European Joint Programme
on Radioactive Waste Management

ROADMAP

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

THIS PROGRAMME HAS RECEIVED FUNDING FROM EURATOM RESEARCH AND TRAINING PROGRAMME 2014-2018 UNDER GRANT AGREEMENT N°847593.

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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.

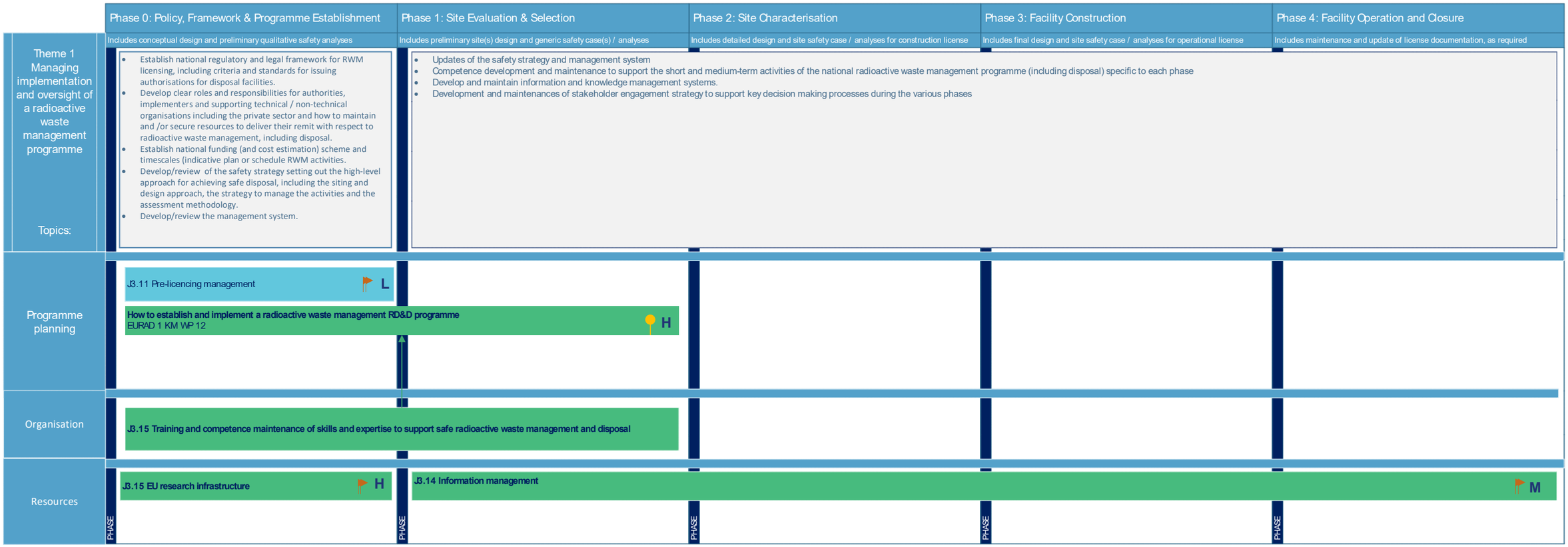
The IAEA phases used in the roadmap are of a general nature and are each applicable to several waste streams and waste types and include scope on knowledge management to share experiences. The same is also true of SRA domains with the topics / sub-topics where, however, some of the topics have less relevance 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)

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



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
	Includes conceptual design and preliminary qualitative safety analyses	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
Theme 2 Radioactive waste characterisation, processing and storage (Pre-disposal activities), and source term understanding for disposal Topics:	• 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.	• 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.		• 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.	• 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	1.2.4 Management of damaged waste packages H2020 Project DISCO 3.7 Links between waste producers & implementers J1.1.3 Novel conditioning methods for problematic wastes. H2020 Project THERAMIN H Waste management routes across Europe EJP1 WP ROUTES H	J1.1.7 Improved understanding of the nature and quantities of the likely chemotoxic component of common decommissioning wastes. M J1.1.2 Technology for characterisation & segregation of historical wastes. H2020 Projects CHANCE, INSIDER & THERAMIN M J1.1.8 Optimisation of novel waste treatment techniques. EJP1 Project SFC M			
Interim storage	3.10 Long-term storage for disused seals radioactive sources 2.4.5 Operational lifespan of interim storage				
Transportation between facilities					
Radionuclide inventory and source term	3.6 Methodologies applied to refine inventory 3.5 Inventory collation J1.1.1 Inventory data and uncertainty treatment. EJP1 WP SFC J1.1.10 Quantification of fissile content of spent fuels. L	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 J1.1.9 Improved understanding of radionuclide release from wasteforms other than spent fuel. H J1.1.4 Improved understanding of radionuclide release from spent fuel, inc. fire and impact. H2020 Project DISCO & EJP1 WP SFC H J1.1.5 Demonstration of geopolymer performance in representative disposal conditions. M J1.1.6 Fourth generation (Gen(IV)) wastes L	1.4.2 Improved understanding of the generation and release of radioactive trace gases and bulk gases from wasteforms and waste packages. H		
Waste acceptance criteria	PHASE	PHASE	PHASE	PH	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
	Includes conceptual design and preliminary qualitative safety analyses	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
Theme 3 Engineered barrier system (EBS) properties, function and long-term performance Topics:	• 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: - 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	• 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: - 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)	• 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)	• 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	• 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.** M			
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 H	**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 H			
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 H **J1.3.4 Improved understanding of low pH cements.** H2020 Project CEBAMA M			
Salt backfills		J1.3.6 Improved understanding of a salt backfill. L			
EBS system understanding	J1.3.8 Identify co-disposal interactions of importance to long-term safety. L	**J1.2.1 Improved understanding of the interactions occurring at interfaces between waste packages and different barriers in the disposal facility.** H **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.** H **J1.3.2 Improved chemical and microbial data to better quantity gas generation and the consequences of microbial processes.** H **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 H **J1.4.4 Improved understanding of gas reactivity in the EBS.** H	**J2.2.2 Improved understanding of plugs and seals** H	

PHASE PHASE PHASE PHASE

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

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

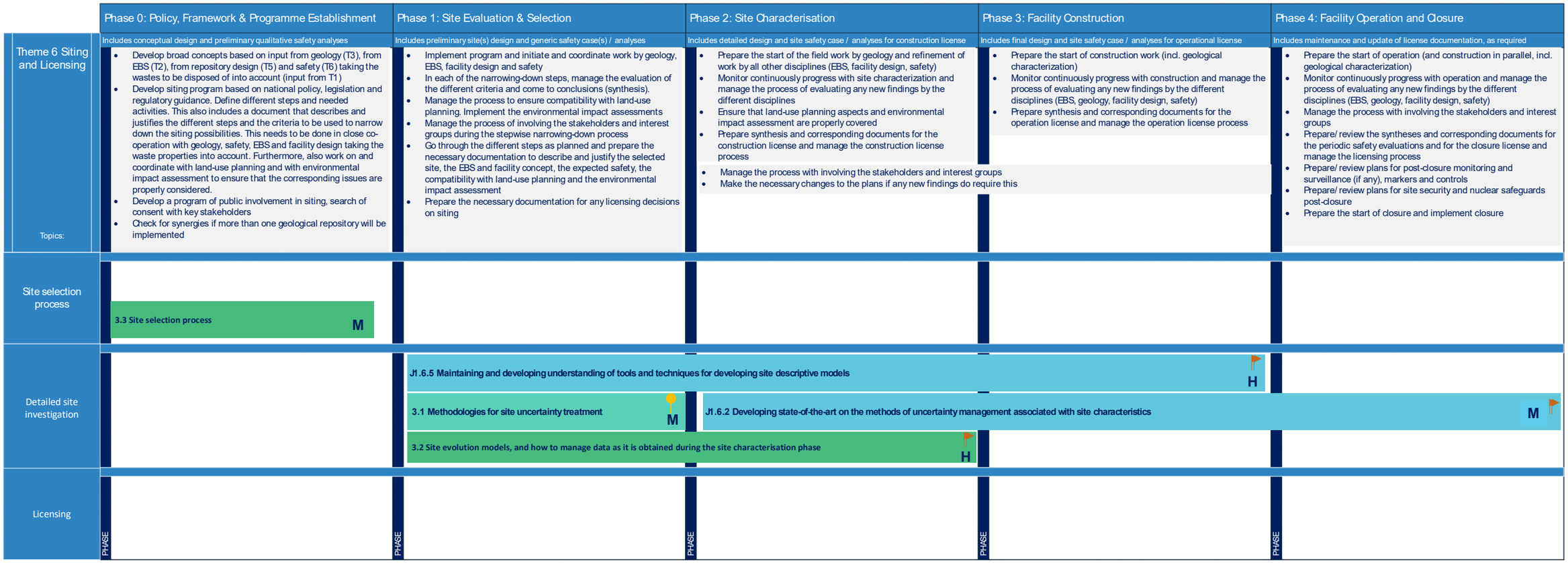
	Phase 0: Policy, Framework & Programme Establishment	Phase 1: Site Evaluation & Selection	Phase 2: Site Characterisation	Phase 3: Facility Construction	Phase 4: Facility Operation and Closure
	Includes conceptual design and preliminary qualitative safety analyses	Includes preliminary site(s) design and 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
Theme 5 Geological disposal facility design and the practicalities of construction, operations and closure Topics:	• 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: -technical feasibility and technology readiness and implement corresponding measures - cost	• 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: -technical feasibility and technology readiness -the necessary infrastructure -cost • Refine selected variants according to programme needs	• 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	• 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	• 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. L J3.12 Managing co-disposal L		J2.4.8 Asset management M		
Constructability, demonstration and verification testing		J2.5.8 Developing cost-effective asset management strategies for use in the design. M	J2.5.6 Improved robustness of disposal system designs using large scale mock ups. L J2.5.7 Optmisation of backfilling and other major implementation processes, including waste emplacement, retrieval and sealing technologies. M		
Health and safety during transport, construction, operations and closure	J3.13 Radiation protection optimisation principle L	J2.4.2 Developing flooding risk assessment methodologies. L	J2.4.4 Accident management and emergency preparedness L		
Monitoring and retrievability	PHASE	J3.17 Reversibility of decisions or retrievability of waste L PHASE	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. H PHASE	J2.5.2 Developing appropriate monitoring technologies for closure and a period of post-closure institutional control in links with relevant parameters for safety M J2.5.3 Developing innovative monitoring technologies. H PHASE	

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 6: JP Priorities and Activities of Common Interest that relate to Siting and Licensing



Roadmap Domain 7: JP Priorities and Activities of Common Interest that relate to Performance assessment, safety case development and safety analyses