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EURAD – the European Joint Programme for research on radioactive waste management between EU members states national programmes

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Abstract. For more than 40 years, considerable scientific and technical knowledge has been acquired in Europe in the field of radioactive waste management, both for near-surface disposal and geological disposal. RD&D will continue to be necessary to develop, maintain and consolidate knowledge throughout the stepwise development, operation and closure of disposal facilities, which will be spread over many decades and make this knowledge available to all end users. Recently, the EC has promoted a step-change in pan-European research cooperation between EU Member States' national programmes by promoting the setting-up of inclusive research joint programmes in Europe gathering those organisations with scientific and technical responsibilities and a national mandate for research in radioactive waste management. Based on the positive achievement of the JOPRAD project (2015–2017), the EC confirmed in 2017 its willingness to co-fund such a Joint Programme in the field of RWM. The RWM community therefore pursued the efforts to establish the Founding Documents (Vision, Strategic Research Agenda, Roadmap, Deployment) and a Work Plan for a first implementation phase of 5-years (2019–2024). In June 2019 the Joint Programme – EURAD – was accepted by the European Commission.

1 Introduction – successful RD&D collaboration across Europe

For more than 40 years, considerable scientific and technical (S/T) knowledge has been acquired in Europe in the field of radioactive waste management (RWM), in particular for deep geological disposal. This has supported countries to progress towards licensing of geological disposal facilities (e.g. Finland, Sweden and France) and contributed to the progress of numerous Member States' disposal programmes. RD&D efforts in radioactive waste management, including disposal, will continue to be necessary to:

- develop, maintain and consolidate S/T knowledge throughout the stepwise development, operation and closure of disposal facilities, which will be spread over many decades and make this knowledge available to all end users;
- ensure optimisation of waste management routes and of disposal solutions;
- address evolving regulatory concerns;
- bridge the risk of shortage of the skilled, multidisciplinary human resources needed to develop, assess, license and operate facilities for RWM; and
- help in gaining and maintaining public confidence.

The European Commission (EC) has supported the acquisition of knowledge at the European level by supporting collaborative RD&D projects through the EURATOM programme on RWM [1] and has also enhanced coordination and networking activities by supporting the establishment of the IGD-TP platform [2] – a network for European Waste Management Organisations and the SITEX Network [3] for the regulatory expertise function undertaken by regulatory authorities, regulators, and their technical support organisations, which are both now independently funded.

Recently, the EC has promoted a step-change in pan-European research cooperation between EU Member States' national programmes by promoting the setting-up of inclusive research joint programmes in Europe, attracting and pooling a critical mass of national resources on specific objectives and challenges. The objective for the EC is therefore to promote and co-fund ambitious programmes rather than individual projects, bringing together those legal entities from EU Member-States

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and associated countries able to direct national funding and/or manage a national research and innovation programme [4–6].

2 A feasibility study towards a Joint Programme on RWM – JOPRAD project

The EURATOM JOPRAD project was launched in June 2015 with the objective to assess if the RWM community could be meaningfully integrated in such a Joint Programme, and if so, to prepare its establishment. By identifying those with key responsibility for directing RD&D in the field of RWM, and engaging them in the process of developing a shared Vision and identifying the S/T basis for shared research agenda, JOPRAD has demonstrated the feasibility and the added-value of creating such a Joint Programme in the field of RWM [7,8].

2.1 Identifying the categories of organisations

Across Europe, the organisation for how RD&D is managed and completed, in support of the safe management of radioactive waste, varies widely. At the highest level, most Member States have programme owners such as a ministry, national/regional authority or private organisation in charge of setting-up and managing a national programme. This is often followed by varying levels of 'programme managers', who have a formal mandate and delegated responsibility for technical RD&D activities associated with the national programme.

The JOPRAD project identified three distinct categories of organisations, from across 28 EU Member States, Switzerland and Ukraine, with S/T responsibilities and a national mandate for research in RWM, and that are willing to share a Strategic Research Agenda (SRA) for European collaborative RD&D:

- **Waste Management Organisations** (WMOs) having the ultimate responsibility for the implementation of geological disposal (which includes the management of a supporting RD&D programme), and for some other topics of RWM (e.g. waste characterisation, treatment and packaging, interim storage, etc.). WMOs from across Europe form a core part of the Joint Programme and provide a driving force for what is needed for successful and practical implementation from an industrial perspective. WMOs have established a network and coordination framework for RD&D needs of the implementers of geological disposal at the European level via the Implementing Geological Disposal Technology Platform (IGD-TP);
- **Technical Support Organisations** (TSOs) carrying out activities aimed at providing the technical and scientific basis for supporting the work and decisions made by a national regulatory body. As safety cases for waste processing, storage and disposal develop, so too do the safety case reviews and independent scrutiny responsibility by regulatory organisations in the framework of the decision-making process. This requires specific skills (such as safety case review methodology) from the regulatory expertise function undertaken by safety authorities, regulators, and their TSOs. Several TSOs, together with other organisations fulfilling a regulatory expertise function and Civil Society Organisations have established the SITEX network to support independent technical expertise in the field of safety of geological disposal of radioactive waste; and
- **Research Entities** (REs) working to different degrees on the challenges of RWM including disposal (and sometime in direct support to implementers or WMOs or TSOs), under the responsibility of Member States. This includes national research centres, some research organisations and some universities that could also be funded by other sources. RE's provide scientific excellence and leading-edge research on basic components and generic processes in relation to the management of radioactive waste, and therefore represent an important proportion of the contributions to the Joint Programme.

Furthermore, the following organisations were identified as key interest groups of cooperative research in the field of RWM:

- **Civil Society Organisations** (CSOs) having an interest in RWM. This includes local organisations (associations, local committees of information, local partnerships), national or European civil society organisations willing to take part in interactions with the nationally mandated actors in EURAD;
- **Waste Producers** and those with a pre-disposal waste management responsibility are engaged via the Nuclear Generation II & III Association (NUGENIA);
- **International Organisations** such as the International Atomic Energy Association (IAEA) and the Organisation for Economic Co-operation and Development – Nuclear Energy Agency (OECD-NEA).

2.2 Identifying the S/T basis for a Joint Programme

Each of these three categories of actors (WMOs, TSOs, REs) then identified S/T activities suggested as suitable for inclusion within a potential future Joint Programme and within the different activities considered, they indicated their preferences and priorities based on their own perceived needs.

The following step-wise process was then used to further define and prioritise the S/T domains of common interest of the different categories of actors:

- Compiling Activities for Inclusion: Drafting a first compilation of combined activities suggested as suitable for inclusion within a potential future Joint Programme. A key part of this step was to organise and coalesce suggested activities (identified from WMO-, TSO- and RE-specific SRAs) into a suitable structure, considering the different types of activities suggested and the adoption of a common terminology and appropriate scope definition for a potential future Joint Programme. Once the first compilation was prepared, it was recognised that this did not represent an exhaustive list of all the potential activities that could enter into the scope of a potential future Joint Programme. It simply indicated activities for which a sufficient level of common interest has been expressed among the JOPRAD contributors.

– Surveying Representative Joint Programme Participant Views: Eliciting JOPRAD participants' opinions on their preferences and motivations for prioritising activities. This was completed by issuing a comprehensive questionnaire of suggested activities, allowing JOPRAD participants to comment and express views on activities suggested by all the represented groups for the first time.
– Identifying Priorities and Activities of High Common Interest between WMOs, TSOs and REs: Analysing the questionnaire responses to identify the themes with high common interest, and the adoption of screening criteria used to prioritise what should be included in the Joint Programme. This step included development of a methodology to cross-check that all prioritised activities met with the established boundary conditions for the Joint Programme (see Sect. 2.3).
– 1st Draft SRA: Drafting a first compilation of the Joint Programme S/T scope with a clear description of prioritised RD&D activities agreed and supported by all JOPRAD participants.
– SRA Consultation and Finalisation: Consultation of the draft S/T scope within the broader European RWM community. Obtaining feedback and end-user input to facilitate updating of the final Programme Document.

2.3 Defining the governing principles for a Joint Programme

The JOPRAD project has defined the following principles that shall be respected for joint programming.

Positive Participation – Contributors will work positively towards achievement of the Vision. All contributions will be valued. Work will be carried out considerately and respectfully by all, maintaining relationships that respect diversity, different roles and boundaries, and respect the knowledge, insight, experience and expertise of others.

Maintenance of Independence – It is possible for different organisations with different roles in their national programme to work together, without prejudice in relation to their own role in the national implementation process. Most important is the independence between the "expertise function" (fulfilled by TSOs and by some Research Entities) and the "implementer function" (fulfilled by WMOs). Different parties (WMOs and TSOs in particular) can have common agreement of what RD&D should be done and how, and Research Entities may furthermore have a long-term vision of general research needs. All can collaborate in doing the basic research; however, maintaining their independence in developing their own views on the interpretation of the generated research results and data is essential.

Transparent Governance – A transparent, balanced and efficient mode of governance is maintained, taking into account the role and independence of the Joint Programme participants with a national mandate for research in RWM.

Scientific Excellence – RD&D activities shall focus on achieving passive safety (safety of a disposal facility is provided for by means of passive features inherent in the characteristics of the site and the facility and the characteristics of the engineered barriers, together with certain institutional controls, particularly for surface facilities) and reducing uncertainties through excellence in science.

Balanced Programme – Recognising that different Member States have a wide variance in the status of their National Programme, the scope should support programmes at all stages of advancement.

Added Value – Ensuring that the Joint Programming provides real added value (e.g. enhanced coordination and improved information and knowledge transfer between national programs, improved financial arrangements, improved stakeholder understanding and acceptance of outputs, more robust RD&D outputs, etc.). Administration costs should represent a small proportion (including ongoing legal, EC admin., etc.) in comparison to the money spent on the technical and scientific scope.

Inclusiveness – Ensuring that the different categories of actors and groups of interest are involved in the definition and implementation of the Joint Programme.

Equitable Financing – Financial costs (financial/in-kind) should be equitable; participants should contribute what they can afford, or what they consider matches their interest in a project.

Complementary Participation – Participation in Joint Programme is complementary to RD&D activities which will continue to be undertaken nationally or jointly outside of the auspices of the Joint Programme where required; and

Tangible Results – The scope is appropriately prioritised and focused on the objective to achieve tangible results within a reasonable timeframe. A key aspect is that participants recognise that the Joint Programme is a distinct change from past work (and other collaborative working) on radioactive waste management. Translating the scientific, technical and societal challenge of RWM (including disposal) into operational reality requires the generation of new knowledge, combined with the consolidation, maintenance and transfer of existing knowledge.

3 Establishing the European Joint Programme on Radioactive Waste Management – EURAD

Based on the good progress and the positive achievements of JOPRAD, the EC confirmed in 2017 its willingness to co-fund such a Joint Programme in RWM with a dedicated topic included in the EURATOM WP2018 (indicative EC available budget for 5 years: 32.5 M€). The RWM community composed of 52 organisations mandated by their Programme Owner (19 WMOs, 13 TSOs and 20 REs) and more than 100 associated research organisations from 23 countries pursued the efforts to establish a Joint Programme in order to be able to submit in September 2018 to the EC its Founding Documents (Vision, Strategic Research Agenda, Roadmap, Deployment mechanisms) and a Work Plan for a first implementation phase of 5-years [9] (Fig. 1).

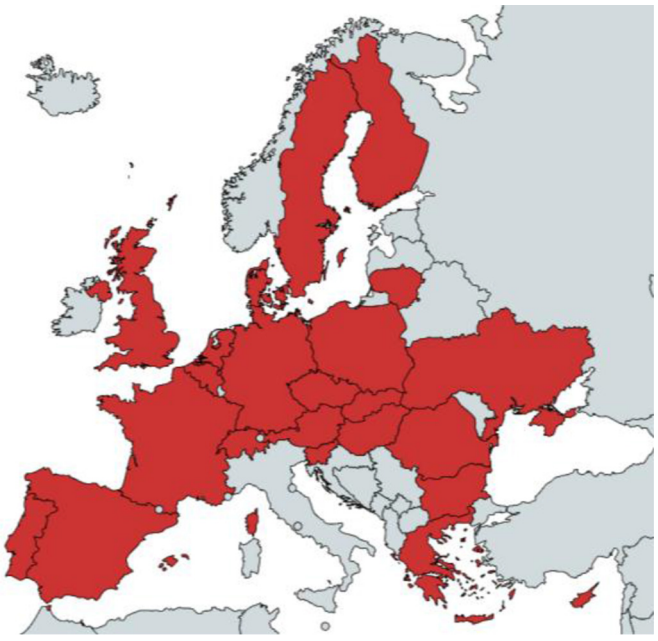

Fig. 1. Representation of countries involved in the joint programming.

3.1 Vision

A step change in European collaboration towards safe RWM, including disposal, through the development of a robust and sustained science, technology and knowledge management programme that supports timely implementation of RWM activities and serves to foster mutual understanding and trust between Joint Programme participants.

By step-change we mean a new era via a more effective and efficient public RD&D funding in Europe, and a deepening of research-cooperation between Member States. The aim is to implement a joint Strategic Programme of research and knowledge management activities at the European level, bringing together and complementing EU Member State programmes in order to ensure cutting-edge knowledge creation and preservation in view of delivering safe, sustainable and publicly acceptable solutions for the management of radioactive waste across Europe now and in the future.

The Joint Programme shall support the implementation of the Waste Directive in EU Member-States [10–13], taking into account the various stages of advancement of national programmes. National RWM programmes across Europe cover a broad spectrum of stages of development and level of advancement, particularly with respect to their plans and national policy towards implementing geological disposal. Programmes differ significantly depending on the national waste inventory, with some member states only responsible for relatively small volumes of medical and research reactor wastes, compared to others that have comparatively large and/or complex waste inventories from large nuclear power (and fuel reprocessing) and defence programmes. Programmes also differ significantly in the way in which they are managed, particularly with respect to the national policy and socio-political landscape with respect to longer-term storage and geological disposal.

Across Europe, the terms '*Advanced Stage Programme*', '*Early Stage Programme*' (or programmes with longer time scales) and '*Small Inventory Programme*' are typically adopted. Regardless of size and stage of implementation, all Member-States are responsible for the safe management of radioactive waste and are required to report periodically on the status of their national programme.

The EURAD therefore gathers Members-States:
- with no nuclear power programme operating, but with research, training or demonstration reactors, and/or other sources of radioactive waste;
- with a nuclear programme;
- with different amounts of radioactive waste to manage;
- at different stages of advancement in the implementation of their national RWM programme; and
- with plans for geological disposal for Spent Fuel, High-level Waste and long-lived intermediate level waste, with different host rocks and different disposal concepts and at different stages of implementation.

3.2 Strategic Research Agenda and roadmap

The EURAD Strategic Research Agenda (SRA) provides a description of S/T Themes and Sub-Themes of common interest between the participants. These needs are grouped into a number of scientific themes and based upon the scope established by the JOPRAD project. The SRA is structured by seven Scientific Themes, as illustrated in Figure 2 and should allow to capture all areas relevant for the implementation of waste management solutions. Although all technical in nature, Theme 1 is an overarching theme, Themes 2–5 are predominantly focussed on fundamental science, engineering, and technology, and Themes 6 and 7 include aspects more of an applied science and integration focus.

The S/T scope in the SRA covers cutting-edge S/T activities on RWM from cradle to grave, including predisposal, interim storage and disposal solutions – mainly geological disposal of spent fuel, high level waste and intermediate level waste[1]. The EURAD SRA has been set up as a dynamic and living document that shall be updated periodically in order to integrate outcomes of RD&D activities as well as any emerging collaboration needs identified by the RWM community during the implementation phases of the Joint Programme.

[1] Specific RD&D required for near-surface or surface disposal and low-level waste (LLW), will be addressed, and is encompassed within the RD&D needs identified for waste characterisation and processing, interim storage and geological disposal of radioactive waste. Nuclear facility dismantling and decommissioning activities are however excluded, although interfaces, and particularly aspects that impact final disposal will be considered.

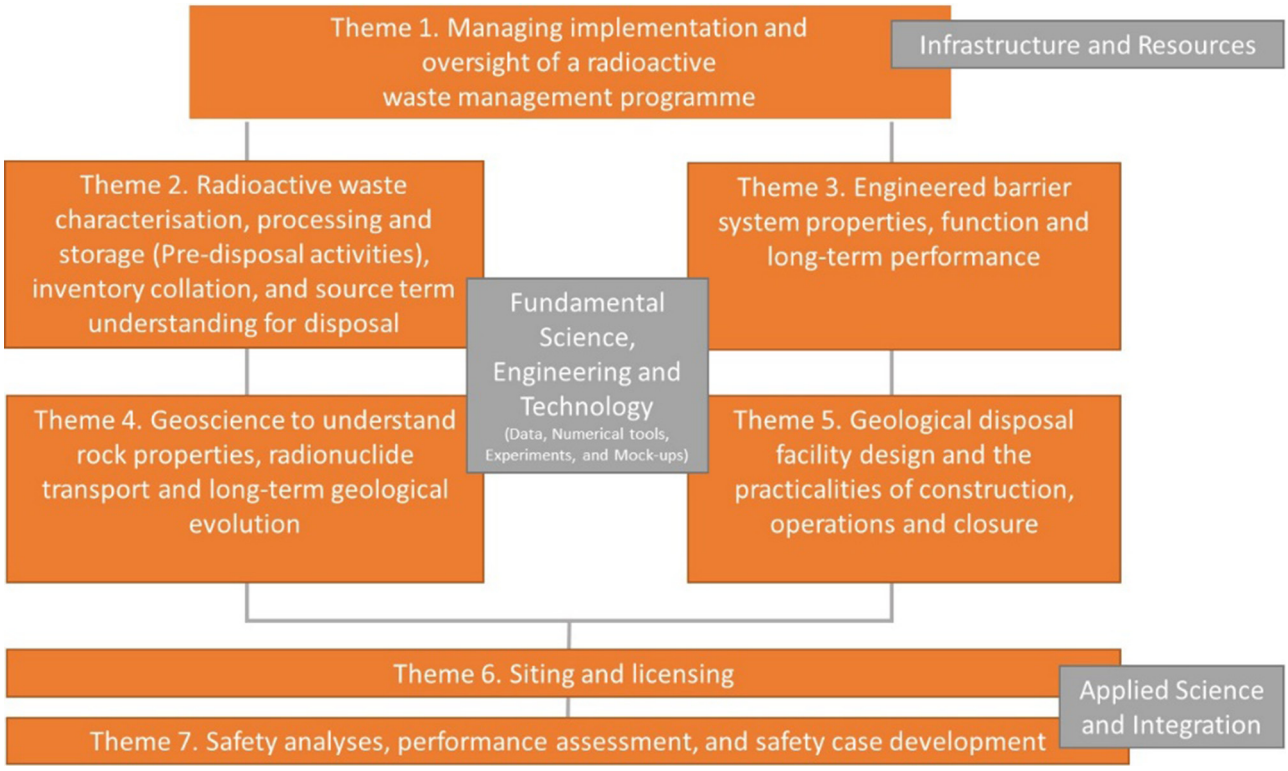

Fig. 2. Scientific themes of the EURAD SRA.

Theme 1: Managing implementation and oversight of a RWM programme

Implementation of a national RWM programme, including geological disposal, requires a national policy reflected in the legal framework, a long-term vision based a sound scientific-technical foundation, appropriate regulatory oversight, funding, organisational infrastructure and sound management systems and processes and formally organized exchange among stakeholders. For programmes in the early phase of establishing national policy or developing a waste management programme, support by international entities (IAEA, NEA) is available and EU-wide good practice and lessons learned can be used to facilitate implementation of suitable organisational structures and strategic decision making.

Theme 2: Radioactive waste characterisation, processing and storage (pre-disposal activities), and source term understanding for disposal

This involves characterizing and documentation of the various waste types (requiring activation calculations, evaluation of contamination carry-over, development of waste treatment and packing technology, etc.), evolution of waste matrix properties during extended interim storage, developing waste acceptance criteria and developing model predictions about future waste. This also includes development of sufficient interim storage capacity. Source term and radionuclide release mechanisms need to be assessed for different waste forms/waste packages considering the interaction of the various interfaces with the disposal environment. In this broad area of work much information is already available or can be acquired through co-operation. The remaining issues are often site and design specific.

Theme 3: Engineered barrier system properties, functions and long-term performance

Engineered barriers (overpack, buffer, backfill, seals, etc.) are in a broad sense comparable in many programmes and much basic information is already available today as there have been many European and international projects to-date. Existing needs can be further developed through continued co-operation, which includes the provision of utilising available Underground Research Laboratories (URL) to conduct large-scale demonstration and verification testing. However, at a National Programme level some specific development work is often necessary to improve the understanding of the system of engineered barriers, optimise it or adapt it to the specific situation at hand. Remaining research issues concern in particular cementitious and to a lesser degree clay-based materials.

Theme 4: Geoscience to understand rock properties, radionuclide transport and long-term geological evolution

Geoscience focusses on host rocks representative for a broad range of geologies also to better understand long-term geological evolution (and stability), and on the detailed understanding of the relevant properties and behaviour of different types of host rocks. This includes the transport properties of radionuclides and fluids, redox phenomena, coupled phenomena to address facility-induced disturbances, and the impact of gases. This also includes the demonstration and verification that the important coupled geomechanical, thermal, hydrological and chemical phenomena are sufficiently well understood to allow for long term assessment of void space closure, fluid movement and behaviour of the material interfaces, in

some cases through full scale experiments in an URL. The broad area of geoscience will require significant activities that are specific to each country (especially regional geology but also the details of specific rocks), but with respect to the properties of rocks, much can be learned from other programmes working on similar rocks and may involve co-operative projects in URLs.

Theme 5: Facility design and the practicalities of construction, operation and closure

Facility design (covering early conceptual design during early programme phases, right through to detailed design for construction, operation and closure). In the area of geomechanics and excavation, much can be learned from the tunnelling and mining industries and the corresponding science and technology developments. The current focus is on the demonstration of waste and engineered barrier emplacement techniques, and to perform demonstration tests under real 1:1 scale and active conditions. URLs and/or rock characterisation facility experiments, incl. monitoring activities often focus on demonstrating that technical aspects of facility construction and operation are suited for their purpose.

Theme 6: Siting and licensing

The selection of a site (or sites) and licensing of a geological disposal facility is clearly the most important challenge of the successful implementation of long-term management of radioactive wastes. Site characterisation (exploration of geometrical aspects such as rock layers and structures, and characterisation of key rock properties), acquiring site property parameters through the use of geophysical techniques, hydraulic and geochemical measurements in boreholes and seismic investigations will contribute to the selection of the site. As part of the full development of the selected site, underground testing will be required to allow detailed in-situ confirmation (and/or refinement) of some of the critical data on rock properties and state parameters before and during the construction of the repository. Site selection policies and procedures, regulatory arrangements and licensing requirements vary between member states, reflecting inter alia the socio-political context, geological factors, and the waste inventory. In this broad area of work a large part is of national focus but much can be learned from science and technology e.g. developed for hydrocarbon exploration, and also the wealth of information available from RWM programmes and from previously existing URLs should be considered. For URL-experiments, significant technology developments have been made (testing tools, sensors, etc.) that are essential for underground testing at repository sites. This area is very much suited for co-operation.

Theme 7: Performance assessment, safety analyses and safety case development

For safety analyses (methodology, numerical tools, compiling all the information and data, drawing the conclusions), a wealth of information is already available. The development of the safety case and the task of integrating all the necessary information will always be specific to the system evaluated and thus, in this area, each country must develop its own capabilities. Nevertheless, information exchange and interaction with experienced experts is considered useful and includes e.g. the exchange on the treatment of uncertainties and development of arguments for confidence building.

There is a need to recognise the need for independence between those supporting and managing safety case development and those supporting or managing the regulatory review and scrutiny of a safety case, this applies to all the SRA Themes, but is especially relevant to Theme 7.

The EURAD SRA has been set up as a dynamic and living document that shall be updated periodically in order to integrate outcomes of RD&D activities as well as any emerging collaboration needs identified by the RWM community during the implementation phases of the Joint Programme.

3.3 Roadmap

The SRA is further complemented by a Roadmap with clear objectives, linking the SRA Themes and Sub-themes to milestones typical for the different phases of a RWM programme as drawn from the IAEA work – *Site evaluation and site selection*; *Site characterisation*; *Facility construction; Facility operation and closure*; *Post-closure* – to which a phase on *Policy, framework and programme establishment* has been added to recognise the needs of Members-States who are in the process of establishing a waste management programme [14].

The Roadmap covers the full scope of the Joint Programme and shows the relevance of the different themes for 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 information and knowledge and active work or future plans. For each of the phases, the Joint Programme Roadmap explains how e.g. the aspects related to disposal facility design and safety case development (and supporting safety analyses) span across all phases. The Roadmap elaborates further on the how the emphasis of work on each of the themes differs and changes through successive Phases.

The Roadmap also provides a framework for future periodic assessment of the Joint Programme, and to evaluate future priorities as new knowledge is acquired or as new needs are identified, and to communicate completed, ongoing and future work activities to those interested in our work.

3.4 Deployment activities

The following types of activities will be established within the Joint Programme:

RD&D activities – The main activities of EURAD will consist of RD&D activities aiming at developing and consolidating S/T knowledge of the EURAD Strategic research Agenda and Roadmap. There shall be a balance between operational RD&D in direct link with implementation of repository concepts as well as safety concerns and prospective RD&D such as short and long-term

EURAD 1 Work Packages (2019-2024)		Indicative Budget	EURAD Strategic Research Objectives	EURAD Beneficiaries		
		Total Cost (EC + Beneficiary Contributions)	How the Work Package will address objectives, priorities and activities of high common interest in the EURAD Strategic Research Agenda	WMOs	TSOs	REs
				◆ = Beneficiary Organisation; ◆ = Coordinating Beneficiary Organisation		
Programme Management Office		**7%**				
WP1	Administration, Scientific Coordination, Communication and Dissemination	€2.7 M		◆◆	◆	◆◆
Collaborative RD&D		**75%**				
WP2	Assessment of Chemical Evolution of ILW and HLW Disposal Cells (ACED)	€5.1 M	Multiscale approach and process integration to improve long-term modelling and assessments .	◆◆◆◆◆	◆◆◆◆◆	◆◆◆◆◆◆◆
WP3	Cement-Organics-Radionuclide-Interactions (CORI)	€4.7 M	Improved understanding of the role of organics (either naturally occurring or as introduced in the wastes) and their influence on radionuclide migration in cement based environments.	◆◆	◆◆◆	◆◆◆◆◆◆◆◆
WP4	Development and Improvement of Numerical Methods and Tools for Modelling Coupled Processes (DONUT)	€3.7 M	Improved understanding of the upscaling of THMC modelling for coupled hydro-mechanical-chemical processes in time and space.	◆◆◆◆	◆◆◆◆◆	◆◆◆◆◆◆◆
WP5	Fundamental Understanding of Radionuclide Retention (FUTURE)	€4.6 M	Quantification of long-term entrapment of key radionuclides in solid phases to inform reactive transport models and the influence of redox.	◆◆	◆◆◆◆◆	◆◆◆◆◆◆◆
WP6	Mechanistic Understanding of Gas Transport in Clay Materials (GAS)	€5.6 M	To increase understanding and predictability of gas migration in different host rocks.	◆◆◆◆◆◆◆	◆◆◆	◆◆◆◆◆◆◆◆
WP7	Influence of Temperature on Clay-based Material Behaviour (HITEC)	€5.3 M	Improved THM description of clay based materials at elevated temperatures.	◆◆◆◆◆◆◆◆◆	◆◆	◆◆◆◆◆◆
WP8	Spent Fuel Characterisation and Evolution Until Disposal (SFC)	€5.8 M	Reduce uncertainties in spent fuel properties in predisposal phase.	◆◆◆◆◆	◆◆◆◆◆	◆◆◆◆◆◆◆◆
Strategic Studies to Address Complex Issues and Expert Networking		**10%**				
WP9	Waste management routes in Europe from cradle to grave (ROUTES) *	€1.7 M	Waste Management Routes across Europe considering different waste types and their specified endpoints.	◆◆◆◆◆◆◆◆◆◆◆◆	◆◆◆◆◆◆◆◆◆◆◆	◆◆◆◆◆◆◆◆◆◆◆◆
WP10	Uncertainty Management multi-Actor Network (UMAN) *	€1.7 M	Further refinement of methods to make sensitivity and uncertainty analyses and the development of a multi-actor network for uncertainty management.	◆◆◆◆◆◆◆◆◆	◆◆◆◆◆◆◆◆◆◆◆◆	◆◆◆◆◆◆◆◆◆
Knowledge Management		**8%**				
WP11	KM State-of-Knowledge (SoK)	€1.4 M	To maintain information, knowledge and records over the long lead- and implementation-timelines of geological disposal programmes, from pre-licensing through to the post-operational phase.	◆◆	◆◆	◆◆
WP12	Guidance	€0.5 M	To identify RD&D and knowledge transfer needs in support of defining pre-licensing activities that can support success in the siting and licensing phase/process.	◆◆	◆◆◆	
WP13	Training & Mobility	€0.6 M	Training and competence maintenance of skills and expertise to support safe radioactive waste management including disposal.	◆◆	◆◆◆	◆◆

* Interactions with Civil Society

Fig. 3. EURAD first implementation phase (2019–2024).

experiments and/or modelling work to demonstrate the robustness of the waste management concepts, to increase understanding and predictability of the impact of fundamental processes and their couplings or to maintain scientific excellence and competences throughout the stepwise long-term management of radioactive waste.

Strategic studies – Complementary to RD&D activities and in support of the implementation of the Member States' national programmes, Strategic Studies shall give the opportunity to participants and expert contributors to network on methodological and strategic challenging issues that are common to various national programmes and in close link with scientific, technical and issues.

Knowledge management – Beyond RD&D and Strategic Studies, ambitious activities of EURAD are to consolidate efforts across Member-States on Knowledge Management – this includes access to existing Knowledge (State-of-Knowledge), guiding the planning and implementation of a RD&D plan of national RWM programme, and developing/ delivering training/mobility in line with core competencies.

Interaction with civil society – The successful implementation of RWM programmes relies on both S/T aspects for a sound safety strategy and scientific and engineering excellence and societal aspects. EURAD shall allow interactions between WMOs, TSOs and REs, and Civil Society Organisations (CSOs) in order to facilitate the translation of S/T results to allow effective interactions with CS and by extension to the public and create the conditions for CSOs to express their expectations and perspectives. Such interactions shall improve the mutual understanding of how and to what extent RD&D on RWM makes sense and contributes to improving decisions.

It shall also contribute to developing ideas, propositions and methodologies on how to interact with Civil Society on S/T results, how to deal with uncertainties, and on how to promote mutual benefit of the available knowledge, based on cooperation and sharing.

4 EURAD first implementation phase (2019–2024)

Building on the initial work of the JOPRAD project, taking into account ongoing projects at the EU level, the RWM community has co-developed an initial five-year deployment plan (2019–2024) as illustrated in Figure 3.

5 Conclusion – how EURAD will complement the National Programmes

The Joint Programme is not intended to replace National Programmes, rather it complements the national efforts and enables effective use of resources by sharing RD&D efforts and by making existing knowledge easily available to end-users. Member-States' Programmes are organised and funded independently, and their participation in the Joint Programme is the responsibility, and at the sole discretion, of each national programme owner. By mandating organisations to participate, Member States demonstrate that EURAD has an EU-added value beyond their National Programme. Overall, the following impacts can be expected:

- **Support compliance with European regulations** – by supporting Member States in implementing RD&D, developing skills and providing for transparency in order to develop solutions for their radioactive waste (see, Waste Directive articles 8, 10 and 12.1(f));
- **Support passive safety of radioactive waste management solutions** – by contributing to the responsible and safe management of radioactive waste in Europe, including the safe start of operation of the first geological disposal facilities for high-level and long-lived radioactive waste / spent nuclear fuel as well as improvement, innovation and development of science and technology for the management and disposal of other radioactive waste categories;
- **Help to gain or maintain public confidence and awareness in RWM** – by fostering transparency, credibility and scientific excellence;
- **Support RWM innovation and optimisation** – by supporting the development of solutions for different waste streams and types and continuously improving and optimising waste management routes and disposal solutions, including identifying needs specific to small inventory programmes with their particular challenges with respect to access to critical mass of expertise and developing appropriate disposal options;
- **Contribute to addressing S/T challenges and evolving regulatory concerns** – by prioritising activities of high common interest, and creating conditions for cross fertilization, interaction and mutual understanding between different Joint Programme contributors and participants;
- **Enhance knowledge transfer to early stage programmes** – by providing an opportunity for less advanced programmes, and in particular those in an early stage of geological disposal programme implementation, to benefit from the cross-European integration in radioactive waste management activities;
- **Foster efficient use of the RD&D resources at the EU level** – by sharing and advancing existing knowledge, facilities and infrastructure rather than repeating and duplicating efforts; and
- **Foster a better transfer of knowledge across generations of experts** – by helping to bridge the risk of shortage of the skilled, multidisciplinary human resources and critical infrastructure needed to develop, assess, license and operate RWM facilities, in view of the long lead-times and the intergenerational operational time-spans.

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