


ROADMAP



*A generic framework to
organise typical
scientific and technical
domains/sub-domains
in a logical manner
against different
phases of a RWM
programme.*

A **Roadmap**, with clear objectives, linking EURAD activities (as listed in the SRA) to milestones typical of different phases of a radioactive waste management (RWM) programme has been developed (focussed on those planning for disposal). The Roadmap relates to Joint Programme Founding Documents (and was not addressed by the preparatory work carried out in the EC JOPRAD project). It draws from the IAEA work (see, [IAEA Planning and Design Considerations for Geological Repository Programmes of Radioactive Waste](#)). The IAEA definitions of recognised phases of a waste disposal programme (and their associated major objectives) are used to provide the Roadmap framework:

- Phase 0: Policy, framework and programme establishment*;
- Phase 1: Site evaluation and site selection;
- Phase 2: Site characterisation;
- Phase 3: Facility construction;
- Phase 4: Facility operation and closure;
- Phase 5: Post-closure.

**Note that Phase 0 was not covered by IAEA-TECDOC-1755, but added to recognise the needs of Members States who are in the process of establishing a waste management programme.*

For each of the phases above, EURAD Roadmap explains how aspects related to, disposal facility design, and safety case development (and supporting safety analyses) span across all phases, including Phase 0. The Roadmap elaborates further on the how the emphasis of work on each of these differs and changes through successive Phases.

The Roadmap demonstrates the totality of scope of EURAD and its relevance to waste management and disposal programmes at different stages of maturity. The Roadmap effectively provides a framework upon which to organise the scientific priorities of the SRA, enabling users and programmes to 'click-in', and to access existing knowledge and active work or future plans. It also provides a framework for future periodic assessment of EURAD, and to evaluate future priorities and new work packages as new knowledge is acquired or as new needs are identified.

The Roadmap comprises 7 tables:

- A domain-specific table showing how identified scope of the EURAD SRA relate to different Phases of implementation and typical Waste Management Programme objectives for each theme ([grey boxes](#)).
- The SRA topics/sub-topics within each Domains are flagged (📌) to illustrate those being addressed in-part or in-full by scope of active EC-funded projects, including those of the EURAD 1. Topics/sub-topics that will be addressed in future work of EURAD are also flagged (📌).
- RD&D, Knowledge Management and Strategic Studies are each coloured differently.













The Roadmap tables will be used throughout EURAD as a tool to support the management of the SRA in reviewing progress, to support prioritisation of new scope suggestions (importance and urgency) and communicating completed, ongoing and future work activities to those interested in our work.

Please note that contrary to the request by the EC for the SRA to be translated into a roadmap, with clear objectives, deliverables and high-level milestones for technical solutions per waste streams and waste types, we have intentionally avoided this. Rather we have utilised a work break down structure using domains and IAEA phases (focussed on geological disposal) that combines topics of RD&D relevant to many waste streams and technical solutions. Technical solutions need to be tailored and developed for the specific needs of a national waste management programme, particularly taking account of the waste characteristics and the options for siting. There is no one size fits all technical solution for each waste stream, choices on this remain the responsibility of the national waste management programme.

The IAEA phases used in the roadmap are of a general nature and are each applicable to several waste streams and waste types and include scope on knowledge management to share experiences. The same is also true of SRA domains with the topics / sub-topics where, however, some of the topics have less relevance for the other disposal routes. Furthermore, it is important to recognise that the disposal routes for the other waste streams (lower activity wastes consisting mainly of shorter-lived isotopes) do often not include geological disposal but surface or near-surface disposal. This technology is well established with a number of variants tailored to the specific needs (volumes and exact types of wastes) and boundary conditions (land use planning, etc.) of the respective countries. Depending upon the needs of the Beneficiaries it is suggested that the topic of developing a Roadmap for these types of waste is managed through the Strategic Study on “waste management routes in Europe from cradle to grave” with the support of experts managed by the Programme Office. This may need some modification of that WP in the course of the first year.

Key to Roadmap Diagrams:





- (1) Top Line - Typical Phases of a Waste Management Programme (Phase 0 to Phase 4);
- (2) Second Line – Design and Safety Case Focus in each Phase (Conceptual to Site-specific);
- (3) Third Line (light grey boxes) – Typical Programme Objectives (How focus evolves from early stage to advanced-stage focus);
- (4) Fourth Line onwards (lines with multi-coloured boxes) - Map of EURAD SRA Topics and Sub-Topics (colour coded according to RD&D, Strategic Studies or Knowledge Management Tasks)

	Phase 0: Policy, Framework & Programme Establishment	Phase 1: Site Evaluation & Selection	Phase 2: Site Characterisation	Phase 3: Facility Construction	Phase 4: Facility Operation and Closure
Theme Title	Includes conceptual design and preliminary qualitative safety analyses				
Topics:	Includes preliminary site(s) design and generic safety case(s) / analyses				
	Includes detailed design and site safety case / analyses for construction license				
	Includes final design and site safety case / analyses for operational license				
	Includes maintenance and update of license documentation, as required				
	<ul style="list-style-type: none"> • 1 Key objectives in this phase of a waste management programme • 2..... • 3..... • 4.....etc. 				
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Topic 1	Collaborative R&D Sub-topic  L		Collaborative R&D Sub-topic  M	Collaborative R&D Sub-topic  M	
	Knowledge Management Sub-topic  H			Collaborative R&D Sub-topic  L	
		Strategic Study Sub-topic  H		Collaborative R&D Sub-topic  H	
Topic 2	Knowledge Management Sub-topic  L		Collaborative R&D Sub-topic  H	Strategic Study Sub-topic  H	
Topic 3	Knowledge Management Sub-topic  H	Knowledge Management Sub-topic			Knowledge Management Sub-topic  M

Programme Objectives	Collaborative RD&D	Strategic Studies	Knowledge Management Activities	H High Priority	M Medium Priority	L Low Priority	 Future	 Currently In Progress
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There are a total of 7 roadmap diagrams (as illustrated above), one for each Theme of the EURAD SRA.

Roadmap Domain 1: JP Priorities and Activities of Common Interest that relate to Managing implementation and oversight of a radioactive waste management programme

	Phase 0: Policy, Framework & Programme Establishment	Phase 1: Site Evaluation & Selection	Phase 2: Site Characterisation	Phase 3: Facility Construction	Phase 4: Facility Operation and Closure
<p>Theme 1 Managing implementation and oversight of a radioactive waste management programme</p> <p>Topics:</p>	<p>Includes conceptual design and preliminary qualitative safety analyses</p> <ul style="list-style-type: none"> Establish national regulatory and legal framework for RWM licensing, including criteria and standards for issuing authorisations for disposal facilities. Develop clear roles and responsibilities for authorities, implementers and supporting technical / non-technical organisations including the private sector and how to maintain and /or secure resources to deliver their remit with respect to radioactive waste management, including disposal. Establish national funding (and cost estimation) scheme and timescales (indicative plan or schedule RWM activities. Develop/review of the safety strategy setting out the high-level approach for achieving safe disposal, including the siting and design approach, the strategy to manage the activities and the assessment methodology. Develop/review the management system. 	<p>Includes preliminary site(s) design and generic safety case(s) / analyses</p> <ul style="list-style-type: none"> Updates of the safety strategy and management system Competence development and maintenance to support the short and medium-term activities of the national radioactive waste management programme (including disposal) specific to each phase Develop and maintain information and knowledge management systems. Development and maintenances of stakeholder engagement strategy to support key decision making processes during the various phases 			
Programme planning	<p>J.3.11 Pre-licencing management  L</p> <p>How to establish and implement a radioactive waste management RD&D programme EURAD 1 KM WP 12  H</p>				
Organisation	<p>J.3.15 Training and competence maintenance of skills and expertise to support safe radioactive waste management and disposal</p>				
Resources	<p>J.3.15 EU research infrastructure  H</p>	<p>J.3.14 Information management  M</p>			

Programme Objectives	Collaborative RD&D	Strategic Studies	Knowledge Management Activities	H High Priority	M Medium Priority	L Low Priority	 Future	 Currently In Progress
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Roadmap Domain 2: JP Priorities and Activities of Common Interest that relate to Radioactive waste characterisation, processing and storage (Pre-disposal activities), and source term understanding for disposal

	Phase 0: Policy, Framework & Programme Establishment	Phase 1: Site Evaluation & Selection	Phase 2: Site Characterisation	Phase 3: Facility Construction	Phase 4: Facility Operation and Closure
Theme 2 Radioactive waste characterisation, processing and storage (Pre-disposal activities), and source term understanding for disposal Topics:	Includes conceptual design and preliminary qualitative safety analyses <ul style="list-style-type: none"> Develop, and maintain national waste inventory (characterization, documentation of waste being produced and estimates for future arisings). Provide input to evaluation of disposal options (waste inventory for planning purposes and to scope preliminary design options and safety analyses). Develop guidance for waste treatment (preliminary waste acceptance criteria) for the different waste disposal routes. Where necessary, develop new waste treatment methods and input to the development of the corresponding waste treatment facilities. 	Includes preliminary site(s) design and generic safety case(s) / analyses <ul style="list-style-type: none"> Adjust waste treatment guidance (preliminary waste acceptance criteria) according to new findings, taking results from site evaluation into account (optimization for safety and other issues (incl. cost)). Refine radionuclide source term treatment and understanding of waste package performance to account for understanding of a prospective/ selected site. Provide inventory and source term understanding for construction license. Develop waste acceptance criteria for construction license. 	Includes detailed design and site safety case / analyses for construction license <ul style="list-style-type: none"> Transform waste treatment guidance into draft waste acceptance criteria and adjust them according to detailed repository layout (optimization for safety and other issues (incl. cost)). Provide inventory and source term understanding) for operational license. 	Includes final design and site safety case / analyses for operational license	Includes maintenance and update of license documentation, as required <ul style="list-style-type: none"> Organize logistics (delivery of waste to repository) and enforce compliance of waste accepted for disposal with waste acceptance criteria in force Ensure compliance with safeguards Maintain national waste inventory and maintain detailed documentation on wastes emplaced in the repository Modify waste acceptance criteria when appropriate to take optimization for safety and other issues (incl. cost)) into account. Provide detailed information (incl. documentation) for closure license.
Waste handling, characterisation, treatment and packaging	<div style="display: flex; justify-content: space-between;"> <div style="border: 1px solid black; padding: 2px;">1.2.4 Management of damaged waste packages H2020 Project DISCO</div> <div style="border: 1px solid black; padding: 2px;">3.7 Links between waste producers & implementers</div> </div> <div style="border: 1px solid black; padding: 2px; margin-top: 5px;">J1.1.3 Novel conditioning methods for problematic wastes. H2020 Project THERAMIN H</div> <div style="border: 1px solid black; padding: 2px; margin-top: 5px; background-color: #e0f2f1;">Waste management routes across Europe EJP1 WP ROUTES H</div>	<div style="border: 1px solid black; padding: 2px; margin-top: 5px;">J1.1.7 Improved understanding of the nature and quantities of the likely chemotoxic component of common decommissioning wastes. M</div> <div style="border: 1px solid black; padding: 2px; margin-top: 5px;">J1.1.2 Technology for characterisation & segregation of historical wastes. H2020 Projects CHANCE, INSIDER & THERAMIN M</div> <div style="border: 1px solid black; padding: 2px; margin-top: 5px; background-color: #e0f2f1;">J1.1.8 Optimisation of novel waste treatment techniques. EJP1 Project SFC M</div>			
Interim storage	<div style="border: 1px solid black; padding: 2px; margin-top: 5px;">3.10 Long-term storage for disused seals radioactive sources</div> <div style="border: 1px solid black; padding: 2px; margin-top: 5px; background-color: #e0f2f1;">2.4.5 Operational lifespan of interim storage</div>				
Transportation between facilities					
Radionuclide inventory and source term	<div style="border: 1px solid black; padding: 2px; margin-top: 5px; background-color: #e0f2f1;">3.6 Methodologies applied to refine inventory</div> <div style="border: 1px solid black; padding: 2px; margin-top: 5px; background-color: #e0f2f1;">3.5 Inventory collation</div> <div style="border: 1px solid black; padding: 2px; margin-top: 5px; background-color: #e0f2f1;">J1.1.1 Inventory data and uncertainty treatment. EJP1 WP SFC</div> <div style="border: 1px solid black; padding: 2px; margin-top: 5px; background-color: #e0f2f1;">J1.1.10 Quantification of fissile content of spent fuels. L</div>	<div style="border: 1px solid black; padding: 2px; margin-top: 5px; background-color: #e0f2f1;">J1.2.2 Improved understanding of the performance of the final waste package (including the waste form) during prolonged storage prior to its transport and disposal. H</div> <div style="border: 1px solid black; padding: 2px; margin-top: 5px; background-color: #e0f2f1;">J1.1.9 Improved understanding of radionuclide release from wasteforms other than spent fuel. H</div> <div style="border: 1px solid black; padding: 2px; margin-top: 5px; background-color: #e0f2f1;">J1.1.4 Improved understanding of radionuclide release from spent fuel, inc. fire and impact. H2020 Project DISCO & EJP1 WP SFC H</div> <div style="border: 1px solid black; padding: 2px; margin-top: 5px; background-color: #e0f2f1;">J1.1.5 Demonstration of geopolymers performance in representative disposal conditions. M</div> <div style="border: 1px solid black; padding: 2px; margin-top: 5px; background-color: #e0f2f1;">J1.1.6 Fourth generation (Gen(IV)) wastes L</div>	<div style="border: 1px solid black; padding: 2px; margin-top: 5px; background-color: #e0f2f1;">1.4.2 Improved understanding of the generation and release of radioactive trace gases and bulk gases from wasteforms and waste packages. H</div>		
Waste acceptance criteria	PHASE	PHASE	PHASE	PHASE	PHASE
			2.1.6 Waste acceptance criteria M		

Programme Objectives

Collaborative RD&D

Strategic Studies

Knowledge Management Activities

H High Priority
 M Medium Priority
L Low Priority

▶ Future
 ● Currently In Progress



Roadmap Domain 3: JP Priorities and Activities of Common Interest that relate to Engineered barrier system (EBS) properties, function and long-term performance

	Phase 0: Policy, Framework & Programme Establishment	Phase 1: Site Evaluation & Selection	Phase 2: Site Characterisation	Phase 3: Facility Construction	Phase 4: Facility Operation and Closure
<p>Theme 3 Engineered barrier system (EBS) properties, function and long-term performance</p> <p>Topics:</p>	<p>Includes conceptual design and preliminary qualitative safety analyses</p> <ul style="list-style-type: none"> Based upon first ideas of the geological possibilities and taking disposal inventory waste characteristics into account, develop possible broad EBS concepts for evaluation by safety and facility design Assess these broad options with respect to: <ul style="list-style-type: none"> contribution of the EBS to long-term safety compatibility of EBS components with one another and other repository materials technical feasibility and technology readiness cost 	<p>Includes preliminary site(s) design and generic safety case(s) / analyses</p> <ul style="list-style-type: none"> For the sites evaluated / eventually selected and for the wastes to be disposed, develop different EBS concepts in co-operation with safety and facility design Assess these concepts in co-operation with safety and facility design with respect to: <ul style="list-style-type: none"> contribution of the EBS to long-term safety of repository system reliability of EBS performance technical feasibility and technology readiness cost Adapt selected variants to site conditions and increase understanding of EBS performance (and reliability of the assessment method) 	<p>Includes detailed design and site safety case / analyses for construction license</p> <ul style="list-style-type: none"> For the site selected, optimize the EBS concepts chosen in co-operation with long-term safety, geology, and facility design Increase the level of understanding (incl. predictability of evolution) of the EBS For those components needed during construction, get industrial production ready (manufacturing, transport, emplacement and quality assurance). For those components needed later (operation, closure), continue development with respect to their later industrialization. If necessary, make demonstration experiments / prototypes (to demonstrate understanding and/or industrial feasibility) 	<p>Includes final design and site safety case / analyses for operational license</p> <ul style="list-style-type: none"> Implement components according to plan (manufacturing, transport, emplacement and quality assurance) For those components needed later (operation, closure), get industrial production ready If necessary, prepare/ continue demonstration experiments / prototypes for (long-term) monitoring Where deemed necessary or useful, continue optimization and increase understanding 	<p>Includes maintenance and update of license documentation, as required</p> <ul style="list-style-type: none"> Implement components according to plan (manufacturing, transport, emplacement and quality assurance) Monitoring of EBS performance (partially in dedicated experiments/ prototypes) Where deemed necessary or useful, continue optimization and increase understanding Provide input to closure and implement components for closure according to plan Provide input to closure license
Spent Fuel and high-level waste disposal canisters		J1.2.3 Developing alternative HLW and Spent Fuel container material options and improved demonstration of their long-term performance.			
Containers for long-lived intermediate and low level wastes					
Clay-based backfills, plugs and seals		1.3.1 Use of clay-based materials in a geological disposal facility H2020 Project BEACON			
		J1.3.1 Characterised bentonite / clay-based material evolution under specific conditions to provide data on hydro-mechanical, thermal and chemical behaviour. H2020 Project BEACON & EJP1 WP HITEC			
Cementitious-based backfills, plugs and seals		1.3.4 Low pH cement understanding			
		J1.3.3 Improved quantification and understanding of cement-based material evolution to improve long-term modelling and assessments. (P) CEBAMA			
		J1.3.4 Improved understanding of low pH cements. H2020 Project CEBAMA			
Salt backfills		J1.3.6 Improved understanding of a salt backfill.			
EBS system understanding	J1.3.8 Identify co-disposal interactions of importance to long-term safety.	J1.2.1 Improved understanding of the interactions occurring at interfaces between waste packages and different barriers in the disposal facility.		J2.2.2 Improved understanding of plugs and seals	
		J1.3.7 Improved description of the spatial and temporal evolution of transformations affecting the porous media and degrading materials in the near-field of HLW and ILW disposal systems.			
		J1.3.2 Improved chemical and microbial data to better quantify gas generation and the consequences of microbial processes.			
		J1.3.5 Improved understanding of the impacts of different metallic and cementitious component phenomena on near-field evolution via improved models. H2020 Project THERAMIN			
		J1.4.4 Improved understanding of gas reactivity in the EBS.			

Programme Objectives
Collaborative RD&D
Strategic Studies
Knowledge Management Activities
H High Priority
M Medium Priority
L Low Priority
 Future
 Currently In Progress

Roadmap Domain 4: JP Priorities and Activities of Common Interest that relate to Geoscience to understand rock properties, radionuclide transport and long-term geological evolution

	Phase 0: Policy, Framework & Programme Establishment	Phase 1: Site Evaluation & Selection	Phase 2: Site Characterisation	Phase 3: Facility Construction	Phase 4: Facility Operation and Closure
<p>Theme 4 Geoscience to understand rock properties, radionuclide transport and long-term geological evolution</p> <p>Topics:</p>	<p>Includes conceptual design and preliminary qualitative safety analyses</p> <ul style="list-style-type: none"> Compile available geological information and use information to screen the country for regions with sufficient geological long-term stability and - within these regions - for geological formations at appropriate depth (minimum depth for protection from surface effects, maximum depth to ensure feasibility of construction) with acceptable barrier performance and acceptable rock mechanical properties for construction. Implement necessary studies to increase geological information as far as needed to start site evaluation 	<p>Includes preliminary site(s) design and generic safety case(s) / analyses</p> <ul style="list-style-type: none"> Refine geological information (incl. focused geological investigations) as input to and in parallel to site evaluation and site selection. Develop and refine understanding of possible long-term evolutions, incl. development of modelling capabilities Develop / refine understanding of radionuclide behaviour within the geological barrier. That includes experimental work and development of modelling capabilities Provide information to assess compatibility of waste, EBS and geological environment (repository-induced effects) Provide geological and hydraulic data sets for repository design and safety assessment, also as input to siting license if needed 	<p>Includes detailed design and site safety case / analyses for construction license</p> <ul style="list-style-type: none"> Develop/ review site characterization program (based on requirements for EBS design, facility design, safety assessment and general geological understanding) and organize / conduct measurements (in situ, lab work). Develop/ review an adequate monitoring and surveillance programme and implement monitoring devices (baseline measurements, start of long-term monitoring) Analyze data and develop/ review geological synthesis (incl. corresponding reports) that includes geological data sets for EBS design, facility design and safety assessment also as part of documentation for construction license 	<p>Includes final design and site safety case / analyses for operational license</p> <ul style="list-style-type: none"> Geological characterization of underground excavations in parallel to construction of the facility. Implement new monitoring devices / long-term experiments underground to confirm key geological information Continue with long-term monitoring Periodic re-evaluation of geological understanding and data-bases based on new information from facility construction and monitoring Maintain an overview on new findings in science Provide/ review information and documentation for operation license 	<p>Includes maintenance and update of license documentation, as required</p> <ul style="list-style-type: none"> Continue with long-term monitoring (incl. measurements underground) Geological characterization of newly constructed disposal rooms. Periodic re-evaluation of geological understanding and data-bases based on new information from facility construction and monitoring Maintain an overview on new findings in science Provide information / documentation for periodic safety evaluations Prepare/ review plans for post-closure monitoring and surveillance (if any), markers and controls.
Long-term stability (uplift, erosion and tectonics)		J3.2 Development of site evolution models, and how to manage data as it is obtained during the site characterisation phase			
Perturbations (gas, temperature and chemistry)		J1.4.4 Improved understanding of gas reactivity in the EBS and different host rocks. EJP1 WP Gas		J1.5.3 Quantification of long-term entrapment of key radionuclides in solid phases to inform reactive transport models.	M
		J1.4.1 To increase understanding of gas migration in different host rocks. EJP1 WP Gas		J1.4.3 Develop and implement two-phase flow numerical codes to increase gas transient representation at the disposal scale.	M
	J1.4.2 Improved understanding of the generation and release of radioactive trace gases and bulk gases from wasteforms and waste packages.		J1.6.1 Improved understanding of the process of fracture filling.		L
		J1.5.11 Developing a geochemical model for volatile radionuclides.			M
		J1.5.6 & J1.5.10 Improved understanding of the role of organics (either naturally occurring or as introduced in the wastes) and their influence on radionuclide migration. EJP1 WP CCR1			M
Aqueous pathways and radionuclide migration		J1.5.8 Improved understanding of the role of colloids and their influence on radionuclide migration.			M
	J1.5.2 Improved representation of sorption mechanisms and coupled chemistry / transport models for various media.		1.6.3 Developing models of groundwater evolution		M
		J1.5.9 Improved understanding of the influence of redox on radionuclide migration.		J2.2.6 Enhanced treatment of climate change, non-human biota, land-use and parameter derivation in biosphere models	M
		J1.5.7 Improved understanding of the influence of temperature on radionuclide migration and representation of effects in geochemical models.			M
		J1.5.5 Improved understanding of bounding conditions for the effects of microbial perturbations on radionuclide migration to support performance assessments.			H
	J1.5.4 Improved understanding of the transport of strongly sorbing radionuclides.			M	
	J1.6.4 Impact of rock matrix diffusion on travel time through the geosphere				

Programme Objectives
Collaborative RD&D
Strategic Studies
Knowledge Management Activities
H High Priority
M Medium Priority
L Low Priority
Future
Currently In Progress

Roadmap Domain 5: JP Priorities and Activities of Common Interest that relate to Geological disposal facility design and the practicalities of implementation

	Phase 0: Policy, Framework & Programme Establishment	Phase 1: Site Evaluation & Selection	Phase 2: Site Characterisation	Phase 3: Facility Construction	Phase 4: Facility Operation and Closure
<p>Theme 5 Geological disposal facility design and the practicalities of construction, operations and closure</p> <p>Topics:</p>	<p>Includes conceptual design and preliminary qualitative safety analyses</p> <ul style="list-style-type: none"> Based upon first ideas of the geological possibilities and taking the properties of the wastes to be disposed of into account, develop together with EBS possible broad design concepts for evaluation by safety Assess these broad options with respect to: <ul style="list-style-type: none"> -technical feasibility and technology readiness -and implement corresponding measures -cost 	<p>Includes preliminary site(s) design and generic safety case(s) / analyses</p> <ul style="list-style-type: none"> For the sites evaluated / eventually selected and for the wastes to be disposed, develop different design concepts in co-operation with EBS and safety Assess these concepts in co-operation with EBS and safety with respect to: <ul style="list-style-type: none"> -technical feasibility and technology readiness -the necessary infrastructure -cost Refine selected variants according to programme needs 	<p>Includes detailed design and site safety case / analyses for construction license</p> <ul style="list-style-type: none"> For the site selected, optimize the design concept chosen in co-operation with EBS and safety. Ensure compatibility of construction method and construction materials with EBS and safety taking the the wastes to be disposed of into account For construction, get the construction concepts ready (construction methods, installations needed, QA procedures, logistics, etc). If necessary, make together with EBS demonstration experiments / prototypes (to demonstrate understanding and/or industrial feasibility) Select the main options for the operational phase and develop technical proposals for the closure of the facility (for inclusion in the license application for construction) Assess feasibility to perform the construction, waste package emplacement, and closure operations 	<p>Includes final design and site safety case / analyses for operational license</p> <ul style="list-style-type: none"> Construction of facility (surface facilities and underground structures) according to plans, incl. QS measures to ensure that the facility is constructed as planned (incl. limited damage to host rock barrier) Allow for geological characterization of underground structures Make/ review adjustments to construction / construction method and materials if needed Implementation of technical installations and equipment according to plans Describe/ review the reference plan (design and technique) for closure of the facility, Prepare/ review the description of facility commissioning that will be performed to confirm that systems function as designed Qualify/ review the methods for emplacing the waste (and, where appropriate, ensuring reversibility or retrievability) Develop/ review detailed operating rules, instructions and procedures Develop/ review procedures for the monitoring and surveillance of the facility and radiation monitoring for operational safety 	<p>Includes maintenance and update of license documentation, as required</p> <ul style="list-style-type: none"> Construction of additional disposal rooms according to plan Operation of facility (packaging waste into disposal canisters, emplacement of canisters, backfilling and closure of disposal rooms), incl. QA measures to demonstrate that waste has been emplaced according to plans Perform inspections and maintenance according to plans When waste emplacement is complete, decommission and remove any remaining operational equipment within the facility Closure of facility according to plans (removal of equipment/ installations, preparation of seals, construction/ implementation of backfill and seals), incl. QA measures to demonstrate that closure has been implemented according to plans
Facility and disposal system design	J2.5.5 Assessment of the technical feasibility and lifecycle adaptation of a geological disposal concept for a specific site and specific nuclear waste type.  		J2.4.8 Asset management  		
Constructability, demonstration and verification testing		J2.5.8 Developing cost-effective asset management strategies for use in the design.  	J2.5.6 Improved robustness of disposal system designs using large scale mock ups.  	J2.5.7 Optimisation of backfilling and other major implementation processes, including waste emplacement, retrieval and sealing technologies.  	
Health and safety during transport, construction, operations and closure	J3.13 Radiation protection optimisation principle  	J2.4.2 Developing flooding risk assessment methodologies.  	J2.4.4 Accident management and emergency preparedness  		
Monitoring and retrievability		J3.17 Reversibility of decisions or retrievability of waste  	J2.5.1 Developing monitoring strategies appropriate to the operational phase (including facility construction and work acceptance) of geological disposal facilities that will not adversely affect the performance of the disposal system.  	J2.5.2 Developing appropriate monitoring technologies for closure and a period of post-closure institutional control in links with relevant parameters for safety  	J2.5.3 Developing innovative monitoring technologies.  

Programme Objectives	Collaborative RD&D	Strategic Studies	Knowledge Management Activities	H High Priority	M Medium Priority	L Low Priority	 Future	 Currently In Progress
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Roadmap Domain 6: JP Priorities and Activities of Common Interest that relate to Siting and Licensing

	Phase 0: Policy, Framework & Programme Establishment	Phase 1: Site Evaluation & Selection	Phase 2: Site Characterisation	Phase 3: Facility Construction	Phase 4: Facility Operation and Closure
<p>Theme 6 Siting and Licensing</p> <p>Topics:</p>	<p>Includes conceptual design and preliminary qualitative safety analyses</p> <ul style="list-style-type: none"> Develop broad concepts based on input from geology (T3), from EBS (T2), from repository design (T5) and safety (T6) taking the wastes to be disposed of into account (input from T1) Develop siting program based on national policy, legislation and regulatory guidance. Define different steps and needed activities. This also includes a document that describes and justifies the different steps and the criteria to be used to narrow down the siting possibilities. This needs to be done in close co-operation with geology, safety, EBS and facility design taking the waste properties into account. Furthermore, also work on and coordinate with land-use planning and with environmental impact assessment to ensure that the corresponding issues are properly considered. Develop a program of public involvement in siting, search of consent with key stakeholders Check for synergies if more than one geological repository will be implemented 	<p>Includes preliminary site(s) design and generic safety case(s) / analyses</p> <ul style="list-style-type: none"> Implement program and initiate and coordinate work by geology, EBS, facility design and safety In each of the narrowing-down steps, manage the evaluation of the different criteria and come to conclusions (synthesis). Manage the process to ensure compatibility with land-use planning. Implement the environmental impact assessments Manage the process of involving the stakeholders and interest groups during the stepwise narrowing-down process Go through the different steps as planned and prepare the necessary documentation to describe and justify the selected site, the EBS and facility concept, the expected safety, the compatibility with land-use planning and the environmental impact assessment Prepare the necessary documentation for any licensing decisions on siting 	<p>Includes detailed design and site safety case / analyses for construction license</p> <ul style="list-style-type: none"> Prepare the start of the field work by geology and refinement of work by all other disciplines (EBS, facility design, safety) Monitor continuously progress with site characterization and manage the process of evaluating any new findings by the different disciplines Ensure that land-use planning aspects and environmental impact assessment are properly covered Prepare synthesis and corresponding documents for the construction license and manage the construction license process Manage the process with involving the stakeholders and interest groups Make the necessary changes to the plans if any new findings do require this 	<p>Includes final design and site safety case / analyses for operational license</p> <ul style="list-style-type: none"> Prepare the start of construction work (incl. geological characterization) Monitor continuously progress with construction and manage the process of evaluating any new findings by the different disciplines (EBS, geology, facility design, safety) Prepare synthesis and corresponding documents for the operation license and manage the operation license process 	<p>Includes maintenance and update of license documentation, as required</p> <ul style="list-style-type: none"> Prepare the start of operation (and construction in parallel, incl. geological characterization) Monitor continuously progress with operation and manage the process of evaluating any new findings by the different disciplines (EBS, geology, facility design, safety) Manage the process with involving the stakeholders and interest groups Prepare/ review the syntheses and corresponding documents for the periodic safety evaluations and for the closure license and manage the licensing process Prepare/ review plans for post-closure monitoring and surveillance (if any), markers and controls Prepare/ review plans for site security and nuclear safeguards post-closure Prepare the start of closure and implement closure
Site selection process	3.3 Site selection process M				
Detailed site investigation		J1.6.5 Maintaining and developing understanding of tools and techniques for developing site descriptive models H	J1.6.2 Developing state-of-the-art on the methods of uncertainty management associated with site characteristics M		
		3.1 Methodologies for site uncertainty treatment M			
		3.2 Site evolution models, and how to manage data as it is obtained during the site characterisation phase H			
Licensing					

Programme Objectives	Collaborative RD&D	Strategic Studies	Knowledge Management Activities	H High Priority	M Medium Priority	L Low Priority	Future	Currently In Progress
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Roadmap Domain 7: JP Priorities and Activities of Common Interest that relate to Performance assessment, safety case development and safety analyses

	Phase 0: Policy, Framework & Programme Establishment	Phase 1: Site Evaluation & Selection	Phase 2: Site Characterisation	Phase 3: Facility Construction	Phase 4: Facility Operation and Closure
<p>Theme 7 Performance assessment, safety case development, and safety analyses</p> <p>Topics:</p>	<p>Includes conceptual design and preliminary qualitative safety analyses</p> <ul style="list-style-type: none"> Based upon first ideas of the geological possibilities and characteristics of the disposal inventory, provide input / requirements to EBS (T3) to develop EBS concepts Assess these broad options with respect to barrier functions, taking long-term evolution and possible perturbations into account, these being internal (thermal, chemical, mechanical, radiological) or external (intrusion, climate change, seismicity) Perform first system analyses to assess feasibility that a sufficient level of overall system safety can be achieved Increase understanding of repository performance (waste, EBS, geological barrier) and its long-term evolution Identify areas where knowledge is lacking or uncertainties are high and establish priorities for further work in the next phase Start developing and exchange with stakeholders 	<p>Includes preliminary site(s) design and generic safety case(s) / analyses</p> <ul style="list-style-type: none"> For the sites evaluated / selected and for the disposed inventory, identify perturbations that affect disposal system performance Refine input / requirements to EBS to further develop EBS concepts and commence design adaption to site characteristics Assess EBS options and facility design with respect to barrier functions, taking long-term evolution and possible perturbations into account Continue activities to increase understanding of repository performance (waste, EBS, geological barrier) and its long-term evolution. This may lead to the start of an experimental programme If needed, prepare/ review safety report for site selection license Identify key uncertainties and establish how they can be managed 	<p>Includes detailed design and site safety case / analyses for construction license</p> <ul style="list-style-type: none"> For the site selected and disposal inventory provide refined input to further develop EBS layout and to optimise repository design Assess EBS layout and facility design with respect to barrier functions, taking long-term evolution, possible perturbations and manufacturing defects into account Increase understanding of repository performance (waste, EBS, geological barrier) and its long-term evolution, and identify knowledge gaps and major uncertainties. Continue experimental programme Analyze any new findings from site characterization Perform/ review preliminary operational safety analyses, for design implementation purposes. Assess possible consequences of residual uncertainties Prepare/ review safety report for construction license 	<p>Includes final design and site safety case / analyses for operational license</p> <ul style="list-style-type: none"> Provide input to EBS layout and facility design (optimization) and make assessments of proposals as far as needed Analyze any new findings and experience feedback during construction (see WENRA SRLs) Continue activities to increase understanding of repository performance (waste, EBS, geological barrier) and its long-term evolution. Continue experimental programme Perform/ review operational safety analyses considering normal operation and accident conditions Substantiate/ verify that safety significant uncertainties have been reduced where possible and that residual uncertainties do not undermine long-term safety and can be managed. Prepare/ review safety report for operation license based on the as-built facility 	<p>Includes maintenance and update of license documentation, as required</p> <ul style="list-style-type: none"> Assess/ review modifications (to operations, e.g., construction, design, waste acceptance criteria and update the safety case accordingly (see e.g. IAEA NSG-2.3) to incorporate information gained during operation and closure (information about the facility as actually built and the waste as actually emplaced, any advances in understanding). Prepare/ review input and documentation for periodic safety evaluations considering advances in science and technology Provide input for any optimization, if needed Update/ review the demonstration that the implementation of the safety strategy has led to the management of uncertainties (including, where possible, their avoidance or reduction) Prepare/ review safety report for closure license
Integration of safety-related information	J3.9 Safety case management and review 	J2.2.3 Improved understanding of the spatial extent and evolution with time of oxidative transients, as well as the possible impact on safety functions  J2.2.4 Improved understanding of the upscaling of THMC modelling for coupled hydro-mechanical-chemical processes in time and space  J2.1.5 Natural analogues 	J2.2.1 Improved understanding and models for the impact of THMC on the behaviour of the host rock and the buffer materials  J2.4.3 Impacts of operational safety 	J2.1.1 Improved understanding of the influence of pre-closure disturbances on long-term safety  J2.4.3 Improve understanding of the impacts of operational safety  J2.3.7 Improved computing  J2.4.1 Improved fire and impact assessment 	
Performance assessment and system models	J2.1.2 Assessment methodologies  J2.1.4 Dose thresholds  J2.3.1 Improved performance assessment tools  J2.3.2 Open-source performance assessment code 	J2.3.5 Improved understanding for the role of physical/ chemical processes at different scales and linking bottom-up and top-down approaches in performance assessment  J2.2.6 Enhanced treatment of climate change, non human biota, land-use and parameter derivation in biosphere models  J1.5.1 Further develop transparent and quality assured thermodynamic databases for use in performance assessments 	J2.3.6 Improved treatment of heterogeneity  J2.2.2 Improved understanding of the performance of plugs and seals  J2.3.3 Improve geosphere transport models  J2.3.4 Improved multi-scale reactive transport models 	J2.1.5 Improved understanding for the impact of deviations in planned implementation scenarios on the performance assessment outputs of the disposal facility 	
Treatment of uncertainties			J2.1.3 Further refinement of methods to make sensitivity and uncertainty analyses 		

Programme Objectives	Collaborative RD&D	Strategic Studies	Knowledge Management Activities	H High Priority	M Medium Priority	L Low Priority	 Future	 Currently In Progress
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