastes between facilities in accordance with regulatory standards (Transport)
	2.2 Engage at an early stage with waste producers to develop and deliver cost-effective waste packaging solutions suitable for transportation, storage and eventual disposal. (Disposability Mgt.)	2.2.1 Work closely with waste producers to ensure the disposability of packaging proposals, influence how wastes are being packaged economically (through specifications and guidance) and that appropriate records are maintained. This could include re-packaging to optimize safety and economics. (Disposability Assessment)
		2.2.2 Ensure that waste packages are designed and produced so that the radioactive material is appropriately contained both during normal operation and in accident conditions that could occur in the handling, storage, transport and disposal of waste. (Waste acceptance criteria)
3: Engineered Barrier System		
Theme	Sub-theme	Domain
3. Develop an engineered barrier system, tailored to the characteristics of the waste and compatible with the natural (geological) barrier, that performs its desired functions, for the long-term disposal of radioactive waste (EBS)	3.1 Confirm wasteform compositions, properties and behaviour under storage and disposal conditions, including impact on the disposal environment (Wasteform)	3.1.1 Spent nuclear fuel (SNF)
		3.1.2 Vitrified high-level waste (HLW)
		3.1.3 Cemented long-lived intermediate level waste (Cemented LL-ILW)
		3.1.4 Other wasteforms such as bituminized waste, ceramics, polymers, non-conditioned or non-encapsulated wastes (Other wasteforms)
		3.2.2 LL-ILW disposal containers (LL-ILW disposal containers)

	3.2 Identify appropriate container materials and designs for each wasteform and their properties with respect to storage and disposal conditions (Waste packages, for disposal)	3.2.3 Containers using advanced materials (other disposal containers)
	3.3 Identify appropriate buffer, backfill and seal/plug materials and designs, and confirm their properties, behaviour and evolution for the selected repository concept (Buffers, backfills, plugs and seals)	3.3.1 Buffer components under storage and disposal conditions (Buffer)
		3.3.2 Backfill components under storage and disposal conditions (Backfills)
		3.3.3 Plug and sealing components under storage and disposal conditions (Plugs and seals)
	3.4 Confirm integrated EBS system understanding and identify compatible EBS designs and materials for facilities containing multiple wasteforms (EBS system integration)	3.4.1 Confirm complete and integrated EBS system understanding, including the design of an optimized interface EBS/repository and the understanding of the interaction with the repository nearfield environment (EBS system)
		3.4.2 Confirm that interactions between different EBS materials in disposal areas for different waste types do not compromise the performance of the disposal system (Co-disposal)
4: Geoscience		
Theme	Sub-theme	Domain
4. Assemble geological information for site selection, facility design and demonstration of safety (Geoscience)	4.1 Provide, or confirm a description of the natural barrier and how it contributes to high level safety objectives (Site description)	4.1.1 Develop a model of the host rock and surrounding geological environment, including distributions of rock types, geometry and properties of structural features, geotechnical properties and the hydrogeological and hydrochemical environment (Site descriptive model)
		4.1.2 Describe bedrock transport properties, including retention material properties (diffusion and sorption) of different geological materials as well as flow related properties (Aqueous transport and retention)
		4.1.3 Characterize or describe the expected gas generation in the disposal system, its impacts on facility evolution and gaseous transport properties from disposal areas to surface (Gas ~~s~~ trans port)
		4.1.4 Characterize or confirm surface ecosystem properties and their potential evolution in the future (Biosphere model)
	4.2 Provide, or confirm a description of the expected evolution of the geosphere in response to	4.2.1 Assess the expected geological and tectonic evolution and the potential for natural disruptive events and their impacts on the stability of the natural barrier (Geological and tectonic evolution)

	natural processes (Long-term stability)	4.2.2 Assess the nature of future climate evolution and its potential impacts on THMC conditions in the repository host rock and surrounding formations (Climate change).
	4.3 Characterise the potential impact of disposal facility construction and operation on the natural geological barrier (Perturbations)	4.3.1 Characterize or confirm the chemical, hydrogeological, geomechanical, thermal, geomicrobiological, gaseous and radiation-induced perturbations which may be caused by facility construction, operations or closure and their impacts on long-term disposal system evolution (Perturbations).
5: Design and Optimisation		
Theme	Sub-theme	Domain
5. Design a facility that fulfils safety and security requirements and that can be practicably constructed, operated and closed (Disposal Facility Design and Optimisation)	5.1 Design and develop a disposal system for the national radioactive waste inventory (Design)	5.1.1 Based on the concept evaluation results, establish a detailed requirements management system leading to design specifications for the preferred concept option and practical methods of design and data verification for facility barriers and components (Design specification)
		5.1.2 Establish design qualification procedures to confirm that structures, systems and components will perform their allocated safety function(s) in all normal operational, fault and accident conditions identified in the safety case and for the duration of their operational lives (Design qualification)
	5.2 Demonstrate and verify that facility components and barriers can be practically manufactured, constructed and installed in accordance with detailed design requirements and specifications (Constructability, demonstration and verification testing)	5.2.1 Develop, adapt and/or buy the technology and systems required to be able to construct and then commission the facility (Pilot-scale, full-scale testing, and active commissioning)
		5.2.2 Continuously consider how the technical solutions can be optimized and made more efficient, without any negative effect on safety (Optimisation)
		5.2.3 Establish reliable manufacturing routes to produce facility barriers and components, and inspections plans for how to test for defects, and overall quality assurance against specified design tolerances and industry standards (Manufacture, inspection and testing)
		5.2.4 Utilise available robotics and remote handling technology to optimise facility construction and operations (Robotics)
		5.2.5 Simulate facility operations by using remote technologies and models to predict the most important variables of the disposal system implementation processes (Virtual Reality / Digital Twin)
	5.3 Prevent theft of nuclear material or sabotage of nuclear facilities and protect sensitive technology, software and information (Security and safeguards)	5.3.1 Establish arrangements to ensure that no nuclear material leaves the system and to ensure effective nuclear materials accountancy during transport, operations and closure of the facility, and that such information is suitable for transfer to a future facility operator (Safeguards).
		5.3.2 Design and provide physical security measures to ensure compliance with regulatory security arrangements for transport and disposal of radioactive materials (Security and physical protection).
	5.4 Develop and maintain operational safety case to demonstrate that the construction, operation and closure of the disposal facility will meet safety standards and	5.4.1 Identify construction hazards or risks, and implement measures to eliminate these or provide a means of preventing the outcome, protecting those affected and reducing the consequences (Construction and Non-Radiological Safety)
		5.4.2 Identify operational hazards or risks, and implement measures to eliminate these or provide a means of preventing the outcome, protecting those affected and reducing the consequences (Normal operations safety)
		5.4.3 Perform design basis accident analysis and optimise with mitigation options for risk reduction for identified faults (Accident safety)

	be robust against potential faults such that the associated risks are restricted to levels that are as low as reasonable practicable (Operational safety)	5.4.4 Demonstrate criticality safety during operations and determine the likelihood and impact of criticality in the long-term (Criticality safety)
	5.5 Establish and implement an overall plan for meeting with national requirements for monitoring, and if required, reversibility and /or retrievability requirements. (Monitoring and Retrievability)	5.5.1 Establish plans and methods for implementing baseline environmental monitoring programme ready for the start of site characterisation (Baseline monitoring)
		5.5.2 Establish plans and methods for implementing a monitoring program for the construction and operational phase of the repository (Monitoring during Construction and Operations)
		5.5.3 Establish technical feasibility of retrieving the waste after emplacement, and if required, demonstrate in full-scale representative conditions before the start of operations (Retrievability)
6. Siting and Licensing		
Theme	Sub-theme	Domain
6. Engage effectively and demonstrate to regulators (and the public) that a properly sited disposal facility will protect people and the environment at the time of disposal and in the very long term, following closure (Siting and licensing)	6.1 Establish and implement an overall plan for the site selection process, and identify potential geological environments using available data (Site selection process).	6.1.1 Identify key decision points, and develop screening guidelines to enable a facility to be located to match national performance criteria and socio-economic, political and environmental considerations (conceptual planning)
		6.1.2 Identify areas that may contain suitable sites by using the developed screening guidelines (site evaluation)
	6.2 Investigate one of more sites to demonstrate that they would be suitable from the safety and other viewpoints (Detailed site investigation)	6.2.1 Initiate a site(s) investigation programme to obtain sufficient data to obtain regulatory approval that the site(s) is/are likely to be suitable and whether the final stage of site confirmation would be likely to result in a license application (site characterisation)
		6.2.2 Continue detailed site(s) investigation, confirmation of the site, and preparation of an environmental impact assessment to the level required for construction and operational license application submission (site confirmation)
	6.3 Obtain the necessary land use permits and nuclear licenses to construct, operate and close the disposal facility (Licensing)	6.3.1 Engage effectively with local government / regulators / consultative bodies / waste producers by providing open access to information, and that their concerns are appropriately weighted and that they can participate in the relevant decision-making processes (Stakeholder involvement).
		6.3.2 Adhere to the licensing process set by national legislation and regulatory bodies (for nuclear installations) and meet the requirements relating to facility authorization (Regulatory licensing)
7: Safety Case		
Theme	Sub-theme	Domain
7. Iteratively quantify and demonstrate, the safety of the disposal system and	7.1 Establish the safety fundamentals as a basis for the	7.1.1 Establish the requirements that must be met to ensure the protection of people and the environment, both now and in the future (Safety requirements)

inform strategic design decisions (Safety Case)	safety assessment (Safety strategy)	7.1.2 Establish safety indicators to complement dose and risk, defined relative to overall safety requirements (Performance indicators)
	7.2 Combine experimental and field data with scientific understanding and qualitative observations to construct models of the possible future behaviour of the disposal system (Integration of safety related information)	7.2.1 Maintain and develop a synthesis of all available information relevant to facility safety, required for regulatory compliance, and to guide forward disposal programme activities (Safety case production)
		7.2.2 Establish a system and adopt international good practice for information, data and knowledge management, modelling, transfer, and preservation (Information, Data, and Knowledge management)
	7.3 Assess radiation risks and assure adequacy and quality of all the safety related work associated with thefacility or activity (Safety Assessment and Tools)	7.3.1 Quantify how the facility and its components behave and evolve to provide continuing safety (Performance assessment and system models)
		7.3.2 Characterise uncertainties and determine their implications for the outcome of the safety assessment (Treatment of uncertainty)
		7.3.3 Evaluate post-closure features, events and processes relevant to safety to create plausible scenarios of disposal system behaviour (Scenario development and FEP analysis)