European Joint Programme on Radioactive Waste Management

ROADMAP

USER GUIDE

Navigating EURAD research priorities and accessible knowledge in Radioactive Waste Management

“The EURAD Roadmap is essentially a representation of a generic Radioactive Waste Management (RWM) Programme enabling users and programmes to ‘click-in’, and to access existing knowledge, ongoing work and future plans. The content is focused on what knowledge, and competencies (including infrastructure) is considered most critical for implementation of RWM, aligned to the EURAD Vision.

If done correctly, our Roadmap will clearly communicate why different activities are supported and prioritized by different programmes according to their phase of implementation, radioactive waste inventory, geology, disposal concept, and national requirements. A key part of this narrative is signposting to existing knowledge, guidance and training – both existing within our EURAD community and elsewhere.

The Roadmap allows one to identify gaps in knowledge and competencies needed individually by each of the member states to take action accordingly. This gap analysis will also support the future orientation of joint activities.

This User Guide describes the structure of the EURAD Roadmap and the variety of ways we are currently using it to support our work.

The greatest asset of EURAD is the many decades of RWM experience, talent and knowledge held within our community. Operating now as a Joint Programme, we are able to better harvest this shared knowledge to help orientate our future research and training priorities, and to structure the transfer of knowledge between programmes and to the future generations.“

Piet Zuidema

EURAD Chief Scientific Officer

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GLOSSARY

The following are common terms used in the context of the EURAD Roadmap:

Capability

The capacity to be used, treated, or developed for a specific purpose. Often it refers to a talent or ability that has potential for development or use.

Communities of practice (CoP)

A voluntary group of peer practitioners who share lessons learned, methods, and best practices in a given discipline or for specialized work. The term also refers to a network of people who work on similar processes or in similar disciplines, and who come together to develop and share their knowledge in that field for the benefit of both themselves and their and other organization(s).

Competency mapping

A mapping process to create a set of required competencies for successfully delivering a radioactive waste management and disposal programme within the different phases of implementation.

Competency

Generic task or a function. The ability to put skills, knowledge and attitudes into practice in order to perform activities or a job in an effective and efficient manner within an occupation or job position to identified standards. This may also involve crucial infrastructure needed for a specific task.

Contaminant

A general term used within the EURAD Roadmap to refer to contaminants originating from radioactive waste, which may include radionuclides, chemotoxic substances, or hazardous chemicals.

Domain

An area of activity, interest, or knowledge, especially one that a particular person, organization etc deals with. Also referred to as 'Topic' or 'Knowledge Area'.

EURAD

The European Joint Programme on Radioactive Waste Management (EURAD). Also referred to as the 'Joint Programme'.

Expert

Someone widely recognized as a reliable source of knowledge, technique or skill whose faculty for judging or deciding rightly, justly, or wisely is accorded authority and status by their peers or the public in a specific well-distinguished domain.

Knowledge

Knowledge: A mix of experiences, values, contextual information and expert insight for acquiring, understanding and interpreting information. Together with attitudes and skills, it forms a capacity for effective actions.

Knowledge base

1. The knowledge available to an organization
2. The knowledge available in a specific knowledge domain
3. A technology used to store complex structured and unstructured information used by a computer system.

Knowledge Management

Knowledge Management coordinates and integrates systemic practices and activities which enable and promote effective knowledge processes and ensure adequate knowledge assets as needed to achieve organizational goals.

Methodological Guidance

Activities consisting of developing a comprehensive suite of instructional guidance documents that can be used by Member-States with RWM programmes.

Mindmap

A diagram used to visually organize information.

Roadmap

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

State of Knowledge (SoK)

Experts' view of the most relevant knowledge and associated uncertainties in a specific domain/sub-domain applied in the context of a radioactive waste management programme. Activities consisting of developing a systematic approach of establishing the state-of-knowledge in the field of RWM research.

State of The Art (SoTA)

Scientific facts underpinning the knowledge base.

Strategic Research Agenda (SRA)

Describes the scientific and technical domains (and sub-domains) and knowledge management needs of common interest between EURAD participant organisations.

Themes

Themes are large groupings of related Knowledge Domains typical in Radioactive Waste Management. They are the highest level of the EURAD Roadmap work breakdown structure.

Training and Mobility

Activities consisting of developing a diverse portfolio of tailored basic and specialised training courses taking stock of and building upon already existing initiatives and creating new initiatives to bridge the identified gaps.

Work Package

A work package is a group of related tasks established within EURAD. Because they look like projects themselves, they are often thought of as sub-projects within the Joint Programme.

Work Breakdown Structure (WBS)

The EURAD work breakdown structure is a functional-oriented breakdown of knowledge essential for radioactive waste management. It originally comprised Themes (Level 1) and Domains (Level 2) during the EURAD establishment of its first SRA. It has subsequently been extended with Sub-Domains (Level 3) for organising Competency Matrices and SoK.

WHAT IS THE EURAD ROADMAP?

All EU Member States generate radioactive waste, with national inventories ranging from single producers or small inventories, up to larger volumes (of high radioactivity). Member States also differ between those with extensive nuclear programmes (some of them including spent nuclear fuel and large volumes of radioactive materials from reprocessing) and variations in national requirements and priorities for RWM implementation (geological and/or near-surface disposal, interim storage or combinations of all these either in operation, construction or planned for the future).

This mix of varying levels of advancement (with respect to implementation of different waste management strategies) combined with a diverse range of national-specific nuclear boundary conditions (including geology, legal requirements) means that there is no "one size fits all" programme for RWM (including repository implementation). Each Member State must develop its own programme, inevitably with scope common and complementary to what others have done or have planned.

Generalities or typical activities common across RWM programmes are the basis of the EURAD Roadmap – organised in a matrix of Phases (the time perspective) and a Thematic Work Breakdown Structure (WBS) of RWM Themes > Domains > Sub-domains. The EURAD roadmap has many 'layers' with content in each organised in a systematic way according to the WBS.

The EURAD Roadmap can be conceptualised as a system, currently paper-based. Its development is a significant advancement since its origins during the establishment of EURAD, when it was initiated exclusively for mapping RD&D needs. Since this time, the functionality and WBS of the roadmap has been further developed, recognising its pivotal role in structuring knowledge, information and data that already exists in the field of RWM to support Knowledge Management.

Typical Phases of Radioactive Waste Management (x-axis)

0. Policy, framework and programme establishment

1. Site evaluation and site selection

2. Site characterisation

3. Facility construction

4. Facility operation and closure

5. Post-closure

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

The IAEA phases of a waste disposal programme (and their associated major objectives) are used to provide the Roadmap time perspective (IAEA, 2014). EURAD added Phase 0 to recognise the needs of Members States who are in the process of establishing a waste management programme.

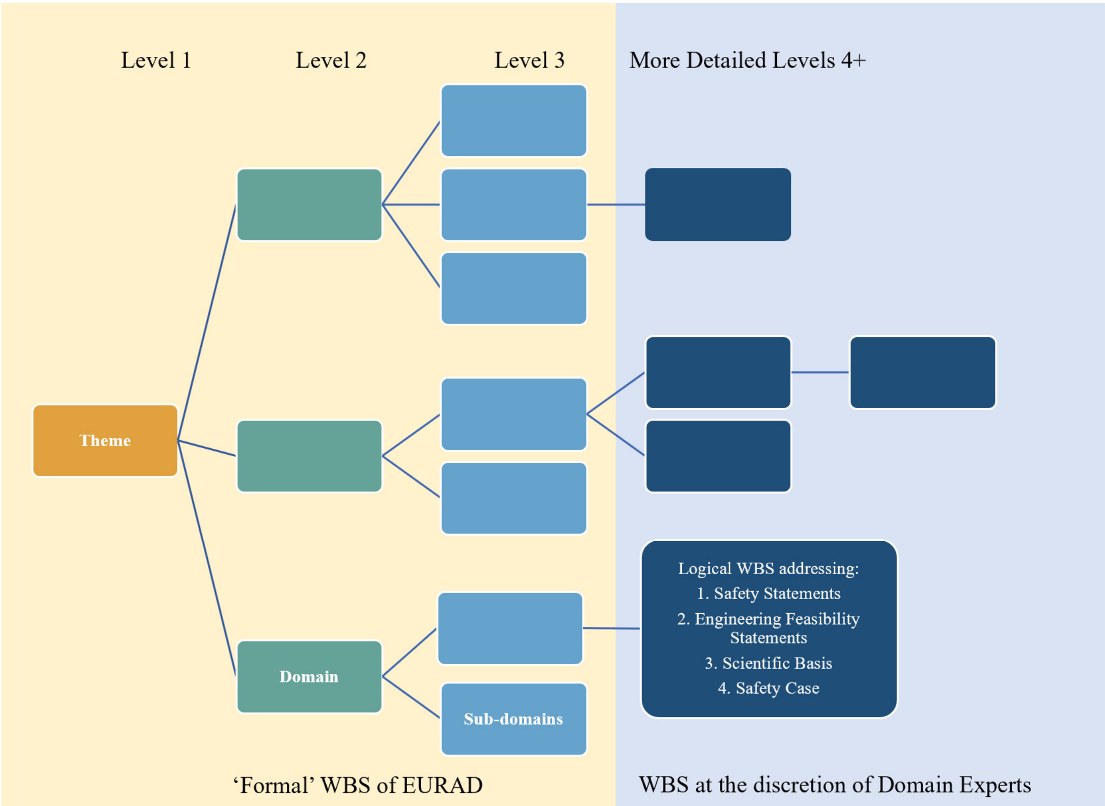
Thematic Work Breakdown Structure (y-axis)

The Roadmap is structured at the highest level by seven themes of the EURAD Strategic Research Agenda (EURAD SRA, 2019):

1. Managing implementation and oversight of a radioactive waste management programme
2. Radioactive waste characterisation, processing and storage (Pre-disposal activities)
3. Engineered barrier system properties, function and long-term performance
4. Geoscience to understand rock properties, radionuclide transport and long-term geological evolution.
5. Facility design and the practicalities of construction, operations and closure.
6. Siting and licensing.
7. Performance assessment, safety analyses and safety case development.

For each theme, the Roadmap sets out clear objectives typical of the different phases of a radioactive waste management (RWM) programme. The Roadmap elaborates further on how the emphasis of work on each of these differs and changes through successive phases.

Each of the seven themes of the Roadmap is further organised and sub-divided into a formal work breakdown structure (WBS), typically with between 3-4 levels:



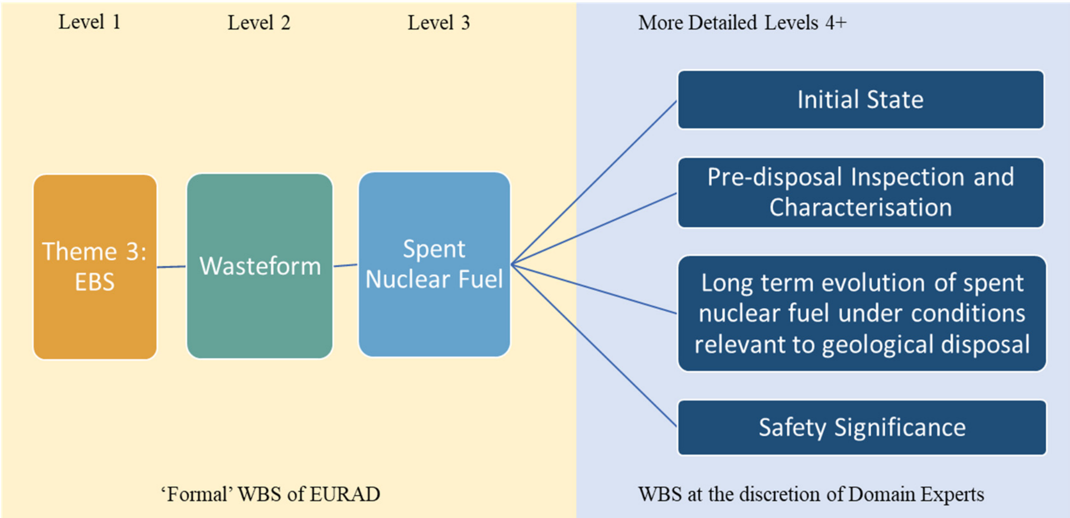
The formal WBS of EURAD exists to provide a common framework at the highest levels. Flexibility is offered at more detailed levels, primarily dependent on preferences of contributing domain experts. The importance or significance of the domain/sub domain to implementation may dictate to some extent how many levels are needed.

Orienting lower levels of the WBS by Safety and Engineering Statements, Scientific Basis, and the Safety Case

The Roadmap is orientated by 'what's important for implementation' but yet covering a large range of radioactive waste management scenarios (i.e. interim storage, near-surface storage, geological disposal, and varying national boundary condition relative to requirements and disposal system options). As such, beyond Level 3, a common 'functional' logic is introduced to support further breakdown:

1. Generic (high-level) safety statements related to performance expectations of the system.
2. Engineering feasibility statements for the implementation period - issues of practicability and industrialisation relative to can it be done, and has it been done.
3. Scientific and technological basis (relative to long-term safety performance and engineering feasibility).
4. Safety case – safety significance, importance and impact (relative to long-term safety).

Case Study 1: Example functional WBS extension for Spent Nuclear Fuel using above logic:



Top Tips

1. Generic safety statements identify the desired functional, performance or design characteristics of, or constraints on, the sub-domain without referring to a specific implementation or solution.
2. Engineering feasibility, issues of practicability and industrialization should be statements about how the RWM solution should be implemented so that it complies with generic safety statements.
3. Scientific and technological basis should be detailed underpinning in support of long-term safety and engineering feasibility. Here clear links with the safety case can be made, recognizing remaining uncertainties.
4. Safety case implications, i.e. how important is it to the safety case?

(See Appendix A: Generic safety and engineering feasibility statement)

Layers of the EURAD Roadmap

The Roadmap Matrix of Phases vs. Themes has several uses. Currently it is being used to map and help users navigate:

RD&D Priorities of the Strategic Research Agenda (SRA) – Describes the scientific and technical domains (and sub-domains) and knowledge management needs of common interest between EURAD participant organisations.

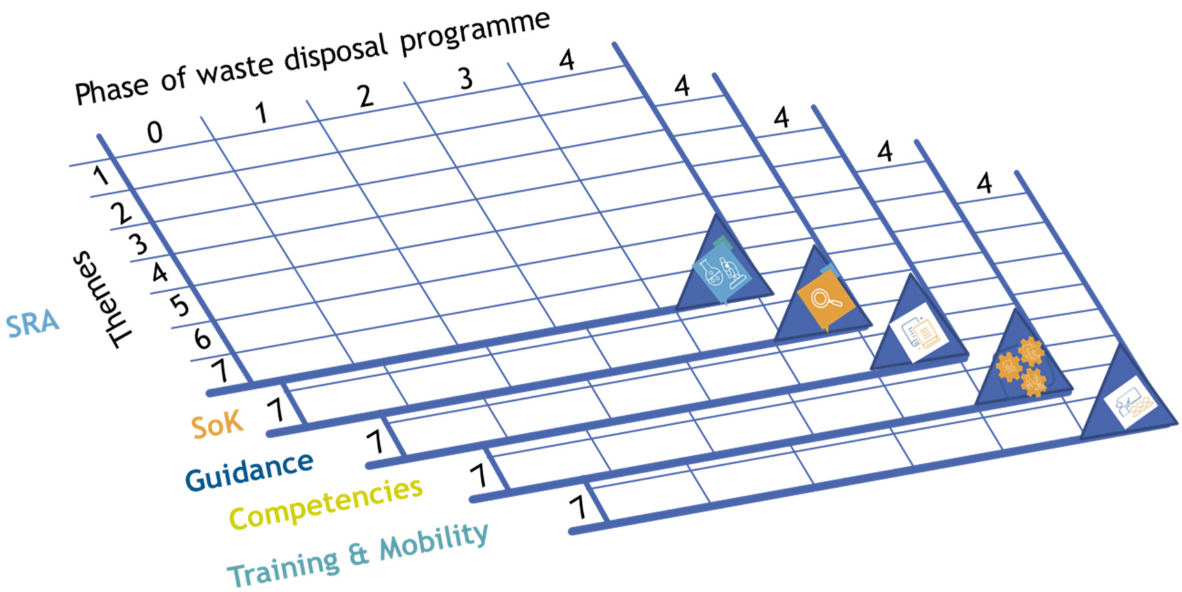
State-of-Knowledge (SoK) – Experts' consensus view of the most relevant knowledge and associated uncertainties in a specific domain/sub-domain applied in the context of a radioactive waste management programme.

Guidance – Instructional guidance documents available in the field of radioactive waste management, focussing on RD&D.

Competencies for RWM – Needed competencies (and accessible infrastructure) for successfully managing a disposal program within the different phases of implementation.

Training and Mobility – Tailored basic and specialised training courses and mobility measures in the field of radioactive waste management, focussing on RD&D.

Each of the Roadmap 'layers' maintains consistency with Levels 1-3 of the formal WBS. It can be visually conceptualised as:



Phases: (0) Programme establishment; (1) Site evaluation & selection; (2) Site characterisation; (3) Facility construction; (4) Facility operation and closure.

Themes: (1) Programme Mgt.; (2) Pre-disposal; (3) EBS; (4) Geoscience; (5) Design & Implementation; (6) Siting & Licensing; (7) Safety Case.

WHERE CAN I ACCESS THE EURAD ROADMAP?

The first published version of the EURAD Roadmap was made available in printable A3 sheets contained at the back of the EURAD Founding Documents – RD&D Priorities of the SRA (EURAD, 2019).

Since this time, and to support the extended collaboration between EURAD contributors on all layers, the Roadmap WBS has been transferred into a mindmap format using the open source FreePlane Software (see below for download details).

It is planned that during the early phase of EURAD-1, the Roadmap WBS be trialled and iterated through applying it across the Knowledge Management Work Packages and during periodic updates of the EURAD SRA. Once mature, and we as a Community become more confident in the effectiveness of the WBS and level of detail for content in each of the layers, we may consider an improved file format with improved user interface and records management functionality.

Until this time, we will continue to regularly update and maintain each Roadmap layer in development. Master versions of all files (together with latest PDF A3 Print-outs) are stored in the EURAD Project Place.

https://service.projectplace.com/pp/pp.cgi/r244733862

How to download the Freeplane Mindmap Software

The EURAD Roadmap (and developed layers) are currently available and maintained in a Mindmap file using the open source Freeplane software. Download instructions are here: Freeplane 2019).

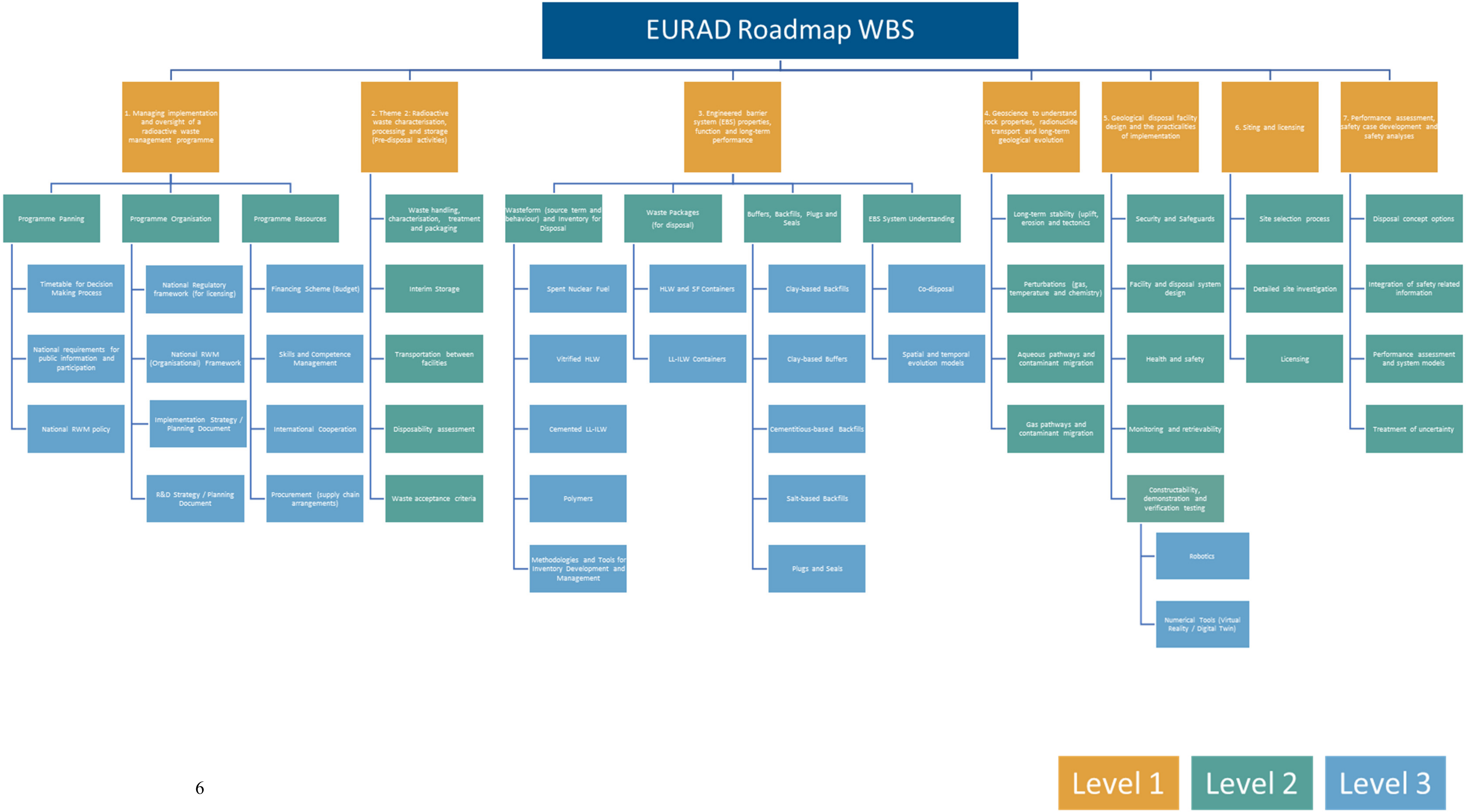
WHO ARE THE USERS OF THE EURAD ROADMAP?

Users are considered people from EURAD mandated organisations (WMOs, TSOs, and REs) and their linked 3rd parties. This includes: General Assembly, Bureau, PMO, WP leaders, WP contributors, etc.

Other end users, external to EURAD are also identified: RWM programme owners, regulators, waste producers, international organisations, interested civil society groups, academics and anyone working in the field of RWM.

The Roadmap will likely be used in different ways. As the Roadmap continues to develop and mature, users will be able to input, feedback and adapt its structure and content in iterative cycles to ensure it becomes and remains an effective tool, meeting the needs of all its users.

WHAT IS THE EURAD ROADMAP WORK BREAKDOWN STRUCTURE?



HOW DO I USE THE ROADMAP TO NAVIGATE EURAD RESEARCH PRIORITIES?

EURAD Roadmap for RD&D, Strategic Studies (SS) and Knowledge Management (KM) Priorities

- This Roadmap was first developed and approved by the EURAD General Assembly during the EURAD Proposal Submission (early 2019). It is next due for update in 2020. Update of the SRA Roadmap will be ongoing thereafter to capture newly identified RD&D needs (suitable for joint programming) originating from the periodic update of each College SRA.
- This Roadmap includes:
  - **Collaborative RD&D** - focused on science, engineering and technology advancements that support the generation of new knowledge to progress radioactive waste management, including disposal, across Europe.
  - **Strategic Studies** to address important and complex issues and enable expert networking. This may also be referred to as 'think-tank' activities.
  - **Knowledge Management** tasks.
- RD&D Tasks are grouped at the Domain (WBS) Level 2.

Top Tips

1. The EURAD Roadmap for RD&D, SS and KM only shows activities prioritised as being of (high, medium or low) common interest between EURAD Colleges. It is not an exhaustive list of remaining RWM RD&D activities globally.
2. Each EURAD College has its own Strategic Research Agenda (SRA) containing RD&D priorities that, for one reason or another, are excluded for inclusion in the EURAD SRA.
3. The scope of EURAD RD&D includes scientific and technical activities on radioactive waste management from cradle to grave (excluding dismantling and decommissioning of nuclear facilities):
   - Radioactive waste characterization and processing (incl. treatment, conditioning and packaging);
   - Interim storage of radioactive waste; and
   - Disposal solutions - mainly geological disposal of spent fuel, high-level waste (HLW) and long-lived intermediate level waste (ILW).

HOW CAN I USE THE ROADMAP TO TAP INTO THE GLOBAL STATE OF KNOWLEDGE (SOK) IN RADIOACTIVE WASTE MANGEMENT?

EURAD Roadmap for signposting to available SoK

- This Roadmap provides a conceptual framework for mapping existing and future generation of global Knowledge on Radioactive Waste Management. It is under continuous development through pilot and demonstration cases to develop SoK documents, to obtain broader EURAD input and approval on the forward approach.
- This Roadmap includes:

  - **(short) documents** for describing the state-of-knowledge and uncertainties by experts, focussing on signposting to existing reports.

  - **mindmap file** of important reports that can be easily found and retrieved by end users.
- EURAD SoK are collated by Experts at the Domain or Sub-domain (WBS) Level 2 or 3.
- Each individual SoK represents the views of the Experts and is not a formal position of EURAD or its contributing Organisations.

Top Tips

1. The EURAD SoK addresses:

   - the issues of relevance for the safe disposal of radioactive waste (post-closure safety) by contextualising content relative to generic safety statements – see Appendix A

   - the implementation of the disposal solution (up to the point where post-closure safety starts and the facility is closed) by contextualising content relative to generic feasibility statements – see Appendix A

   - the scientific and technological basis (i.e. what knowledge is needed 'broadly' for each domain/sub-domain and what knowledge is available, with signposts to most important reports)

   - the important to the overall safety case, safety significance.
2. The scope of each EURAD SoK is established by the contributing Experts, aligned to a Domain or Sub-domain of the WBS, which is at a higher level and broader scope compared with EURAD RD&D WPs

HOW DO I FIND EXISTING GUIDANCE IN RADIOACTIVE WASTE MANAGEMENT?

EURAD Roadmap for signposting to available Guidance

- This Roadmap points to guidance documents (from outside of EURAD).
- EURAD guidance will be developed in the future, based on gaps identified. It is considered that such guidance will be particularly useful for Member-States with RWM programmes that are at an early stage of development with respect to their national RWM programme. Although guidance will be developed such that it supports all Member-States, regardless of their level of advancement.

Top Tips

1. The EURAD Guidance Roadmap will signpost to available existing guidance (e.g. IAEA, NEA or other high quality sources recommended by EURAD participants) across the broad scope of RWM.
2. Where significant gaps are identified, a prioritised programme of guidance documents for future development will be established, with continuous engagement with IAEA, NEA and EURAD Colleges to ensure EURAD does not duplicate similar work planned or delivered by others.
3. The Guidance documents developed by EURAD will focus on aspects related to RD&D and the broader scope of implementing Radioactive Waste Management.

WHAT COMPETENCIES ARE ESSENTIAL FOR RWM?

EURAD Competency Matrix

- This Roadmap provides a conceptual framework for developing a common list of generic competency statements aligned with the IAEA Systematic Approach to Training (IAEA, 2018).
- IAEA describes competence as the ability to apply skills, knowledge and attitudes in order to perform an activity or a job to specified standards in an effective and efficient manner.
- Once a clear approach is agreed upon with EURAD, using examples and guidance, competency statements will be developed for prioritised areas of the EURAD Roadmap.

Top Tips

1. Competency includes skills (and infrastructure) that is available to an organisation either in-house or accessible from outside 3rd parties
2. Competency statements will be generic, focussed on skills, knowledge and attitudes most critical to implement RWM
3. Competency statements will be based on learning outcomes, drafted with an action verb which is specific to the type of learning in terms of knowledge and skills. A formal taxonomy will be developed in the guidance, similar to the Bloom's taxonomy, which identifies six categories of learning in the cognitive domain
    - Knowledge
    - Comprehension
    - Application
    - Analysis
    - Synthesis
    - Evaluation

- See Appendix B for example competency statements for the Spent Nuclear Fuel sub-domain of the EURAD Roadmap Theme 3.

HOW DO I ACCESS EURAD TRAINING AND MOBILITY SCHEMES?

EURAD Training and Mobility Roadmap

- This Roadmap is at a conceptual stage of development, currently focussed on identifying training needs and mobility providers from within EURAD and improving access to existing training materials (e.g. training modules developed in association with past EC projects and ongoing WPs of EURAD and other related RWM Projects internationally).
- Scope within EURAD to develop new training courses and material will be aimed at acquiring both state-of-the-art scientific background and at accessing the vast amount of "tacit" knowledge available within EURAD-1 through targeted hands-on training.
- Mobility programme will provide access to dedicated infrastructures associated with the Mandated Actors/Linked Third Parties within EURAD.

Top Tips

1. Training portals and websites exist, frequently at a national level, where existing training materials can be accessed in the field of RWM – the point of the EURAD training and mobility Roadmap is to sign-post to these and provide a clear indication of those deemed of high quality, up-to-date, and valuable based on the feedback and experience of EURAD participants.
2. EURAD does not formally endorse or approve a specific sub-set of training providers, it simply aggregates what is existing focussed on the experience of EURAD participants, and aligned to RWM implementation needs.
3. The 'school of RWM' is also used to describe this aggregation and umbrella term for the entire training and mobility Roadmap, linked to:

   - EURAD beneficiaries (organised and owned by); and

   - External providers.
4. Recognising that EURAD Work Packages include many PhDs and new entrants to the field of RWM, more general courses and learning initiatives will be delivered in the frame of a 'summer school' or other EURAD activity.

REFERENCES

IAEA (2014), Planning and Design Considerations for Geological Repository Programmes of Radioactive Waste, IAEA TECDOC No. 1755, 2014, ISBN 978-92-0-109914-3.

IAEA (2018), Developing a Systematic Education and Training Approach Using Personal Computer Based Simulators for Nuclear Power Programmes, IAEA TECDOC No. 1836, 2018, ISBN 978-92-0-109217-5.

EURAD (2019), Strategic Research Agenda, 2019.

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APPENDIX A: GENERIC FEASIBILITY AND SAFETY STATEMENTS

The below tables include (1) generic feasibility statements for the period of implementation up to closure; and (2) generic safety statements for long-term safety during post-closure – to be used by users and contributing experts of the SoK for contextualising how available knowledge relates to requirements of a RWM programme.

Feasibility Statements	***Contextualising SoK*** *– Key considerations in understanding of how the feasibility of the RWM solution can be assured. The feasibility statements apply to the process of getting a closed repository that has the desired properties and fulfils the desired functions.*
1. Engineering practicability	Practical implementation according to specifications (requirements): - disposal waste packages can be fabricated - repository can be constructed, operated, and closed - performance of the disposal system can be monitored (if required)
2. Reliable implementation	Reliability of implementation according to specifications (requirements): - robust design process - adequately maintained safety case
2. Flexibility	Possibility for corrections and adaptation: - security of supply - options
3. Security and safeguards	Fissile materials can be handled appropriately from a security, safeguards and criticality perspective: - prevent diversion - security of surface and underground facilities can be assured
4. Operational safety	The safety of workers, the public and the environment can be managed during the operational phase: - non-radiological risks can be managed - radiological risks can be managed - consequences resulting from hypothetical accident scenarios and external events can be tolerated
5. Environmental impact	- compatibility with nature and the environment - compatible with land use planning
6. Optimisation	Optimisation, within the boundary conditions to implement within reasonable time at reasonable cost: - costs can be accounted - efficient use of resources

Safety Statements	***Contextualising SoK*** *– Understanding of how safety functions can be provided by means of a physical or chemical property or a process that contributes to safety – linking to relevant SoK domain/sub-domains. The safety statements apply to the end product, the closed repository.*
1. Isolation from people and accessible biosphere	The facility is sited, designed and operated to provide features that are aimed at isolation of radioactive waste' for a specified period of time: - human intrusion is unlikely - sufficient depth
2. Containment of radionuclides	Containment within the barriers is ensured for specified period of time: - no loss of integrity of the barriers
3. Immobilisation of radionuclide	The release rates from the waste forms are limited: - waste forms have a limited degradation rate
4. Retention, retardation and dispersion of radionuclides	Transport of radionuclides is affected by: - the multiple barriers, including the host rock, displays sorption capacity for many radionuclides - the solubility of many radionuclide is limited -properties that promote hydraulic dispersion and dilution of radionuclide concentrations
5. Long-term stability of barrier system	The disposal system is robust with respect to possible disturbances, e.g.: - evolution of the disposal system due to changes in its environment - evolution of the host rock due to repository excavation, operation and closure - evolution of the EBS with time - compatibility of barrier of components - potential for formation of a critical mass as the repository evolves is unlikely
6. Compatibility of barrier components	Mutually complementary interactions of the components of the EBS and the host rock: - Undesirable impacts are limited.
7. Security and safeguards	Fissile materials can be handled appropriately from a security, safeguards perspective: - site selected at easily monitored location to simplify detection of diversion attempts - impractical to recover and extract fissile material
8. Non-radiological hazards	Isolation and containment measures to limit the release and impacts of exposure to chemotoxic materials: - release rates below allowable concentrations in the environment

9. Optimisation of protection	A disposal facility should be sited, designed, constructed, operated and closed so that safety is optimised, social and economic factors being taken into account.
10. Operational safety	- see feasibility statements above, plus: - arrangements to detect and respond to anticipated operational occurrences and possible accidents.
11. Uncertainty Management	It is demonstrated that uncertainties significant to safety are adequately taken into account in the safety case.

APPENDIX B: EXAMPLE COMPETENCY STATEMENTS

Example Competency Statements for the Sub-domain of Spent Nuclear Fuel (Theme 3):

Initial State

- Demonstrate understanding of the commercial and research operations that are of relevance for the management of the national inventory of radioactive waste.
- Understanding of the nuclear processes responsible for the formation and decay of radionuclides.
- Proficient in providing critical reviews of waste producer inventory data and in specifying necessary enhancements when deficiencies are identified.
- Understanding of the nuclear processes responsible for the formation and decay of radionuclides.
- Proficient in specifying mathematical algorithms to model these nuclear processes and their associated hazards within inventory software
- Proficient in specifying work to generate algorithm parameters (such as those that model gamma and neutron dose rates external to waste packages).
- Understanding of the requirements and capabilities of calculation tools (such as FISPIN, ORIGEN and FISPACT) used to derive the inventories of spent fuels and activated materials.

Predisposal Inspection & Characterisation

- Proficient in handling, preparing and characterising SNF fuel rods before hot cell experiments followed by post-experimental characterisation e.g. in dedicated radiation-shielded analytical instruments
- Proficient in using and maintaining an aging (>50 years old) fleet of hot cell infrastructures, capable to handle full-length SNF rod, in Europe
- Understanding of the mechanical integrity of SNF rods under wet and dry storage conditions
- Understanding of the handling requirements of SNF rods after dry and wet storage
- Proficient in preparing (e.g. drying), handling and packaging SNF rods for disposal

Understanding of the Long-term Evolution

- Understanding of disposal system evolution models (for key parameters affecting spent fuel dissolution).
- Understanding of spent fuel/water interaction for matrix, grain boundaries, on cladding behaviour as function of time and change of radiation field and evolution of hydrogen partial pressure.
- Understanding of the basic knowledge on UO2/water interaction, considering carbonate and redox conditions.
- Understanding of the differences between long-term UO2/UOX and MOX behaviour (what is the same, what is different and why, what are the uncertainties) including different fuel structure and burn-up history.
- Understanding of secondary phase formation, and modelled and experimentally-derived data for radionuclide release as function of fuel state and environmental boundary conditions.