Deliverable n°5.1
Roadmap for a Joint Programme on Radioactive Waste Management and Disposal

Work Package 5

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<thead>
<tr>
<th>Dissemination Level</th>
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<td>PU</td>
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A Roadmap, with clear objectives, linking the EuropJoint Programme 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, the Joint Programme 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 the Joint Programme 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 the Joint Programme, 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 theme-specific table showing how identified activities of the Joint Programme SRA relate to different Phases of implementation and typical Waste Management Programme objectives for each theme (blue boxes). The SRA tasks are flagged (†) to illustrate those being addressed in-part or in-full by scope of active projects EC-funded projects, including those of the Joint Programme. Tasks that will be addressed in future work of the Joint programme are flagged also (††). RD&D, Knowledge Management and Strategic Studies are each colour differently also - **once KM Work Package descriptions available we can colour code those that are active Vs. those for the future. Please note that roadmap diagrams are still draft and work-in-progress as WPs develop.

The Roadmap tables will be used throughout the Joint Programme as a tool to support managing the SRA in reviewing progress, updating on how new work should be prioritised (importance and urgency) and communicating the completed, ongoing and future work activities to those interested in our work.
Roadmap Overview: Map of Joint Programme Tasks (as prioritised by EC JOPRAD project) for each Scientific Theme mapped to Typical Phases of a Waste Management Programme

### Waste Management Programme Phases of Implementation (0-4):
- Top line corresponds to IAEA Phases, second line describes the design and safety case emphasis in each Phase

<table>
<thead>
<tr>
<th>Phase 0</th>
<th>Policy, Framework &amp; Programme Establishement</th>
</tr>
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<tbody>
<tr>
<td>Phase 1</td>
<td>Site Evaluation &amp; Selection</td>
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<td>Facility Operation and Closure</td>
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#### Scientific Theme

- Tasks are assigned across phases and sub-theme for where they are most relevant
- Tasks show EC-funded work by yellow marker, inc. name of the Horizon H2020 project or EJP1 work package
- Tasks are colour coded to show if they are predominantly an RD&D, Strategic Study, or KM activity
- Tasks identified by the JP as a priority for future work are indicated with double blue flag and marked H/M/L
Roadmap Theme 1: JP Priorities and Activities of Common Interest that relate to Managing implementation and oversight of a radioactive waste management programme

<table>
<thead>
<tr>
<th>Phase 0: Policy, Framework &amp; Programme Establishment</th>
<th>Phase 1: Site Evaluation &amp; Selection</th>
<th>Phase 2: Site Characterisation</th>
<th>Phase 3: Facility Construction</th>
<th>Phase 4: Facility Operation and Closure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Includes conceptual design and preliminary qualitative safety analyses</td>
<td>Includes preliminary detail design and generic safety cases / analyses</td>
<td>Includes detailed design and site safety cases / analyses for construction license</td>
<td>Includes detailed design and site safety cases / analyses for operational license</td>
<td>Includes maintenance and update of license documentation, as required</td>
</tr>
</tbody>
</table>

**Phase 3: Facility Construction**

- Includes final design and site safety case / analyses for operational license

**Phase 2: Site Characterisation**

- Includes detailed design and site safety case / analyses for construction license

**Phase 1: Site Evaluation & Selection**

- Includes preliminary design and generic safety cases / analyses

**Phase 0: Policy, Framework & Programme Establishment**

- Includes conceptual design and preliminary qualitative safety analyses

Sub-Themes:

- Establishment of national regulatory and legal framework for radioactive waste management licensing framework, including criteria and standards for issuing authorisations for disposal facilities - See IAEA INFCIRC/546.
- 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.
- Establishment of national funding (and cost estimation) scheme and timescales (indicative plan or schedule) for radioactive waste management, including disposal.

- Programme planning

  - J3.11 Pre-licensing management
  - J3.15 Training and competence maintenance of skills and expertise to support safe radioactive waste management and disposal
  - J3.14 Information management

- Organisation

  - J3.15 Training and competence maintenance of skills and expertise to support safe radioactive waste management and disposal

- Resources

  - J3.15 EU research infrastructure

**Theme 1: Managing implementation and oversight of a radioactive waste management programme**

**Programme Objectives**

- High Priority
- Medium Priority
- Low Priority

**RD&D Activities**

- High Priority
- Medium Priority
- Low Priority

**Strategic Studies**

- High Priority
- Medium Priority
- Low Priority

**Knowledge Management Activities**

- High Priority
- Medium Priority
- Low Priority
### Roadmap Theme 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

<table>
<thead>
<tr>
<th>Phase 0: Policy, Framework &amp; Programme Establishment</th>
<th>Phase 1: Site Evaluation &amp; Selection</th>
<th>Phase 2: Site Characterisation</th>
<th>Phase 3: Facility Construction</th>
<th>Phase 4: Facility Operation and Closure</th>
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</thead>
<tbody>
<tr>
<td><strong>Programme Objectives</strong></td>
<td><strong>RD&amp;D Activities</strong></td>
<td><strong>Strategic Studies</strong></td>
<td><strong>Knowledge Management Activities</strong></td>
<td><strong>High Priority</strong></td>
</tr>
</tbody>
</table>

**Phase 0: Policy, Framework & Programme Establishment**
- Develop and maintain national waste inventory, characterization, and treatment technologies.
- Develop and maintain national waste acceptance criteria and standards.

**Phase 1: Site Evaluation & Selection**
- Provide input to the development of disposal options, including waste inventory and site-specific safety analyses.
- Develop guidance for waste management, including waste acceptance criteria for different disposal facilities.
- Where necessary, develop new waste management methods and protocols for the development of the corresponding waste management facilities.

**Phase 2: Site Characterisation**
- Adjust waste treatment guidance, preliminary waste acceptance criteria, and refined site-specific safety analyses 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 perspective selected site.
- Provide inventory and source term understanding for construction license.

**Phase 3: Facility Construction**
- Transform waste treatment guidance into draft waste acceptance criteria and adjust them according to detailed planning and development (optimization for safety and other issues (incl. cost)).
- Provide inventory and source term understanding for operational license.

**Phase 4: Facility Operation and Closure**
- Organize logistics (delivery of waste to repository) and enforce compliance of waste disposal facilities.
- 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.
### Roadmap Theme 3: JP Priorities and Activities of Common Interest that relate to Engineered barrier system (EBS) properties, function and long-term performance

<table>
<thead>
<tr>
<th>Phase 0: Policy, Framework &amp; Programme Establishment</th>
<th>Phase 1: Site Evaluation &amp; Selection</th>
<th>Phase 2: Site Characterisation</th>
<th>Phase 3: Facility Construction</th>
<th>Phase 4: Facility Operation and Closure</th>
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</thead>
<tbody>
<tr>
<td><strong>Theme 3 Engineered barrier system (EBS) properties, function and long-term performance</strong>&lt;br&gt; Sub-Theme:&lt;br&gt;Spent Fuel and high-level wastes&lt;br&gt;Clay-based backfills, plugs and seals&lt;br&gt;Cementitious-based backfills, plugs and seals&lt;br&gt;Salt backfills&lt;br&gt;EBS system understanding</td>
<td><strong>Sub-Theme:</strong>&lt;br&gt;JP Priorities and Activities of Common Interest that relate to Engineered barrier system (EBS) properties, function and long-term performance</td>
<td><strong>Sub-Theme:</strong>&lt;br&gt;Knowledge Management Activities&lt;br&gt;Strategic Studies</td>
<td><strong>Sub-Theme:</strong>&lt;br&gt;Programme Objectives&lt;br&gt;R&amp;D Activities</td>
<td><strong>Sub-Theme:</strong>&lt;br&gt;Implementation components according to plan (manufacturing, transport, employment and quality assurance)&lt;br&gt;Monitoring of EBS performance (partially in dedicated experimental prototypes)&lt;br&gt;Where deemed necessary or useful, continue optimization and increase understanding&lt;br&gt;Provide input to closure and implement components for closure according to plan</td>
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- 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<br>- Assess these broad options with respect to: - contribution of the EBS in long-term safety - compatibility of EBS components with one another and other repository materials - technical feasibility and technology readiness cost<br>- For the site selected, optimise the EBS concepts chosen in cooperation with long-term safety, geology, and facility design - contribution of the EBS in long-term safety of the 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)<br>- For the sites selected, optimise the EBS concepts chosen in cooperation with long-term safety, geology, and facility design<br>- Increase the level of understanding (incl. predictability of performance and reliability of the assessment method)<br>- Adapt selected variants to site conditions and increase understanding of EBS performance (and reliability of the assessment method)<br>- For those components needed during construction, get industrial production ready<br>- For those components needed during operation, get industrial production ready<br>- If necessary, prepare demonstration experiments / prototypes (to demonstrate understanding and/or industrial feasibility)<br>- For the site selected, optimise the EBS concepts chosen in cooperation with long-term safety, geology, and facility design<br>- Implement components according to plan (manufacturing, transport, employment and quality assurance)<br>- Monitoring of EBS performance (partially in dedicated experimental prototypes)<br>- Where deemed necessary or useful, continue optimization and increase understanding<br>- Provide input to closure and implement components for closure according to plan |

#### Programme Objectives
- **High Priority**
- **Medium Priority**
- **Low Priority**

#### R&D Activities
- **High Priority**
- **Medium Priority**
- **Low Priority**

#### Strategic Studies
- **High Priority**
- **Medium Priority**
- **Low Priority**

#### Knowledge Management Activities
- **High Priority**
- **Medium Priority**
- **Low Priority**
### Roadmap Theme 4: JP Priorities and Activities of Common Interest that relate to Geoscience to understand rock properties, radionuclide transport and long-term geological evolution

<table>
<thead>
<tr>
<th>Phase 0: Policy, Framework &amp; Programme Establishment</th>
<th>Phase 1: Site Evaluation &amp; Selection</th>
<th>Phase 2: Site Characterisation</th>
<th>Phase 3: Facility Construction</th>
<th>Phase 4: Facility Operation and Closure</th>
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</thead>
<tbody>
<tr>
<td>Includes programme design and project management capability (M)</td>
<td>Includes detailed design and site safety case / analyses for construction licence</td>
<td>Develop site characterisation program (based on requirements for BSS design, facility design, safety assessment and general geophysical understanding and ingenuity – construct integrated models of the geosphere – plan and conduct integrated field investigations in parallel to construction of the facility. Implement new monitoring devices / long-term experiments to confirm key geological information – continue with long-term monitoring – develop geological synthesis (incl. corresponding reports) that includes geological data sets for BSS design, facility design and safety assessment also as part of documentation for construction licence</td>
<td>Includes final design and site safety case / analyses for operational licence</td>
<td>Includes review and additional documentation as required</td>
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<tr>
<td>Includes detailed design and site safety case / analyses for construction licence</td>
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<tr>
<td>Compile and disseminate geological information and new information to review the site for regions with sufficient geological long-term stability and within these regions – for geological formations, including geological effects, maximum depth to ensure feasibility of construction – with acceptable barrier performance and acceptable rock mechanical properties for construction – include necessary studies to increase geological information also as needed to start site evaluation</td>
<td>Develop site characterisation program (based on requirements for BSS design, facility design, safety assessment and general geophysical understanding and ingenuity – construct integrated models of the geosphere – plan and conduct integrated field investigations in parallel to construction of the facility. Implement new monitoring devices / long-term experiments to confirm key geological information – continue with long-term monitoring – develop geological synthesis (incl. corresponding reports) that includes geological data sets for BSS design, facility design and safety assessment also as part of documentation for construction licence</td>
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<tr>
<td>Review geophysical information (incl. proposed potential of investigations) as input to and in parallel to site evaluation and site selection</td>
<td>Implement new monitoring devices / long-term experiments to confirm key geological information – continue with long-term monitoring – develop geological synthesis (incl. corresponding reports) that includes geological data sets for BSS design, facility design and safety assessment also as part of documentation for construction licence</td>
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<tr>
<td>Implement necessary studies to increase geological information also as needed to start site evaluation</td>
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<td>Long-term stability (sedi, erosion and weathering)</td>
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<td>Perturbations (gas, temperature and chemistry)</td>
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<tr>
<td>Aquifer pathways and radionuclide migration</td>
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**Roadmap Theme 5: JP Priorities and Activities of Common Interest that relate to Geological disposal facility design and the practicalities of implementation**
Roadmap Theme 6: JP Priorities and Activities of Common Interest that relate to Siting and Licensing

### Theme: Siting and Licensing

#### Sub-themes:
- Site selection process
- Detailed site investigation
- Licensing

#### Phase 0: Policy, Framework & Programme Establishment
- Develop vision, mission, and programme goals
- Identify key stakeholders
- Develop programme plan and budget
- Establish programme management structure

#### Phase 1: Site Evaluation & Selection
- Develop site evaluation criteria
- Assess site options
- Select the most suitable site

#### Phase 2: Site Characterisation
- Conduct site characterisation
- Analyse site data
- Develop site models

#### Phase 3: Facility Construction
- Develop site for construction
- Construct facility
- Operate facility

#### Phase 4: Facility Operation and Closure
- Operate facility
- Close facility

#### Programme Objectives

<table>
<thead>
<tr>
<th>RD&amp;D Activities</th>
<th>Strategic Studies</th>
<th>Knowledge Management Activities</th>
<th>Currenty In Progress</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>H High Priority</td>
<td>M Medium Priority</td>
<td>L Low Priority</td>
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</tbody>
</table>
**Roadmap Theme 7: JP Priorities and Activities of Common Interest that relate to Performance assessment, safety case development and safety analyses**

<table>
<thead>
<tr>
<th>Phase 0: Policy, Framework &amp; Programmes Establishment</th>
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</thead>
<tbody>
<tr>
<td>Includes conceptual design and preliminary site safety analyses</td>
<td>Includes preliminary safety design and generic safety safety cases / analyses</td>
<td>Includes detailed design and site safety case analyses for construction license</td>
<td>Includes final design and site safety case analyses for operation license</td>
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**Integration of safety-related information**

<table>
<thead>
<tr>
<th>Change Theme 7 Performance assessment, safety case development, and safety analysis objectives</th>
<th>Integration of safety-related information</th>
<th>Performance assessment and system models</th>
<th>Treatment of uncertainties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Includes conceptual design and preliminary site safety analyses</td>
<td>Includes detailed design and site safety case analyses for construction license</td>
<td>Includes final design and site safety case analyses for operation license</td>
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</tbody>
</table>

**Key Points**

- Phase 0: Policy, Framework & Programmes Establishment
  - Includes conceptual design and preliminary site safety analyses

- Phase 1: Site Evaluation & Selection
  - Includes preliminary safety design and generic safety safety cases / analyses

- Phase 2: Site Characterisation
  - Includes detailed design and site safety case analyses for construction license

- Phase 3: Facility Construction
  - Includes final design and site safety case analyses for operation license

- Phase 4: Facility Operation and Closure
  - Includes maintenance and update of license documentation, as required

**Programme Objectives**

- High Priority
- Medium Priority
- Low Priority

**R&D Activities**

- Future
- Currently in Progress