

DEPLOYMENT PLAN 2019-2024



*A step change in
European
collaboration
towards safe
radioactive waste
management.*

H2020 EUROPEAN JOINT PROGRAMME COFUND - PARTICIPATION RULES

In the *EJP Cofund* scheme, the participation as **Beneficiary** is limited to organisations having received a mandate by their national programme owner(s) (usually Ministry/regional authority) to participate in the Joint Programme implementation phases and that are willing to share a Vision/Strategic Research Agenda/Roadmap for European collaborative RD&D. The mandate shall confirm that organisations are responsible for managing/implementing a national programme and/or managing/implementing a RD&D programme needed for implementation (programme managers).

The EURATOM **JOPRAD** preparatory phase identified three distinct categories of organisations with scientific and technical responsibilities and a national mandate for research in the field of radioactive waste management:

- **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
- **Nationally funded 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.

Beneficiaries can call for **Linked Third Parties** (LTP) to carry out part of the work plan in the Work Packages. A Linked Third Party is an organisation to which a Beneficiary has a pre-existing legal relationship (options are: Memorandum of Understanding, agreement, contract, affiliation, joint research unit...) which is not based on a contract for the purchase of goods works or services.

Other legal entities (such as association) may participate if justified by the nature of the action, in particular entities created to coordinate or integrate transnational research efforts.

Reference documents are the [H2020 Participation rules](#), and the [EJP Co-fund Annotated Grant Agreement Model](#).



EURAD Deployment Plan

A step change in European collaboration towards safe radioactive waste management.

DEPLOYMENT MECHANISMS

The EURAD Vision, SRA and Roadmap is delivered through 5-year implementation phases according to the EJP Co-fund Instrument. The Work Plan of an implementation phase is broken down into a set of Work Packages, Tasks and Sub-Tasks. To deliver against EURAD objectives, four different types of Work Package (WP) have been adopted, as well as specific cross-cutting tasks - interactions with Civil Society and providing access to knowledge/results – that will be directly embedded in specific WPs. These are each described below.

- **RD&D Work Packages**

RD&D WPs focus on science, engineering and technology advances that support the generation of new knowledge to progress RWM, including disposal, across Europe. The activities to be carried out are a balance between those with a direct link to operational RD&D (direct links with implementation of deep geological disposal or other waste management route) and prospective RD&D (long-term experiment and/or modelling works to demonstrate the robustness of the waste management concepts and contribute to maintain scientific excellence and competences throughout the stepwise long-term management of radioactive waste).

- **Strategic Studies Work Packages**

Strategic studies WPs are initiated in order to agree upon and define in some detail the needs for future activities, including further specific thematic studies or RD&D at the forefront of science. This may also be referred to as ‘think-tank’ or networking activities to determine if there is a RD&D need on an emerging issue, if there is a need of a position paper or if it is considered mature and suitable for knowledge management activities. Such studies will enable experts and specialists to network on methodological/strategical issues and advance significant challenges that are common to various national programmes and that are in direct link with scientific and technical issues.

- **Knowledge Management Work Packages**

Knowledge Management is enabled by three permanent WPs that derive directly from EURATOM expectations under WP2018, and that will be implemented through the Annual Work Plan:

State of Knowledge - Activities under this WP consist of developing a systematic approach of establishing the state-of-knowledge in the field of RWM research. This shall be done on a stepwise basis: i) establishing of procedures to document the state of knowledge (SoK); ii) testing and improving these procedures on a few demonstration topics/sub-topics (of the Roadmap); iii) performing a review on existing tools/platforms and evaluating the added-value of establishing such a platform dedicated to provide access to SoK developed in EURAD.

Methodological guidance - Activities under this WP consist of developing a comprehensive **suite** of instructional guidance documents that can be used by Member-States with RWM programmes that are at an early stage of development with respect to their national RWM programme. Such WP shall pursue and complement the work initiated with the [PLANDIS Guide](#).

Training/mobility - Activities under this WP consist of developing a diverse portfolio of tailored basic and specialised training courses under the umbrella of a “School of Radioactive Waste Management”, taking stock of and building upon already existing initiatives (i.e. IAEA and NEA) and creating new initiatives to bridge the identified gaps. The end-users are defined as professionals and potential new professionals at graduated and post-graduated level from EU and non-EU countries (via the IAEA and NEA programmes), and in particular the next generation of experts. This WP will also organise

a mobility programme to provide access to dedicated infrastructures associated with the Mandated Actors/Linked Third Parties within EURAD. This work will be carried out in close interaction with European networks having a recognised experience in training/mobility in the field of RWM.

- **Programme Management Office Work Package**

A WP will be dedicated to the activities of the Programme Management Office (PMO) which is responsible for the proper coordination and implementation of the overall work plan of the JP implementation phase as approved by the General Assembly. The Programme Management Office is in charge of:

- Scientific and technical coordination of the overall programme (RD&D, Strategic Studies, Knowledge Management, Civil Society Interactions);
- Support in the extension/updates of the Roadmap and SRA;
- Day-to-day management (budget follow-up, reporting exercises...);
- Communication/dissemination activities (Annual JP meetings, Newsletters, website...); and
- Administration of online access tools (Extranet, Knowledge Management platform, EC Grant Agreement system).

- **Interaction with Civil Society – cross cutting component**

As described in the Vision Document, one objective of EURAD is to allow innovative ways for close interactions between experts from WMOs, TSOs and REs and Civil-Society Organisations. Based on a model of pluralistic interactions as developed and tested in previous projects (SITEX-II, JOPRAD, Modern2020, etc.), EURAD proposes a framework for interaction that consists of:

- Translating scientific/technical results for communication to CS group at the annual workshops of CS and by extension to the public;
- Gathering CS views on future EURAD activities;
- Improve the mutual understanding on RD&D performed to support the development of safe solutions of processing and disposal of radioactive waste ;
- Develop propositions on how to interact with CS on scientific and technical results, how to deal with uncertainties (inherently linked to the long timeframes and numerous processes considered for geological disposal), and on how to interact with CS stakeholders in order to promote mutual benefit of the available knowledge, based on cooperation and sharing.

To do so, the EURAD has the ambition to establish interaction activities with a group of representatives of civil society organisations (the CS group). The composition of the CS group will be established at the start of EURAD via an open call by the EURAD consortium to CS organisations such as local communities having interest in RWM (local association, local Committee of Information, local partnership), national or European CS Organisations taking part in interactions in the field of RWM at the national or European level. The candidates shall demonstrate evidence of a standing engagement in the follow-up of RWM activities. Each participant of the CS group will approve the principle of participating in EURAD ICS activities as described in the EURAD Terms of Reference.

The interactions with the CS group will be facilitated by Civil Society facilitators (also called CS experts), working for Linked Third Parties to mandated actors in EURAD, having a long-term engagement on RWM and/or having skills/experience on the involvement of Civil Society in scientific and technical issues. The CS experts will interact with the institutional experts from the WMOs, TSOs and REs in order to understand the field of study and to prepare interactions with the CS group. The process will enable CS group to express their views on the RD&D performed to support the development of safe solutions for processing



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and disposal of radioactive waste. The CS experts will work in an organised process together with representatives from WMOs, TSOs and REs.

Type of WP	Type of actions	Examples of possible deliverables
Collaborative RD&D WPs	Activities aiming at developing and consolidating scientific and technical knowledge. Activities shall be a balance between those with a direct link to operational RD&D (direct links with implementation of deep geological disposal or other waste management route as well as safety concerns) and prospective RD&D (short and long-term experiment and/or modelling works 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).	State-of-the-art ¹ (initial and update), S/T deliverables, reports, demonstrator, pilot, prototype, plan designs, software, technical diagram...
Strategic Studies WPs	Actions consisting of enabling experts and specialists to network on methodological/strategical issues and advance significant challenges that are common to various National Programmes and that are in direct link with scientific and technical issues.	Position paper (e.g. emerging needs for future RD&D/Strategic Studies/KM activities), report on generic methodologies, best practices...
Knowledge Management WPs	Actions consisting of developing State of Knowledge; developing descriptive methodological guidance and developing/delivering Training modules and mobility measure.	State-of-knowledge documents; Guidance documents, Training delivery and materials...
Programme Management Office WP	Day-to-day administrative, financial and legal management, reporting exercises, interactions with EC, communication and dissemination activities, administration of JP website, Extranet, Scientific and technical coordination/integration of the overall JP (monitoring EURAD progress)	Management tools, Periodic reports, financial statements, website, platforms...

¹ SOTA reports to be prepared by all EURAD WPs, will be compiled in line with international good practice. This will include communication of the existing knowledge related to post-closure safety. In the final version this will be done in a general or generic way, without direct reference to specific safety assessments, safety cases or national programmes. It is the responsibility of the National Programmes to evaluate outputs and results with respect to their own needs (towards implementation) as specified in Section 6.2 of the EURAD Founding Documents and section 1.2 of the Part B. In the initial version of the SOTA report (before start of the WP), those that participate in the corresponding WP should explain their motivation specific to their national programme to actively participate in the WP.

FLEXIBILITY MECHANISMS

According to the EC, the EURAD must remain flexible to **include new activities** in order to be as needs-driven as possible; and to **integrate new organisations** that would be mandated after the submission of the proposal or during the course of an implementation phase.

For RD&D WPs, the principles of flexibility is implemented as follows: about 70% of the RD&D budget shall be allocated to WPs/tasks that will start at Month 1 of EURAD 1. The remaining 30% shall be allocated to WPs/tasks that will be approved by the EURAD Consortium (General Assembly) during year 2 and start at Month 24 (for a maximum duration of 36 months).

For Strategic Studies WPs, the principles of flexibility are implemented as follows: about 70% of the budget for Strategic Studies shall be allocated to WPs/tasks that will start at Month 1 of EURAD 1. The remaining 30% shall be allocated to WPs/tasks that will be approved by the EURAD 1 Consortium (General Assembly) and that will start from Month 24 (for a maximum duration of 36 months).

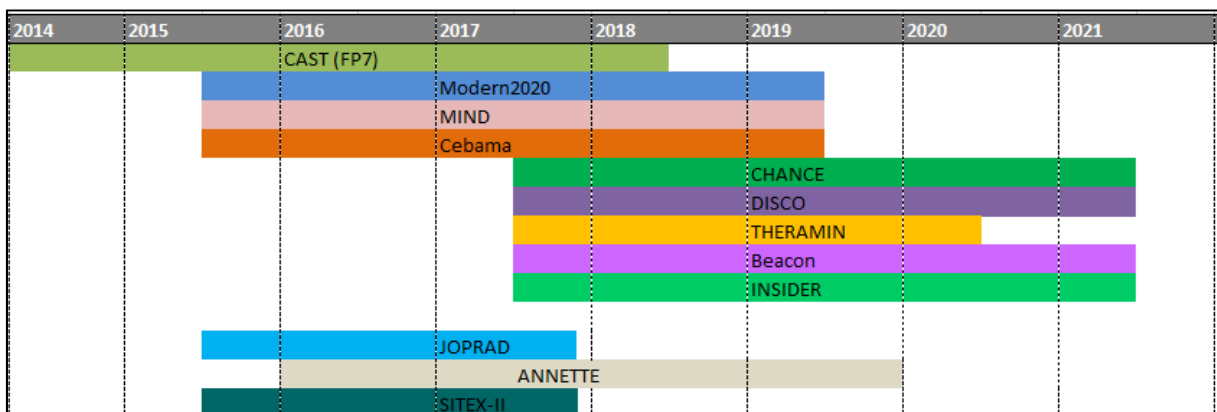
Proposals for new RD&D and Strategic Studies WPs will emerge as EURAD progresses, these will be considered in an open and transparent manner via the PMO and GA. The EURAD Roadmap will support this by providing the framework for performing a structured gap analysis. A technical coordinator will be appointed and will take the lead of the proposal development. When ready, the WP will be reviewed and approved by the General Assembly, if approved, it will be included in EURAD 1 and will start at Year 3.

For Knowledge Management, the principle of flexibility is ensured by a yearly allocation of KM budget. About 20% of the KM budget will be allocated to tasks that will be implemented in the first year. The KM budget will be then allocated on an annual basis.

EURAD-1 (2019-2024) WORK PLAN

This EURAD-1 overall work plan (“first wave”) is the result of a collaborative process between WMOs, TSOs and REs that is fully described in the Annex 3 of the EURAD Founding Documents. During the preparation phase of EURAD, the WMOs, TSOs and REs collaboratively established the RD&D/Strategic Studies WPs to be launched as a first wave of EURAD-1, respecting the following boundary conditions:

- i. Each WP shall be in line with EURAD Vision and the JOPRAD Programme Document (Basis of EURAD Strategic Research Agenda). Specifically, each WP has to address mainly topics of high or medium level of common interest from the JOPRAD Programme Document.
- ii. WPs shall be of common interest by REs, TSOs and WMOs.
- iii. The WPs shall avoid (i) duplication of existing international activities (e.g. from NEA or IAEA) and (ii) re-doing what has been done in the past (at national or European level).
- iv. The WPs shall address topics which are not currently addressed by ongoing EC projects. The ongoing EC projects are given on the following figure. The different topics addressed in ongoing EC projects are the following: monitoring (Modern2020), microorganisms (MIND), concrete alteration (Cebama), non-destructive assay methods (CHANCE), waste thermal treatment (THERAMIN), bentonite mechanical evolution (Beacon) and characterization of dismantling waste (INSIDER). The aim of this is to wait for feedback from these ongoing projects before launching any follow up WP within EURAD-1.



List of EC ongoing projects at the time of the development of EURAD proposal

The selection process followed a top-bottom approach. In March 2017, a first list of WPs was prioritized by IGD-TP Executive Group (EG) for the WMOs, and SITEX for the TSOs. Following this, the Core Group established a list of potential WPs and issued a call for interest.

WMOs Proposal

The main ideas that guided the selection of the IGD-TP EG were first to find a good balance between mature and emerging projects to be launched at start of EURAD-1, and then to keep it simple for the first round.

As a result, a set of four topics was first issued. This list included three mature projects and four new and challenging topics. The three mature projects are listed hereafter:

- Cement-Organics-Radionuclides-Interactions: this topic address both surface disposal and deep geological disposal. It needed to be reworked and significantly improved;
- Safety of Extended dry storage of nuclear spent fuel: this project may not be relevant to all EG members. It needed to be reworked and significantly improved;

- High temperature clay interactions: the topic is a first step toward optimization of the architecture of the deep geological disposal. The idea was to continue the work begun at WG3 from EF7.

The four emerging topics fall into two different categories:

- The topic dedicated to the assessment of chemical evolution of ILW and HLW disposal seems adequate in the context of an Joint Programme towards implementation of actual repositories. It corresponds to an integration challenge that all WMO's are facing or will be facing at some point (managing the complexity of the phenomenological evolution of these subsystems, managing uncertainties...);
- The other three topics fit in the area of long-term scientific endeavour to strengthen safety cases, reduce conservatism and maintain skills:
 - Fundamental understanding of radionuclide mobility;
 - Mechanistic understanding of gas migration; and
 - Numerical methods and tools applied to performance assessment.

TSOs proposal

The five following topics have been suggested:

- Metallic component behaviour along the stages of storage and disposal programmes;
- Gas migration;
- Radionuclide migration through disturbed engineered barrier systems and host rocks,
- Conditions for closure; and
- Management of uncertainties.

Based on the proposals from WMOs and TSOs, the Core Group established the following list of RD&D/Strategic Studies WPs:

- (RD&D) Modelling of process couplings and numerical tools applied to PA;
- (RD&D) Assessment of chemical evolution of ILW and HLW disposal cell;
- (RD&D) Mechanistic understanding of gas migration (mainly in clay-based materials);
- (RD&D) Influence of temperature on clay-based material behaviour;
- (RD&D) Cement-Organics-Radionuclide-Interactions;
- (RD&D) Fundamental understanding of radionuclide mobility;
- (RD&D) Spent Fuel characterization and evolution until disposal;
- (Strategic Studies) Understanding of uncertainty, risk and safety; and
- (Strategic Studies) Waste management routes in Europe from cradle to grave*.

* This Strategic Studies emerged in April 2017 following the JOPRAD Programme document workshop in London in order to meet the expectations from small / early stage programmes.

This list of potential WPs was then checked and agreed by REs.

Based on this list of potential WPs, a Call for Interest was issued in April 2017 to collect interest/ potential contributions by the different organisations. All WPs received a high-level of interest. Nine working groups have been established in June 2017 to officially start the proposals development.

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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

RD&D WPs

WP2 - Assessment of Chemical Evolution of ILW and HLW Disposal Cells (ACED)

Multiscale approach and process integration to improve long-term modelling and assessments

‘What’ - This WP improves the methodology to integrate knowledge on the geochemical processes in and between the materials in a disposal cell for ILW and for HLW waste in order to understand and assess the long-term evolution of such complex system. A multi-process and multi-scale modelling framework will enable the assessment of the chemical evolution at various materials interfaces and thermal, hydraulic and/or chemical gradients from the microscale to the disposal cell scale (ILW, HLW) considering the near field environment and the host rock for larger temporal scales. Starting from small-scale process understanding, it seeks to evaluate in which detail geochemical processes need to be included for representative assessments of the chemical evolution in view of the needs in repository design and post-closure safety assessment.

‘Why’ - The WP ACED is included already in EURAD-1 as it covers an important number of high priority items of the roadmap of EURAD. These are in particular the EBS systems understanding in phase 1, 2 and 3 of the Roadmap:

- Improved understanding of the interactions occurring at the interfaces between waste packages and different barriers in the disposal system
- Improved description of the spatial and temporal evolution and transformations affecting the pore space and the alteration of materials in the near field of HLW and ILW disposal systems
- Concerns also the high priority item for phase 1 in performance assessment and systems models
- Improved understanding of the role of physical/chemical processes at different scales and linking bottom-up and top-down approaches in performance assessment

More specific, the work will allow identifying in which detail and complexity these processes should be incorporated in models for different types of studies related to safety and performance. The information gained through investigation of generic but representative HLW and ILW disposal cells representative for European programmes can later be used and adapted for more specific, national disposal cell designs.

The outcomes will impact the safety case and repository design in different ways e.g. with respect to material specifications and establishment of requirements for disposal procedures. The representative designs are defined for ILW and HLW in both crystalline and sedimentary rock types, representing prevailing designs by the WMOs as end-users. The clear interest of the mandated actors in this WP is demonstrated by the fact that the WP activities are carried out by a large number of partners, with a good balance between WMO, TSO and RE representatives.

Duration: 01/06/2019 – 31/05/2023

Involved Beneficiaries :



WP3 - Cement-Organic-Radionuclide interactions (CORI)

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)

‘What’

This WP aims to improve the in-depth understanding of the interaction of cementitious materials with organic matter and with radionuclides. Organic materials are present in some nuclear waste and as additives in cement-based materials and can potentially influence the performance of a geological disposal system, especially in the case of low and intermediate level waste disposal. The potential effect of increasing mobility of organic molecules on radionuclide migration is related to the formation of complexes in solution with some radionuclides of interest (actinides and lanthanides) which can (i) increase radionuclide solubility and (ii) decrease radionuclide sorption. The WP's raison d'être is to better quantify the impact of organic material on accelerating radionuclide migration in the post closure phase of geological repositories for ILW and LLW/VLLW, including surface/shallow depth disposal.

‘Why’

The thematic represented by the WP CORI has been selected for the first phase of EURAD as “improved understanding of the role of organics (either naturally occurring or introduced by the wastes) and their influence on radionuclide migration” was identified as an important subject in theme 4 (Geoscience to understand rock properties, radionuclide transport and long-term geological evolution) in phase 1 and 2 of the roadmap. Due to the potential degradation of organic matter, this subject is particularly challenging in cementitious environments. Due to the importance of this subject in national programs, various mandated actors are working already since long time on the issues addressed by this WP (see for instance the meetings of the former TSWG in May 2013, Ghent, Belgium, leading to CEBAMA, or the latter extended discussion on CORI at the IGD-TP EF 6 (2015) in London, UK). Over this entire period, partners were eager to join forces for a strong improvement in scientific understanding allowing assessing long-term radionuclide mobility in organic rich cementitious waste disposal environments.

Duration: 01/06/2019 – 31/05/2023

Involved Beneficiaries :



WP4 - Development and Improvement Of Numerical methods and Tools for modelling coupled processes (DONUT)

Improved understanding of the upscaling of THMC modelling for coupled hydro-mechanical-chemical processes in time and space

‘What’

This WP will develop and improve specific numerical methods and tools that allow efficient modelling of coupled processes, considering (i) the versatility of numerical methods used in the various tools used by “end-users”; and (ii) a demonstration of robustness and added-value of developments by benchmark of the methods and tools on representative test cases at large repository temporal and spatial scales.

‘Why’

The DONUT WP has been selected for the first phase of EURAD as it will address the following activities identified as a high or medium level of common interest in Theme 7 “Performance assessment, safety case development and safety analyses” of the Roadmap:

- Improved understanding of the upscaling of THMC modelling for coupled hydromechanical-chemical processes in time and space (Phase 1 of the Roadmap).
- Improved understanding and models for the impact of THMC on the behaviour of the host rock and the buffer materials (Phase 2 of the Roadmap).
- Improved multi-scale reactive transport models (Phase 2 of the Roadmap)
- Improved performance assessment tools (Phases 0 and 1 of the Roadmap).
- Further refinement of methods to make sensitivity and uncertainty analyses (Phases 2 and 3 of the Roadmap)
- Improved computing (Phases 3 and 4 of the Roadmap).

Furthermore, by improving the numerical methods and tools that are able to manage multi-physical coupled processes, the work conducted in this WP is relevant for better descriptions of site evolution and design optimization. Both can be applied to deep geological and near surface radioactive waste disposal. Finally, by providing efficient numerical means for analysis, DONUT will contribute to abstraction for simplified models to be used for the safety case (quantification of safety margins, detailed assessment of safety functions allocated to components...).

Duration: 01/06/2019 – 31/05/2023

Involved Beneficiaries :



WP5 - Fundamental understanding of radionuclide retention (FUTURE)

Quantification of long-term entrapment of key radionuclides in solid phases as input to reactive transport models also considering the influence of redox

‘What’

This WP aims at realizing a step change in quantitative mechanistic understanding of radionuclide retention in the repository barrier system, the key mission of any repository for radioactive waste. In consequence, the raison d'être of this WP concerns the identification of constraints and the increase in predictability of RN migration properties in “real” clay and crystalline rocks, quantifying the influence of key parameters of the heterogeneous rock/water system such as rock structure, redox interfaces, water saturation, reversibility etc. with the goal to develop multicomponent mechanistic sorption models, fracture and/or pore scale simulations of radionuclides transport in both in crystalline and clay rocks considering the combined analysis of reactivity, structure, flow field, and RN mobility/retention.

‘Why’

“Radionuclide mobility” has been identified by the mandated actors of WMO, TSO and RE as one of the key themes (4) of EURAD, the SRA and its concretization in the roadmap. It is a key theme in all radioactive waste management countries in Europe, a cornerstone for any proof of safety of nuclear waste disposal concepts. Hence, it was evident to all actors that this theme should also be part of the EURAD-1, acknowledging that there has been research on the various topics of radionuclide migration for more than 30 years, often funded by the European Commission, but realizing as well that various key themes have not been addressed in previous European projects (e.g. FUNMIG, SKIN, RECOSEY) in great depth for their application in the real repository systems in clay or crystalline rocks. The results of the project are expected to reduce uncertainties and improve the scientific basis and the realism for the safety case of deep geological disposal in clay and crystalline rocks.

Duration: 01/06/2019 – 31/05/2023

Involved Beneficiaries :



WP6 - Mechanistic understanding of gas transport in clay materials (GAS)

To increase understanding and predictability of gas migration in different host rocks

‘What’

This WP provides data and develop process-level models to improve mechanistic understanding of transport processes in natural and engineered clay materials, including couplings with mechanical behaviour and impact on the clay properties. Experimental work determines, for each identified gas transport regime, the conditions under which that regime is possible, in clay materials representative for host rock and clay EBS components. Data is to be obtained that are pertinent for low (diffusion) to high (advection) gas transport rates. Work s also show how knowledge gained from lab and in situ experiments is integrated in the conceptualisation of gas transport through different components of a repository system and how gas could affect (or not) the performance of the system. This involves (i) more detailed development of phenomenological descriptions of gas transport and of its likely consequences at the relevant scale and (ii) additional testing of different approaches to represent the effects of gas at repository scale and bounding its consequences in terms of repository performance.

‘Why’ - Theme 4 of the EURAD Roadmap (Geoscience to understand rock properties, radionuclide transport and long-term geological evolution), increasing the understanding of gas migration is a high priority topic. Gas generation and transport is a key issue as it is possible that gas could be generated at a faster rate than it can be removed through clay host rocks (and clay EBS components) without creating discrete, gas-specific pathways through these low-permeability components. In several disposal concepts, the potential for migration of free gas containing radionuclides to the biosphere is an important issue. Consequently, the WP raison d’être is to answer two key end-users questions:

- How can gas migrate within the repository and which water soluble and volatile radionuclides could be associated with it?
- How and to what extent could the hydro-mechanical perturbations induced by gas affect barrier integrity and performance?

This WP builds on the outcomes of FORGE and other projects. Experiments in FORGE revealed complex mechanisms and emphasized the importance of the mechanical control exerted by the porous material on gas transport. It was suggested that this complexity can be addressed as long as one can bound the effects of these mechanisms using simple and robust descriptions for evaluation purposes (e.g. two-phase flow models for gas transient representation at repository scale, identified as a medium priority under Theme 4). A necessary condition for this is that the scientific bases are integrated properly, in a traceable way throughout the system conceptualisation process. Hence, the structure of this WP follows this process, imposing interactions at each step to ensure close cooperation between experimentalists, process modellers and those involved in evaluation of system performance. This should allow the development of robust evaluation approaches that support the expert judgement formulated at the end of FORGE that gas is not a feasibility challenging issue for geological disposal but more a challenge of managing uncertainties.

Duration: 01/06/2019 – 31/05/2024

Involved Beneficiaries :



WP7 - Influence of temperature on clay-based material behaviour (HITEC)

Improved THM description of clay-based materials at elevated temperatures

‘What’

This WP aims to develop and document improved THM understanding of clay-based materials (host rock and buffer) exposed to elevated temperatures ($>100^{\circ}\text{C}$) for extended durations. The WP’s raison d’être is to evaluate whether or not elevated temperature limits (of $100\text{--}150^{\circ}\text{C}$) are feasible and safe for a variety of geological disposal concepts for high heat generating wastes (HHGW).

HITEC will study clay host rock formations ($<120^{\circ}\text{C}$) and establish the possible extent of elevated temperature damage in the near or far field (e.g. from over-pressurisation) and also the consequences of any such damage. The WP will also look at buffer bentonite and determine if temperature influences the buffer swelling pressure, hydraulic conductivity, erosion or transport properties (i.e. inhibits buffer safety functions).

‘Why’

The HITEC WP has been selected for the first phase of EURAD as the activity “Characterise bentonite/clay-based material evolution under specific conditions to provide data on hydro-mechanical, thermal and chemical behaviour” was identified as a high priority subject in theme 3 (EBS properties, function and long-term performance) phases 1-3 of the roadmap. Furthermore, the theme 4 (Geoscience to understand rock properties, radionuclide transport and long-term geological evolution) topic of “Improved understanding of the influence of temperature on radionuclide migration and representation of effects in geochemical models” was also rated as a medium priority activity.

For the disposal of HHGW it is important to understand the consequences of the heat produced on the properties (and their long-term performance) of the natural and engineered clay barriers. Most safety cases (for disposal concepts that involve clay) currently involve a temperature limit of 100°C . Being able to tolerate higher temperature, whilst still ensuring an appropriate performance, would have significant advantages (e.g. shorter above ground cooling times, more efficient packaging, fewer disposal containers, fewer transport operations, smaller facility footprints etc.).

This WP has the potential to effectively integrate with the parallel SFC RD&D WP (i.e. interrogate the validity of the currently applied thermal limits and also the importance of the accuracy of the assumed radiological waste properties).

Duration: 01/06/2019 – 31/05/2023

Involved Beneficiaries :



WP8 - Spent Fuel characterisation and evolution until disposal (SFC)

Reduce uncertainties in spent fuel properties in predisposal phase

‘What’

This WP will develop and document an experimentally verified procedure to accurately determine the properties of irradiated spent fuels. It will also develop characterisation techniques that will allow to more fully understand the physiochemical evolution of irradiated spent fuels (pellets and cladding) under normal and credible accident scenarios following reactor discharge (i.e. during interim storage (wet and dry), transport to and emplacement in a GDF).

‘Why’

Accurately determining key properties (see “...management of inventory data and uncertainty treatment”) and their evolution (see “Improved understanding of the impacts of extended storage...”) of spent fuel is fundamental to safety assessment. This is reflected in the fact that both of these Roadmap theme 2 activities are given high priorities. Parameters such as decay heat and nuclear reactivity (fissile content) need to be known to decide how much fuel can be safely loaded into a disposal container and how closely disposal containers can be emplaced at disposal. In the absence of accurate knowledge there is a possibility that these parameters could be too conservatively estimated. Conservatisms would then affect container loadings and facility layouts, potentially resulting in substantially more containers than necessary, more transport operations and ultimately a larger facility footprint. This would have safety and cost ramifications. Conversely, the alternative is also possible (i.e. too optimistic parameters are estimated), which could then be detrimental to safety, i.e. inadvertently breach a thermal or criticality safety limit.

WMOs are particularly interested in the possibility of an NDA technique that could allow swift and accurate corroboration of spent fuel records, prior to loading the fuel into the container (i.e. compliance with waste acceptance criteria (WAC), such as a fuel burn-up measurement or a thermal limit acceptance check). WAC is a key thematic area under theme 2 of the EURAD Roadmap and is typically of most interest to more advanced stage programmes (Phase 2 onwards).

This WP has the potential to effectively integrate with the parallel HITEC RD&D WP (i.e. scrutinise actual thermal output and also the validity of currently applied thermal limits).

Duration: 01/06/2019 – 31/05/2023

Involved Beneficiaries :



Strategic Studies WPs

WP9 - Waste Management routes in Europe from cradle to grave (ROUTES)

Share experience & knowledge on RWM routes between WMOs, TSOs and REs from different countries, with programmes at different stages development, with different amounts/types of waste

‘What’ - This WP describes and compares the different approaches to characterisation, treatment and conditioning and to long-term waste management routes between MS (member states). The interested organisations are from different countries, with programmes at different stages of development, with different amounts and types of radioactive waste to manage. In this WP, the safety-relevant issues and their R&D needs associated with the waste management routes (cradle to grave) are identified, including the management routes of legacy and historical waste. The WP considers past and present EU projects on the topics of interest and other initiatives carried out at the international level by IAEA and NEA in order not to duplicate the work. The aim of this WP is to identify relevant R&D topics which could be collaboratively launched in the second wave of EURAD.

‘Why’ - As noted under the EURAD Roadmap Theme 2 - Radioactive waste characterisation, processing and storage (Pre-disposal activities), and source term understanding for disposal - the pre-disposal activities including radioactive waste characterization, treatment and conditioning as well as storage are considered as high priorities. Moreover, as highlighted in the Roadmap, sufficient knowledge of the radionuclide and chemical content of the waste is a prerequisite for the development of the complete waste management route.

The common interests addressed in the ROUTES strategic studies are identified in the Roadmap and related to the Theme 2: Inventory collation and forecasting (3.5), the Methodology to define radionuclides inventories (3.6), understanding of the potential for long-term storage as a management option for disused sealed radioactive sources (3.10), the management of damaged waste packages and methods for reprocessing aged waste (1.2.4), waste acceptance criteria (2.1.6). All these subtopics are related to Roadmap Phase 0 (Policy, Framework & Programme Establishment), except the subtopic WAC which is related to Phase 2 (Site Characterisation) and Phase 3 (Facility Construction).

Consequently, the raison d'être of this WP is to provide an opportunity to the organisations of the Member-States to share their experience and to identify common R&D interests on these topics. For this, safety-relevant issues and R&D needs associated with the waste management routes (cradle to grave) are identified, considering waste characterisation, the development of preliminary waste acceptance criteria (WAC) prior to the availability of disposal facilities, options for disposal of small waste inventories. In addition to providing an overview of good practices for different steps in radioactive waste management and guidance for research activities, the WP provides an opportunity to consider sharing of technology and facilities.

Duration: 01/06/2019 – 31/05/2024

Involved Beneficiaries :



WP10 - Understanding of uncertainty, risk and safety (UMAN).

Further refinement of methods to perform sensitivity and uncertainty analyses and the development of multi-actor network for uncertainty management

‘What’ - This WP is dedicated to the management of uncertainties potentially relevant to the safety of different radioactive waste management concepts and designs. It includes various activities such as exchanges on views, practices and uncertainty management options and the review of existing strategies, approaches and tools. Interactions between different types of actors including civil society are central to this WP. These interactions are aimed at meeting the shared objective of fostering a mutual understanding of uncertainty management strategies, approaches and preferences. A particular focus is put on uncertainties directly linked with RD&D WPs and with a high (and where relevant medium) priority subdomain of the SRA for which exchanges of information and experiences and strategic studies have been identified as beneficial by the JP actors themselves. The WP will consider past and present EU projects on the topics of interest and other initiatives carried out at international level by IAEA and NEA to avoid duplicating existing work. The WP will allow identifying the contribution of past and on-going RD&D projects to the overall management of uncertainties as well as remaining and emerging issues associated with uncertainty management that could be addressed in subsequent waves of EURAD.

‘Why’ - Decisions associated with radioactive waste management programmes are made in the presence of irreducible and reducible uncertainties. Several choices made on the basis of limited information in early programme phases may also have to be confirmed before or during the construction and operation of the facility. At the end of the process, some uncertainties will inevitably remain but it should be demonstrated that these uncertainties do not undermine safety. Hence, the management of uncertainties is a key issue when developing and reviewing the safety case of waste management facilities and, in particular, of waste disposal facilities due to the long-time scales during which the radiotoxicity of the waste remains significant.

As noted under the EURAD Roadmap Theme 1 - Managing implementation and oversight of a radioactive waste management programme - a clear strategy and commitment to involvement of stakeholders is essential to the decision-making process at all stages of a waste management programme. It is also explained that scientific activities associated with a waste management programme (site characterisation, process modelling, safety assessment etc.) are evolving over time leading to new view points and sometimes new uncertainties and are not fully predictable in outcome, duration or resources that may eventually be required to resolve emerging issues. Accounting for such uncertainty has thus become a key part of successful programme planning, and would benefit from continued sharing of methodologies and experience.

Therefore, uncertainty is a cross-cutting issue of the different themes and stages identified in the Roadmap. The term “uncertainty” is also explicitly mentioned in the title of several activities of common interest considered as having a medium or a high priority: Inventory uncertainty (1.1.1), Site uncertainty treatment (3.1), Geological uncertainties (1.6.2), Uncertainty treatment (2.1.3). Furthermore, RD&D activities are aimed at improving the state-of-knowledge and thus are expected to reduce uncertainties. Understanding the contribution of these activities to the overall uncertainty management is important for the different actors involved in the decision-making process as well as for the identification of future EURAD priorities and activities.

Consequently, the *raison d’être* of this WP is to provide an opportunity to the organisations and different actors of the Member-States to share their experience and views on uncertainty management and to identify emerging needs associated with this topic. The WP will also contribute to understanding the added value of RD&D activities for the safety case and the decision-making process within the different programmes. It also contributes to the vision of EURAD by fostering mutual understanding and trust between Joint Programme participants.

Duration: 01/06/2019 – 31/05/2024

Involved Beneficiaries :



Knowledge Management WPs

Under EURAD-1, Knowledge Management is enabled by three permanent WPs that are directly derived from EURATOM expectations under WP2018:

WP11 - State of Knowledge - Activities under this WP consist of developing a systematic approach of establishing the state-of-knowledge in the field of RWM research. This shall be done on a stepwise basis: i) establishing of procedures to document the SoK; ii) testing and improving these procedures on a few demonstration topics/sub-topics (of the Roadmap); iii) performing a review on existing tools/platforms and evaluating the added-value of establishing such a platform dedicated to provide access to SoK developed in EURAD.



WP12 - Methodological guidance - Activities under this WP consist of developing a comprehensive suite of instructional guidance documents that can be used by Member-States with RWM programmes that are at an early stage of development with respect to their national RWM programme. This WP will pursue and complement the work initiated with the [PLANDIS Guide](#).



WP13- Training/mobility - Activities under this WP consist of developing a diverse portfolio of tailored basic and specialised training courses under the umbrella of a “School of Radioactive Waste Management”, taking stock of and building upon already existing initiatives (i.e. IAEA and NEA) and creating new initiatives to bridge identified gaps. The end-users are defined as professionals and potential new professionals at graduated and post-graduated level from EU and non-EU countries (via the IAEA and NEA programmes), and in particular the next generation of experts This WP will also organise a mobility

programme to provide access to dedicated infrastructures associated with the Mandated Actors/Linked Third Parties within EURAD. This work will be carried out in close interaction with European networks having a recognised experience in training/mobility in the field of RW.



In addition to the three permanent Knowledge Management Work Packages above, there are additional Knowledge Management activities integrated with the RD&D Work Packages, for example, state-of-the-art activities.

As emphasised with respect to Methodological Guidance, identified as a priority and clearly underlined in the EURATOM WP2018 call, there is a need to carry out a prioritisation exercise with WMOs, TSOs and REs in order to identify key existing knowledge and target competences that shall be covered in both State-of-Knowledge and Training/Mobility WPs under the EURAD-1 for the target audiences.

Thus, a very first task of both State-of-Knowledge and Training/Mobility WPs (as part of the first Annual Work Plan) shall consist of carrying out this prioritisation of existing knowledge. This will be coordinated by the Programme Management Office. The outputs will be directly integrated into the EURAD Roadmap and will serve as the framework for establishing the State-of-Knowledge and Training/Mobility WPs' Annual Work Plans and also help the evaluation of new RD&D proposals to ensure their relevance and that no duplications will occur. This knowledge management scope will consider the large body of information produced by WMOs over past decades that is in the public domain (in addition to other knowledge sources), and therefore should be considered as complementary to (and not in-conflict with) commercial consultancy services offered by some WMOs.

Interaction with Civil Society Organisations

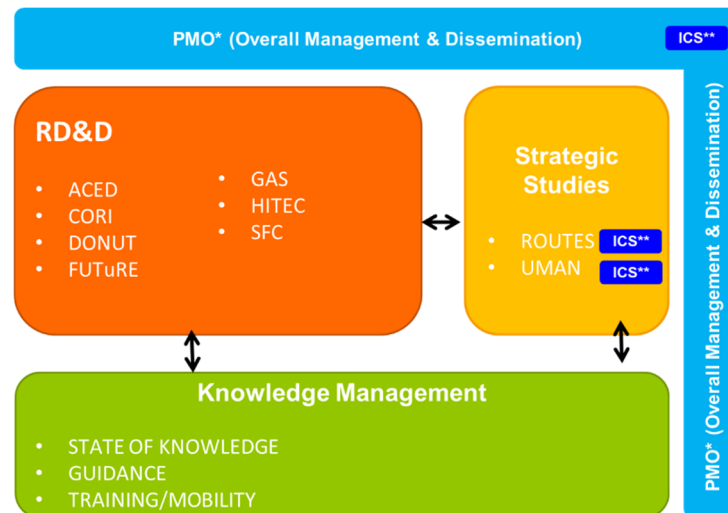
For the first wave of the EURAD-1, the two Strategic Studies Work Packages have been selected for specific contribution from civil society because they are focusing on generic aspects of radioactive waste management and are of interest for civil society in EU countries:

- SS WP9 - Waste Management routes in Europe from cradle to grave (ROUTES); and
- SS WP10- Understanding of uncertainty, risk and safety (UMAN).

In close collaboration with the WP Boards (WP Leader and task leaders) the role of **CS Experts** (in charge of translating the WP work content and results to the CS group) is to:

- Sketch out and map the key stakes related to the work performed in the different tasks/subtasks of the WPs from a CS point of view in order to translate the work content and the results to the broader CS group and gather its feedback at annual workshops;
- Contribute to the work performed in the tasks/subtasks of the selected WPs and participate in key working meetings of these tasks;
- Raise awareness of the broader CS group on the scientific/technical research issues for radioactive waste management solutions by preparing and animating a specific session dedicated to the selected WPs in the CS annual workshop of EURAD (see above).

Furthermore, under the PMO WP, a **dedicated coordination task** is established to coordinate, support and integrate at the programme level all the interactions activities with Civil Society. This coordination task will consist of providing methodological support for CS interactions with RWM stakeholders: elaboration of material, methodologies, processes and sessions to prepare EURAD participants and CS representatives in order to facilitate fruitful interactions, as well as the assessment of the on-going experimental model of Interaction between EURAD participants and Civil Society. This coordination work will also consist notably of organizing yearly a workshop involving the participants of the CS group, the CS Experts together with a panel of experts from WMOs, TSOS and REs participants in EURAD.



*Programme Management Office

** Interactions with Civil Society

PMO - Update of the SRA/Roadmap during EURAD-1

During EURAD-1, and in addition to its responsibility of administrative, legal and financial management and the coordination of the overall scientific and technical coordination/integration/evaluation of impacts (RD&D, Strategic Studies and KM), the PMO shall support the EURAD General Assembly in the task of extending/updating the SRA and the Roadmap. During EURAD-1, the following extensions/updates are anticipated:

[Year 1] **Roadmap Extension** - Complete EURAD Roadmap with a **Competency Matrix**, to identify competencies needed for the different Actors (WMOs, TSOs and REs) and to **map existing/available SoK, Guidance and Training material** (open access) against Themes of EURAD SRA for different phases of implementation of a RWM programme. This shall support the identification of the key need-gaps, which will then be used to prioritise the scope of each of the main KM WPs. This task will be undertaken by the PMO, with inputs from participants of the KM WPs and with oversight and guidance by the appointed Joint Programme Fellows/Experts.

[Year 2] **'Soft' update of the SRA/Roadmap** in view of the preparation of the 2nd wave of RD&D and Strategic Studies WPs where it is anticipated that minor edits and additions should be made, e.g. assessing the level of common interest of topics that emerged lately in the process of developing the SRA; identification of emerging RD&D needs and assess level of common interest.

[Year 4-5] **‘Extensive’ update** of the SRA/Roadmap (exact timing to be adjusted in order to be in line with Euratom work programme) to coincide with preparation and prioritisation of the scope of the potential EURAD-2. During this extensive update, it is anticipated that significant changes may result to take account of learning from EURAD-1 and align the Vision, SRA, Roadmap and RD&D, Strategic Studies and KM Work Packages scope and methodologies with how things evolve, particularly with respect to governance scheme and how the criteria used to identify needs of the WMOs, TSOs and REs.