



Deliverable 1.17: Evaluating the impact of European Programme on Radioactive Waste Management

Work Package 1

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Authors	Zuidema Piet (Chief Scientific Officer), EURAD Programme Management Office members

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Executive Summary

EURAD - the European Joint Programme on Radioactive Waste Management - has operated for 5-years since its inception in 2019 and has successfully achieved a step-change towards a more effective and efficient use of public funding in Europe by bringing the European waste management community and its experts together, and a deepening of research-cooperation between Member States. It has delivered 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.

Besides looking at the impact of EURAD, this evaluation also looks at the suitability of the processes and the structure used by EURAD to provide added value to the National Radioactive Waste Management Programmes. Besides the 'personal' judgement of the CSOff (using the contributions and the comments on drafts of this document by reviewers), this evaluation also builds upon the input of some representatives of the Member States received through specific interviews and discussions in the framework of the lessons learned organized during the last year of the programme.

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1. Introduction

As mentioned in the founding documents of EURAD, it is the responsibility of the National Programmes to evaluate the output and the results of EURAD with respect to their own needs (towards implementation). Nevertheless, the Chief Scientific Officer (CSOff) with the help of the Programme Management Office (PMO) have the obligation to also make an evaluation of the impact of EURAD that, however, does not replace the evaluation by the National Programmes. This also applies to the impact of the detailed findings of the work packages, as the importance of these findings depends upon the disposal system looked at; no general comments can be made. For assessing the outcome of EURAD and its impact, the following issues are addressed:

- The results of the different EURAD work packages (a broad summary of the deliverables and some overall conclusions in chapter 3).
- EURAD as an education platform (MSc students, PhD students, Post Doc's, etc.) mentioned in the conclusions of chapter 3.
- The 'soft impact' of EURAD, e.g. the value of EURAD as a platform to interact and for networking for the communities (the Colleges and civil society) and the EU Member States / associated countries involved in EURAD (summarised in chapter 4)
- The overall 'added value' of EURAD for the communities involved (the Colleges and Civil Society) and for the participating Member States (including supporting the EU Member States in fulfilling their duties relative to the 'waste directive' [2011/70/Euratom]) and associated countries is summarised in chapter 5.

For assessing the processes and structures available to achieve this outcome, the following issues are addressed:

- The framework of EURAD
- The governance – the structure and processes used for conducting the work
- The platform provided by EURAD for interaction and networking

2. A step change in European collaboration

2.1 Introduction

The boundary conditions for developing EURAD were given by the call of the Commission in 2018 and – equally important – the preparatory work done within the EC project JOPRAD that allowed to act thoughtfully upon the call. Key elements of the call and the preparatory work are based on an envisaged step-change in European collaboration through joint programming with the following broad characteristics.

Instead of having individual projects chosen based on a competitive approach with the themes to be addressed being defined by the European Commission, joint programming foresees coordinated work packages with the themes and corresponding work packages proposed by the mandated actors of the participating Member States and associated countries that are then also in charge of performing the work with the help of linked 3rd parties and international partners. This means that the end-users are defining, executing and reporting the complete programme, thus governs the content and outcomes. The governing body (General Assembly) was also the possibility to change the content during execution in case it is needed.

The framework of EURAD is described in its founding documents. The key elements of the framework are:

- the vision of EURAD¹,
- the governance,
- the Strategic Research Agenda ² and the Roadmap,³
- the deployment plan⁴.

Besides the content of the founding documents, the broad support EURAD found is an important issue. Having 27 EU Member States that have to deal with radioactive material, mandated actors from 20 EU Member States are signatories of the founding documents. Additionally, 3 associated countries are participating to the programme. Thus, one can say that EURAD brings the radioactive waste management community of Europe together.

2.2 The Vision of EURAD

The vision of EURAD is described in the founding documents as follows:

'A step change in European collaboration towards safe radioactive waste management (RWM), including disposal, through the development of a robust and sustained science, technology and knowledge management programme that supports the 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 vision can be summarised with the following bullet points:

- EURAD organises a **step-change** in European collaboration:
 - by **supporting the Member States** in their timely **implementation** of radioactive waste management activities,
 - by giving the **power to the Member States** through their mandated actors to **define** a joint roadmap for implementing radioactive waste management and a strategic programme of research and knowledge management to identify the **activities to be worked on**, based on this joint strategic programme,
 - resulting in a **more effective & efficient** use of resources by bringing the European experts together,
 - and through **deepening the cooperation** between Member States with their actors (consisting of waste management organisations, technical support organisations (related to regulatory activities) and research entities) and through the structured interaction and strategic studies with representatives of civil society.
- This European collaboration
 - is based on cutting edge **knowledge creation and preservation**,

¹ <https://www.ejp-eurad.eu/publications/eurad-vision>

² <https://www.ejp-eurad.eu/publications/eurad-d19-update-eurad-sra>

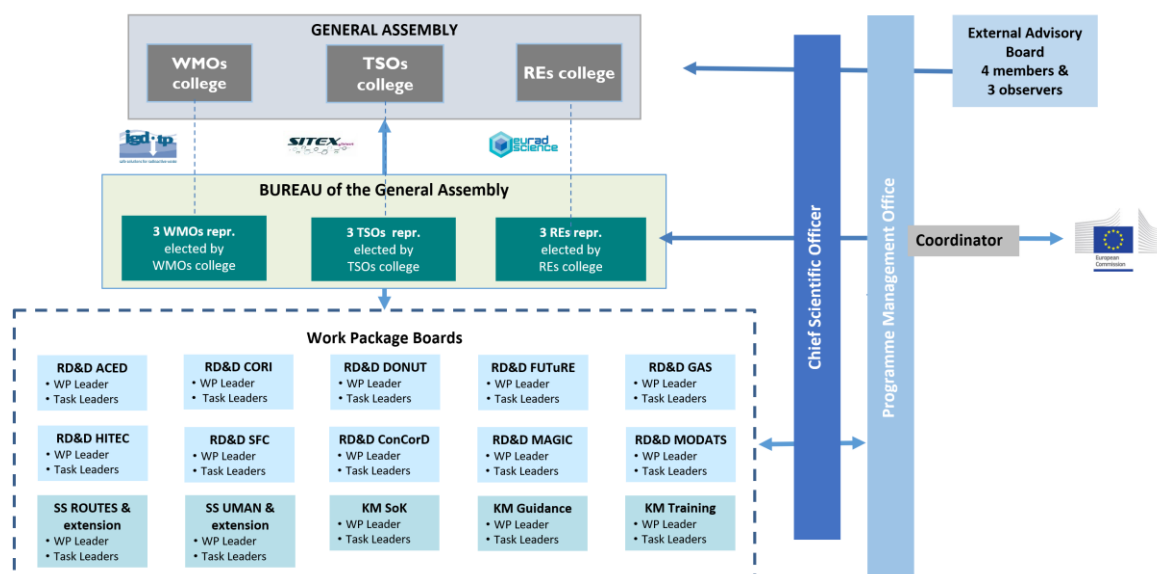
³ <https://www.ejp-eurad.eu/roadmap>

⁴ <https://www.ejp-eurad.eu/publications/eurad-deployment-plan>

- is strengthened by **elaborating upon complex issues** by bringing together interested actors to jointly conduct strategic studies and networking,
- fosters **mutual understanding and trust** between the participants,
- **supports the delivery** of safe, sustainable & publicly acceptable solutions for RWM activities,
- makes the output available to the RWM community and the public.

2.3 The Governance

The governance of EURAD is summarised with the following organisational scheme.



The key characteristics of the governance are:

- At the highest level is the **General Assembly** (GA). The members of the GA are one representative of each EURAD Beneficiary (nationally mandated organisation)
- The **Colleges** are organised entities (waste management organisations (WMO) with the Implementing Geological Disposal of radioactive waste Technology Platform (IGD-TP), the technical safety / support organisations (TSO) with Sustainable network for Independent Technical EXPertise on radioactive waste management (SITEX) Network and the research entities (RE) with EURADSCIENCE. Each of the Colleges has a framework for discussion and to develop opinions / views and to prepare position papers.
- The **Bureau** that consists of three elected representatives of each College. The bureau acts on behalf of the General Assembly in close interactions with the Programme Management Office (PMO). In reality, it is responsible to make the link between the Colleges and the coordinator / project management office (PMO) and the General Assembly
- The R&D, Strategic Study (StSt) and KM **Work Packages** (WPs) each have a **Work Package Leader** (WPL), sometimes a deputy, and Task Leaders. They constitute the **Work Package Board**.
- The work within the WPs is performed by the **Mandated Actors** and **Linked 3rd Parties** (linked to mandated actors). Mandates are given by the responsible organisation in each country (often ministries / government offices). Furthermore, in a few WPs **International Partners** (beyond the EU countries and the associated countries (Switzerland, Ukraine and the UK)) participate, but they receive no funds from the EC. Finally, formal connections exist with **International**

Organisations (IAEA and OECD/NEA) to coordinate the work and to take advantage of synergies and to avoid duplications.

In some of the WPs, **Civil Society** / Civil Society Organisations are involved by using the ‘double wing’ model (Civil Society experts participate in the WPs but bring and discuss the information to a broader group)

To perform the work, different instruments (different types of work packages) were available:

- **R&D** – perform cutting-edge science and technology,
- **Strategic studies** (StSt) – identify and elaborate upon complex issues by bringing together interested actors to jointly conduct strategic studies and networking,
- **Knowledge management** (KM) – support the knowledge transfer between the different stages of waste management programmes and between generations through a comprehensive knowledge management programme.
- The **External Advisory Board** (EAB) advises the GA on strategic issues related to the EURAD Vision and provides external advice and recommendations for how best practice is adopted and used across EURAD at a high level. The EAB is composed of scientific and technical experts at international level, furthermore one representative from DG-ENER, DG-JRC and DG-RTD participate as observers in some of the EAB meetings. The EAB is invited to the EURAD GA meetings and Annual Events.
- The overall day-to-day management and communication activities, scientific and technical coordination of the implementation of the programme, is the responsibility of the **Project Management Office** (PMO). The PMO is housed on the premises of the Coordinator.
- The Coordinator is the legal entity acting as the intermediary between the Parties and the European Commission. It is, among other tasks, responsible for chairing the PMO, administering the financial contribution of the Commission and monitoring compliance by the Parties.
- The **Chief Scientific Officer** (CSOff) has the role to enforce the scientific leadership of EURAD on aspects of science, technology and knowledge management towards fulfilment of the EURAD Programme Vision, the Strategic Research Agenda and the Roadmap and to act as a EURAD high-level spokesman to contextualize EURAD progress and results. The Chief Scientific Officer independently serves and reports to the EURAD General Assembly, the Bureau and the PMO.

This governance used turned out to be effective in running EURAD:

- The **General Assemblies** were divided into two parts: a block of information and a block with decisions. For each of the items, documents were prepared and distributed prior to the GA. The GA (many of them by video conference, initially due to Covid-19, later for reasons of efficiency) were focused on managerial issues and kept short. Participation to the GA was restricted to GA members and (without having the right to vote) to the PMO, the Bureau members, the CSOff, the WP Leaders and a CSO observer.

After each GA, feedback was requested that was overall positive (though with a limited number of participants providing feedback and some variability in the feedback). Thus, the functioning of the GA and its format are considered to be fit for the purpose and effective.

The Annual events turned out to be a very important instrument, as it allowed to present and discuss the themes covered by EURAD and to go into more depth in breakout sessions. The annual events were open to all EURAD participants, end-users and stakeholders. The participation to those events was open to anyone whose organisation was involved in the programme.

The concept of bringing the three Colleges together to cooperate and to work together on important issues has turned out to be positive. To have the different perspectives of each of the Colleges provided significant added value⁵. The joint activities strengthened the mutual understanding and trust (see e.g. the decision making related to identification of the second wave work packages and the update of the Strategic Research and Knowledge Management Agenda)

.0However, from the point of view of the PMO members and the CSOff, there are still some limitations in the interaction – not enough in-depth (controversial) discussions and still too much striving for consensus (see e.g. update of the SRA). Furthermore, no joint position papers were developed, although enough material deserving such an activity existed.

Furthermore, the issue of having the Regulatory View sufficiently reflected within EURAD is an issue to be considered in future, as many countries in the strict sense do not have a TSO.

- The involvement of Civil Society complemented the perspectives of the Colleges by an additional view with their participation in some of the WPs and contributed to increase the mutual understanding and trust. However, the question about the representativeness of the Civil Society participants is not yet fully clarified.
- The concept with **Bureau** making the interface with the Colleges and the WPs and the Coordinator / the PMO worked out very well, However, the workload turned out to be rather heavy, especially for the Chair of the bureau.
- The structure of the **Work Package** leadership was in most cases very effective for day-to-day management and for the link between the PMO and WP. However, in the view of the CSOff and the PMO, the 'loose' involvement of **End-Users** in nearly all WPs turned out to be a weakness. End-users should be formally involved (already defined in the programme of work) with clearly defined responsibilities (e.g., to provide timely formal feedback both on the orientation of the work and on the significance of the results). Also, the review of documents, results and workplans turned out to be difficult. The involvement of reviewers should be more rigorously planned, e.g. in the Annual Programme of Work.

Some of the WPs were run as previous EC projects (though with reduced administrative burden) with limited interaction between the WPs. A clearer planning of inter-WP interactions from the start of the project would be useful.

- The involvement of the **External Advisory Board** was in some parts excellent (e.g. the meetings with the observers from DG-ENER, DG-JRC and DG-RTD and also the presentations made at the different meetings). However, the agreement, on an annual basis, on the EURAD work programme of the External Advisor Board did never happen; this should be improved in a future joint programme.
- The work done by the **Coordinator** and the **Programme Management Office** is considered to be good (view of CSOff) as far as overall project management is concerned. Initially there was a substantial problem with managing contracts with external experts as it was not planned in the programme, but that was solved by the Coordinator making all external contracts. The workload was pretty heavy and the follow-up of the work of the WPs requires PMO members with broad and good knowledge; the availability of such persons with the time needed is a critical issue and needs attention. The scientific/technical and strategic leadership by the PMO was

⁵ The categorisation of the contributing actors in terms of being a member of one of the three Colleges each with its specific role does not always match reality in the national waste management programmes as some actors sometimes have broader / multiple roles, e.g. with research entities sometimes also having a TSO function, and research is also being done by WMOs.

limited and monthly meetings between the WP leaders and the Coordinator where not used in this regard.

- According to the review by the experts of the European Commission and the feedback received from EURAD participants, the role of the **Chief Scientific Officer** is important and useful. A broad overview and his independence to provide feedback on the work done and to put the EURAD results in a broader context are acknowledged.
- Some terms of reference (e.g. the EAB) need to be more in line with the reality of the performed tasks.
- Overall, the **EURAD founding documents** have proven to be a good basis for joint programming and have only a very few limitations.

2.4 The Roadmap and Strategic Research and Knowledge Management Agenda

The original Strategic Research Agenda was developed in JOPRAD (H2020, 2014-2018) and was the basis for the founding documents. It was shared by the three Colleges. It is based on the EURAD Roadmap representing a generic Radioactive Waste Management (RWM) Programme enabling users to access existing knowledge, ongoing work and future plans. The content is focused on what knowledge, and competencies (including infrastructure) is considered most critical for implementation of RWM activities, aligned to the EURAD Vision. The Roadmap allows one to identify gaps in knowledge and competencies needed individually by each of the Member States. Since the time of the founding documents, the Roadmap has been updated using a goals breakdown structure for the broader scope of all activities needed for RWM activities leading to (geological) disposal, making it less centred on RD&D only and more modular and useful for end users. The needed RWM capabilities in each theme captures not just physical activities but also the competences needed, including when what is needed at the national level and must be maintained / developed, and what is available on the international RWM market.

In the EURAD deployment plan, an early soft update of the Strategic Research Agenda (SRA) was planned to integrate the issues that came up in the late phases of EURAD preparation and did not make it anymore into JOPRAD. The plan of the soft update was abandoned; instead, the originally planned extensive update was started somewhat earlier than originally planned, already in 2022. This update was based on the concept of applying several filtering steps, starting with the issues needed for waste management (the themes of the roadmap – to be checked for completeness) and then by narrowing down with eliminating those issues that are covered by the market (sufficient basic knowledge available), and then with eliminating the issues not suitable for joint programming. Thus, in principle for the first broad steps, something like a gap analysis should have been made, but in the documentation, nothing is visible about this. The remaining issues are then included in the SRA.

For the issues included in the SRA, the Colleges jointly decided not to use priorities for the issues (as it was done in JOPRAD), and thus leave the priority setting to a broader community at a later stage. Instead, the issues included in the SRA are characterised by so-called drivers that give an indication on the reasons why an issue is entered into the SRA. This results in a list of items that could be addressed in the upcoming joint programme(s), taking a planning horizon of 5 to 10 years into account – to decide on the items to be chosen, the drivers play an important role and were intensely discussed with the result of having 6 drivers (implementation safety, tailored solution, scientific insight, innovation for optimisation, societal engagement, knowledge management). Before being re-used (e.g. in a next update of the SRA) their usefulness may benefit from an assessment to check, whether they provide the information on *'what is important and what not in the near future.'*

All the work on the SRA was done based on the input by the three Colleges coordinated by the Bureau. The discussions of narrowing down and on characterising the different entries in the SRA were driven by the goal to reach consensus and resulted in the deliverable that was accepted by the GA.

However, there are still some questions in how far the drivers, their application and the approach to reach a consensus provide the 'full' picture about the strategic needs as input to future joint programmes. Some (e.g. the CSOff and some members of the PMO) would have liked to see at least for some items some differences in views as one would expect this for the broad spectrum of interested organisations being represented by the SRA (e.g., WMO vs. TSO vs. RE; pragmatic support vs. cutting edge science⁶; early-stage vs. mid stage vs. advanced programs; differences in waste inventories waste categories (SF/HLW vs. LILW) and size of inventory (small inventory Member States (SIMS) vs. large inventory Member States (LIMS)), etc). Although agreement is needed on what to include in a joint programme, this does not necessarily require consensus on the needs – thus, the basic idea when developing an SRA (and other things) could more be like *'reach an agreement on what to take on the list, but do not strive for a consensus on the underlying needs and interests*. A SRA would profit from a better / more detailed link to the Roadmap and a short documentation of the different views about the needs as this is essential for reaching later an agreement on the issues to be included in a deployment plan. The SRA would also have benefited from an analysis of which research fields might be considered closed for the time being, considering that sufficient understanding has been gathered over the years for implementation, optimisation or safety assessment. Finally, it would have been interesting to have an (informal) input by the regulators on the SRA.

2.5 The broad participation within EURAD and the coordination with external organisations and projects

The participation within EURAD can be seen as an indicator of the expected usefulness of joint programming through EURAD. With 20 Member States (out of 27 EU Member States that have to deal with radioactive waste), and three associated countries involved in EURAD, a broad participation can be considered as a clear signal about the expected added value to be generated by EURAD.

Nearly in parallel to EURAD, PREDIS (pre-disposal management of radioactive waste) was developed. From the start of PREDIS on, systematic coordination of activities was done, and a close cooperation developed; this was facilitated by the fact that several persons / organisations participated both in EURAD and PREDIS. The coordination / cooperation with PREDIS and the decision by the Commission to integrate PREDIS into EURAD-2 are considered as positive points.

EURAD also benefited from close interactions with international organisations such as NEA and IAEA.

Those interactions are summarised hereafter.

- NEA
 - Integration Group for the Safety Case (IGSC): the CSOff was invited to the Annual Meeting of the IGSC and to some of their events. There are significant synergies between EURAD and IGSC as both work on same subject (safety case) with complementary activities (EURAD: contributing to the scientific basis; IGSC: working on the methodology). This, it is important to maintain the contacts in particular in the definition of priorities.

Through the work on guidance on 'requirements managements for disposal' it was possible for EURAD to be involved in an Ad-hoc Group of the IGSC. There, the idea came up to

⁶ In this context, the external EC reviewers made in their mid-term review the following remark: *It (EURAD) addresses the important needs of managing and disposing of spent fuel and radioactive waste in the EU MS. For this programme it is not so much a matter of innovation and competitiveness, as it is of utilising and developing existing knowledge and spreading competence and capability needed for radioactive waste management in European countries.*

(jointly) develop a requirements data base (equivalent to FEP data base); this should be followed up.

- Working party on 'Information, Data and Knowledge Management (IDKM): From the outset, it was essential that the established EURAD KM programme did not replicate KM activities already completed (where guidance and good practice is documented) or begin to duplicate pipeline activities in KM by NEA or IAEA. To achieve this EURAD exchanged regularly with the NEA Community of Practice (the NEA IGSC IDKM Working Party) whose membership includes representatives from most of the European national programmes. Through this exchange EURAD was able to leverage their existing KM activities and work together on several roadmap documents.
- IAEA
 - International Nuclear Information System (INIS): The dissemination of all EURAD KM relevant document (Roadmap, Theme Overviews, Domain Insights, State-of-the-Art, Knowledge Management and Networking programme, guidance document, conference papers related to EURAD KM and some R&D conference papers has been published in the IAEA INIS database in a special EURAD section.
 - information exchange: EURAD was invited to several IAEA meetings (e.g., URF Network, Conferences (e.g. IAEA NKM+HRD 2024), etc.), as well as IAEA has been invited to EURAD annual meeting, webinars and workshops
 - There was a continuous information exchange between IAEA and EURAD on issues, such as knowledge management, EURAD document dissemination, invited participation to respective organisations conferences, workshops, webinars and discussion fora.
 - Furthermore, scientific results obtained in EURAD R&D WPs were presented at different IAEA technical working groups.

To ensure real synergies between joint programmes and international organisations, / other projects, this needs the involvement of these organisations already in planning phase to optimise synergies and to have their commitment.

2.6 Conclusions

The framework provided by the founding documents are considered very useful.

Key strengths of EURAD are:

- Joint programming giving the power to the Member States / associated countries with their mandated actors in EURAD to propose the themes of common interest to be addressed:
 - first wave work packages of EURAD prepared within JOPRAD,
 - new / extended work packages of EURAD, using a reserve budget (second wave) allowing to incorporate 'emerged issues' and 'lessons learned',
 - having the possibility to modify the Description of the Action of EURAD, e.g., by combining deliverables, etc.

Thus, the 'mandated actors' that have (in principle) the responsibility to ensure that the needs of the Member States are addressed and eventually met, have the power to define and modify the programme of work (if needed); this reflects the 'flexibility mechanism' defined in EURADs founding documents. Member States also contributed to the success of EURAD by providing national funding.

- Joint Programming having different & powerful instruments to address the different themes,
 - R&D to deliver a cutting-edge science & technology programme on important issues,
 - Strategic Studies to bring actors together to elaborate upon complex issues,
 - Knowledge Management to support the transfer of knowledge between programmes and generations (making knowledge accessible, providing guidance, providing mobility / training, lunch & learn, forming (student) networks and ‘communities of practice’).

The concept to have different instruments, tailored to the different needs of work to be done, is considered very useful.
- Joint Programming providing a platform to bring experts and actors together and to support the interaction,
 - between the three Colleges (WMO, TSO, RE), civil society, reviewers, stakeholders (waste generators, representatives from different EC-directorates, regulatory organisations, e.g. ENSREG) and end-users from Member State actors (SIMS / LIMS) that provides a broad spectrum of perspectives and fosters mutual understanding and trust, including interaction between newcomers (students...) and experts.
 - within WP, between WPs, with external organisations (IAEA, NEA, ...) and projects (e.g. PREDIS) provides synergies and new perspectives.
- Joint Programming providing the context for the themes discussed and work performed by the Roadmap (what, when), the Strategic Research and Knowledge Management Agenda (‘open’ issues clearly explained / justified) and other instruments (e.g., indicative requirements from requirements management).

3. Impact of the work packages

As previously described EURAD developed three types of work packages: R&D, Strategic Studies and Knowledge Management. The following comments apply to all of them.

The means to assess the meaning/significance of the results of the performed work should be improved and formalised. In a first step, the work done should be categorised with respect to the Roadmap (the themes and phase). Then, some more detailed evaluation may be useful, e.g.:

- For the R&D work packages related to post-closure safety, their impact on better understanding the performance of the investigated objects / processes should be evaluated (impact of results on safety evaluations, impact on optimisation of repository design, impact on sustainability etc.), e.g. with end-users working in performance assessment (part of the safety case) and end-users working on repository implementation etc.
- For Strategic Studies, the outcome should also be evaluated with end-users and experts, in fact, end-users should be more strongly integrated in the Strategic Studies. The outcome should indicate what should be done next (with the options enough done, convert into KM, alternatively, problem identified and that may need some R&D)
- The same also applies to Knowledge Management, where end-users should be involved to provide their feedback on needs and orientations.
- The interaction between the work packages was in the founding documents not sufficiently stressed and in the first wave WPs not considered in the programme of work; in the WPs of the second wave, this was clearer articulated and also implemented by these WPs. Common goals for the interaction and the work needed should be planned in sufficient detail prior to the start of the programme.

- Sufficient attention should be paid to planning the involvement of external organisations (e.g. activities with the IAEA and NEA but also with non-European programmes) and of external projects to ensure that the mutual expectations are met. This needs to respect that Europe creates own critical capabilities, not to be dependable on non-EU programmes.
- In most WPs, the use of Key Performance Indicators (KPI) was not done carefully enough; their effectiveness as management tool was limited. That means that the KPI's needs to be both quantitative and qualitative. Thus, there is some room for improvement.
- In most WPs the involvement of end-users was limited and normally not formalised. It is recommended that in future the involvement of end-users should be formalised where the end-users have the formal responsibility to provide feedback during the ongoing work ('participatory review' to provide timely feedback to immediately initiate corrective actions if needed). Ideally, the end-users involve both generalists (that can put the findings in a broader context) and specialist (that are able to also comment the scientific details) or a very technically knowledgeable generalist.

In many WPs there were significant difficulties to find qualified reviewers that were available at the time they were needed; this also needs better planning.

The reporting by the WPs (in addition to the contractual annual work plan) was limited to a formal interim progress (IPR) report to support the overall project management on a high technical level. The results were, however, of very mixed quality; sometimes very poor, sometimes copy/paste from one year to the next. Besides their scientific competence, the WPLs need to have the administrative capability and sufficient interest in doing also this work properly. A stronger formalised involvement of the PMO contact for the WP in the writing of the IPR might help. Also, on the PMO level, the IPR has not really be used to trigger collaboration between the WPs. It shall be more used to organise exchanges and to provide information from one WP to another. In EURAD, the WPs were strongly hindered by COVID-19, but cost-neutral extensions were possible that allowed most of the WPs to produce the deliverables according to the initial planning. This shows the value of having the power with joint programming to make these changes.

- It is encouraged that each WP has a WP leader and a co-leader as there are many WPL duties such as interaction with other WPs and with international knowledge providers, producing training material, and State-of-Knowledge documents, surveys on progress, WP meetings and workshops.
- The long-term storage / archiving of the information developed is not decided and will require a near-term action.
- Data base handling (mainly of all data generated in R&D and StSt WPs) was addressed, but not implemented to a satisfactory level.
- Any programme depends on input from the end-users which means interactions with end-users, either in-person (expensive) or through surveys and questionnaires. In EURAD the response rate from end-user organisations is low which is far too low to steer a programme. In order to increase the response rate, it is proposed to agree with the surveyed organisation on the number of questionnaires per year, the subjects and when in the year they are planned. Such agreement leads to higher response rate, more representative answers and increased end-users' involvement in the programme.

3.1 R&D WPs

Below, the achievements of the R&D-WPs are briefly summarised.

3.1.1 ACED

ACED (Assessment of Chemical Evolution of ILW and HLW Disposal Cells – R&D) looked at and addressed the processes at the interfaces in ILW and HLW near-field systems of deep geological repositories (DGRs) with a combination of focused experiments and modelling studies. With these activities, ACED provided a lot of valuable models, information and insights on the nearfield evolution for relevant systems.

3.1.2 CORI

CORI (Cement-Organic-Radionuclide-Interactions – R&D), looked at and addressed the system (radionuclides – cement – organics), but also the 'sub' systems (cement – organics; cement – radionuclides) with a broad spectrum of experiments providing a lot of additional information and understanding confirming the broad conclusion that '*organics can't be ignored*'. Because of budget restrictions it was not planned to perform systematic modelling studies using the new data. Overall, the WP provided much insight and excellent data for assessing the potential impact of organics containing wastes on the safety of repository systems, and also for future modelling activities.

3.1.3 DONUT

DONUT (Development/improvement of numerical methods & tools for modelling coupled processes – R&D), looked at and addressed a broad spectrum of methods and tools, highlighting the importance of numerical models for waste management. It looked at the 'full' story (coupling, different scales, artificial intelligence / machine learning, ...) with making the 'added value' of the deliverables (incl. open-source codes) of WP for waste management well visible, demonstrating the importance of numerical models in radioactive waste management. A dedicated effort was made to discuss 'digital twins' in a broad and well-coordinated effort with the conclusion, that 'digital twins' (and KI, machine learning) are expected to be upcoming issues of high importance for waste management.

3.1.4 FUTURE

FUTuRE (Fundamental understanding of radionuclide retention – R&D) looked at and addressed several barrier systems, successfully building upon mechanistic understanding of radionuclide-retention ('bottom up' approach) both in clay and granite systems and provided a clear connection to application – a directly applicable methodology and demonstrated expertise in safety assessment. The WP produced a lot of new high-quality data, with one of the important conclusions being that sorption competition and redox reactions at interfaces are important issues and should be considered in safety assessment. The WP confirmed that the 'bottom up' approach followed over many years is a great success!

3.1.5 GAS

GAS (Mechanistic understanding of gas transport in clay materials – R&D) looked at gas transport through clay materials – a complex issue, with understanding the 'gas issue' being an evolutionary process that started many years ago. A 'full model' is not yet feasible. Thus, the approach taken relies on process-level models and 'visualization' that are combined with comprehensive 'story boards' and thus provide the 'elements' to build up a convincing chain of arguments to assess the impact of gas and to define 'gas-related' requirements. Furthermore, the WP has developed input to sample handling and experimental protocols for future experimental work.

3.1.6 HITEC

HITEC (Influence of temperature on clay-based material behaviour – R&D), looked at and addressed a highly relevant topic – the optimization of repository design for SF/HLW. The synergies in the work between clay-based buffer material and clay host rocks turned out to be smaller than originally expected. Modelling tools are now available that are adapted to higher temperatures for system-specific applications.

3.1.7 SFC

SFC (Spent Fuel Characterisation and Evolution until Disposal – R&D) provided experimentally verified procedures to reliably determine fuel properties for managing the fuel prior to disposal. It was possible to reduce the uncertainty of heat producing radionuclides in spent fuels and their vectors for optimisation of spent fuel canister loading, to improve the understanding of the behaviour of spent fuel rods / assemblies during prolonged interim storage, encapsulation, transportation, and emplacement in the repository. Furthermore, also the impact of postulated accident scenarios has been taken into account. With this, the information needed to safely manage the fuel until it has been emplaced in a disposal facility has been extended. A strong interaction with the IAEA working group on the Nuclear Fuel Cycle options and spent fuel management (TWG-NSCO) and the OECD-NEA group on SF decay heat has been established. Furthermore, results from this WP have been presented at OECD-NEA to the “SFCOMPO Technical Review Group” with an effort ongoing to include also Decay Heat data into the SFCOMPO database.

3.1.8 ConCORD

ConCorD (Container corrosion under disposal conditions – R&D) was despite its short duration of only 3 years able to cover with focused experiments and modelling a broad spectrum of issues, leading to new scientific insights (corrosion (impact of irradiation, microbes), sealing of ceramics, ...) and very valuable material e.g., for use in performance assessment. This was possible because of the strong participation in the WP and the support provided by a formal 'external' review group.

3.1.9 MAGIC

MAGIC (Chemo-mechanical aging of cementitious materials – R&D) addressed in multidisciplinary approach a broad range multiscale and upscaling issues, filling the gap in the understanding of the long-term physical integrity of underground cement constructions considering chemo-mechanical evolution (effect of carbonation, sulphates) and impacts of microorganism. The WP relied as far as possible on existing experiments. Significant progress has been made; a good starting point has been reached to continue in a future project.

3.1.10 MODATS

MODATS (Monitoring equipment & data treatment for safe repository operation & staged closure – R&D) looked at existing experiments using artificial intelligence and machine learning as new elements. Then, some improvements in technology and tools (including data management) have been made. This provides the means to collect highly relevant data that are also of strong interest to civil society.

3.1.11 Conclusions

- The R&D WPs created a large amount of cutting-edge science. All WPs produced a significant amount of new data and insights in the studied mechanisms.
- Unfortunately, the visibility of the novelty of this information is often not that well described. Ideally, it should become clear whether the work in the broad sense confirmed earlier understanding with some nuances having changed or if some issues at a ‘high level’ have changed that could – depending upon the system looked at – be of significant relevance for a disposal system.

- To improve understanding the importance of the work done in the past and the contribution of the work done in the project, all R&D WPs developed State-of-the-Art reports (SotAs) at the start of the programme and an update at the end of the programme including the important new experimental findings. These reports are an excellent source of information, and also put the new results in context. Some SotAs will be published in the open literature to improve accessibility.
- An issue of high importance is the documentation and quality assurance related to the detailed scientific work as the results generated in the R&D WPs will most likely be used by many programmes and be a long-lasting building block of (future) licensing applications and thus, traceability of the results and their quality will be an important issue for a long time.
- The R&D-WPs have made a significant contribution to educate the young generation with more than 105 PhDs / post-docs / master students in the waste management field, financed by the programme.

3.2 Strategic Studies

The strategic studies WPs represented a think-tank activity on important actual issues in radioactive waste management, addressing representatives of all Colleges, many Member States and civil society representative.

3.2.1 ROUTES

ROUTES (Waste management routes in Europe from cradle to grave - StSt) looked at a broad range of issues, including issues of high importance for small inventory Member States (SIMS), e.g., shared solutions, waste acceptance criteria (WAC), managing challenging waste, etc. Thus, the voices and the needs of SIMS are now better heard and seen. The interaction with civil society increased the mutual understanding and trust. The WP was also used to identify R&D needs as input to the update of the strategic knowledge and research agenda (SRA) to also incorporate the views of SIMS.

Overall, ROUTES did provide an excellent platform for exchange and learning (value of cross-cutting participation).

3.2.2 UMAN

UMAN (Uncertainty Management multi-Actor Network - StSt) put the main emphasis on a pluralistic view on uncertainty management with also involving civil society to better understand the different views on uncertainty. As part of the 2nd wave, the scope of UMAN was enlarged to also include the nearfield in the study. As planned, no work was done on mathematical / statistical approaches to uncertainty management; the main emphasis was on the pluralistic view.

From the point of view of the CSOff, using a pluralistic view provides important added value. However, using this approach for addressing uncertainties, it is very important to make sure that the issues raised are clearly defined and are treated correctly and thus require people that have the necessary expertise in the issues raised. Otherwise, the discussions may lead to differences in views that are not based on a 'solid scientific evaluation' but more related to different 'feelings' / 'beliefs' having no or only a limited scientific basis.

Overall, the WP highlighted the differences in views of the different actors (e.g. on implementation uncertainty)

3.2.3 Conclusions

- The instrument of ‘Strategic Studies’ could have been more extensively used with the possibility to have projects of shorter duration and with a smaller budget.
- Strategic Studies should be more widely used as ‘think tank’ activities to elaborate on emerging issues to find out whether there is a need for more comprehensive studies / projects; such work should be done within a few years not the whole duration of the programme.
- One can use Strategic Studies also in a different manner. They can be used to provide a platform for interaction to learn from each other, covering a broad theme that consists of a range of topics as it has been done in ROUTES to also support the knowledge transfer from advanced programmes to early-stage programmes.
- The experience with Strategic Studies indicates that in some cases an agile work package with actors allowing to influence the work and with involvement of subject matter experts can provide the information is a good way to work.
- The link between the Strategic Studies and the overall programme of EURAD needs to be improved. The interactions between Strategic Studies and R&D WPs need to be clearly defined at the start of the programme.
- The Strategic Studies allowed the participation of some organisations which do not have a large taskforce. They were also largely used by less advanced programmes to communicate their vision and needs.

3.3 KM WPs

Knowledge management programme to support the EU Member States in their timely delivery of safe disposal solutions, that consists of the following elements:

- A Roadmap that briefly describes the phases and themes / domains of relevance for the implementation of disposal solutions.

With that, the roadmap provides a structure and context to clearly see which themes are, when and why, of importance for repository implementation and to understand the interactions between the different themes. This structure and context support the integration of the knowledge available in the national programmes and it also helps to identify the key capabilities (competencies & infrastructure) needed in the national programmes for a successful disposal implementation. Furthermore, the State-of-Knowledge (SoK) documents, produced in the WP11 (SoK), are inter-linked with the Roadmap and give recommendations on knowledge gaps, available training courses, guide documents as well as existing networks.
- For each of the themes/domains, the SoK document captures the available knowledge and signposts to key references in a hierarchical structure, is an issue that will take considerable time. Within EURAD, only a 40 out of 80 SoK has been made and that activity needs to be continued.
- Guidance documents has been developed for implementation issues important to early and middle-stage programmes. To identify guidance gaps, a review on existing guidance was made. The most recent guidance documents have been prepared with the direct involvement of end-users.
- Finally, a programme with training and allowing for mobility has been performed. To access these KM activities and complementary students’ relevant information (such as EU infrastructures, list of PhD students, recordings of webinars, upcoming trainings, conferences, workshops, etc.) the “EURAD School of Radioactive Waste Management” has been created.

This programme was complemented with a number of webinars (Lunch & Learn) and events directed to the EURAD students' group.

These activities are a start to support the knowledge transfer between programmes (from advanced programmes to early-stage stage programmes) and between generations and also provide important elements for educating the young generation.

3.3.1 KM SoK

SoK (State-of-Knowledge - KM) worked on the structured representation of up-to-date knowledge to provide context (link to roadmap, hierarchy in documents), prepared information (roadmap & context) and documents (Theme Overview descriptions, Domain Insights, SoK reports) and investigated the possibilities to ensure accessibility of knowledge (collecting experience, a web-based system is under development). The activities have to be seen as a successful start to collect and to make knowledge available to the Member States and future generations – this has to be continued and regularly updated to ensure 'long-lasting added value'.

For capturing the current understanding, it might in future also be worthwhile to use the comprehensive documentation from recent license applications for signposting to the key documents for the different themes of importance for these projects.

3.3.2 Guidance

Guidance (KM) made a careful selection of themes for developing guidance (based on a thorough review on existing guidance), developed some guidance documents with experiencing a learning curve in developing such documents that showed the importance to involve end-users in the development from beginning (broad participation). This led to the conclusion that producing guidance together with future end-users is the 'way to go'; this could also result in networking and creation of 'communities of practice'.

3.3.3 Training & Mobility

Training & mobility (KM) organised a programme of training courses and training material, based on a survey investigating the end-users training needs, and on an oversight developed on available training. This resulted in establishing a number of training courses (all of them positively rated – Appendix C) and training material (Appendix B). For the training, a platform for learning (School of radioactive waste management) with different instruments for different target groups is implemented.

Furthermore, a mobility programme was launched that allowed 'learning by doing' by visiting experienced institutions with corresponding infrastructure; the mobility programme was hindered / limited due to COVID but turned out to be used effectively with 79% of the planned funds used. (Appendix A)

Finally, a broad programme 'lunch & learn' was offered that found broad interest (Appendix D).

The School of RWM has demonstrated remarkable success across most of its four main pillars ((i) courses and webinars, (ii) Mobility Programme, (iii) panorama, and (iv) supporting the PhD Community), positioning itself as a valuable resource for end-users. It has proved itself to be a valuable resource in competence building with the European RWM community (and beyond). Furthermore, it actively contributed to EURAD's KM Programme by ensuring heightened awareness of KM principles.

In future, this type of WP activity might be used to implement 'communities' of practice', as these are important for developing expertise.

3.3.4 Conclusions

It is very important to remember that KM is more than just documents, the exchange between persons makes the differences; thus, in future there is a need for something like 'communities of practice' that ideally are kept active without external support. This also clearly shows the importance of continuity in KM.

It can be summarised that a number of components have contributed to a useful KM programme, such as:

- KM strategy and a programme that is embraced by all programme participants.
- Full and sincere engagement on practically all EURAD levels (European Commission, Bureau, Programme Management Office, External Advisory Board, Work Package leaders and task leaders as well as support from end-users and stakeholders) to KM activities.
- Access to subject-matter expertise (both programme internal and external).
- Handling of the presentation materials produced within each R&D WP should have got a better visibility as it complements the scientific papers and reports (e.g. State of Knowledge documents, EURAD R&D deliverables, SotA),
- Sufficient budget (not only for the KM WP, but also budget to engage top-level experts for State-of-Knowledge document production, guidance and training activities).
- Knowledgeable and flexible KM WP leaders that takes own initiatives and tests new methods/activities, thus developing and enlarging the KM activities.
- Coordination with other knowledge providers (national RWM organisations, IAEA and OECD/NEA).
- Students' engagement in the KM programme and its development.
- Handling of all R&D and Strategic studies (raw)data could have been better structured:
- Dissemination and socialising the R&D, Strategic Studies and KM outcomes/deliverables are not the end point of a joint programme, but rather the knowledge and networking /Community of Practices (CoP) formed during the programme and the joint/mutual increased knowledge base.

3.4 Conclusions

With these WPs, a large number of deliverables have been created. All WPs contributed to the creation a lot of added value, such as:

- The RDD-WPs did bring the experts and responsible organisations together to develop cutting-edge science and technology (deliverables with excellent new findings and SotAs to provide an overview and to give context).
- Strategic Studies provided suitable platforms for discussing and clarifying important issues (think tank activities) and for information exchange and transfer of knowledge (deliverables with insights and building up 'network').
- Knowledge management & knowledge transfer with the Roadmap providing a 'structure' and context for starting the mapping knowledge (theme descriptions, domain insights, a few state-of-knowledge documents); with developed guidance documents, some of them with involving end-users (resulting in a (temporary) 'community of practice'), by providing training (incl. material for future use) and allowing for mobility to see and learn from other institutes / organisations.
- The WPs made a significant contribution to maintaining competences needed by educating new professionals in waste management by working in different work packages (MSc students, PhD's, Post Doc's), by making participation in trainings possible, by supporting mobility, by having a 'network' and providing 'lunch & learn' sessions.

- Cooperation of the three Colleges and involvement of civil society has been successfully implemented leading to increased mutual understanding and trust through increased cooperation and information exchange.
- Some of the WPs used the interaction with IAEA / NEA and other projects / programmes to have access to other people and information (needing explicit planning), including having end-users from external organisations, to summarise, EURAD created significant impact through the following 'channels':
 - Platforms with discussion with more than 920 dissemination actions including presentations at conferences and workshop, 31 Lunch-and-Learn sessions and 14 civil society events.
 - Informing the 'external' world with more than 430 publications, 10 state-of-the-art reports.
 - Educating and 'learning by doing' with more than 140 PhD students master students, Post Doc's with overall about 900 individuals involved in the EURAD WPs.

4. A platform for interaction and networking

4.1 Elements providing a platform for interaction and networking

The following elements of EURAD provide the opportunity for and contributed to interaction and networking among the European RWM actors:

- The concept of involving the main RWM actors in the form of the three Colleges (WMO, TSO, RE – with mandated actors) and civil society in EURAD and ensuring their interaction and cooperation through their participation in WPs and other activities (e.g. Annual Events),
- Participating in WPs to interact and network with the other participants in that WP. This applies to all WPs, but is most pronounced in the Strategic Studies,
- Interaction between WPs, including joint activities of WPs on EURAD level,
- Being involved as end-user in one or more WPs, although this instrument was not sufficiently used,
- Mobility allowing persons (mainly young generation) to experience hands-on-training and make new contacts for interaction (incl. learning) and for later networking,
- Training providing an excellent platform to build up a network with persons interested in similar topics,
- Developing guidance with active involvement of end-users,
- Annual Events with broad participation, including the young generation,
- A high degree of international dissemination of R&D results, Strategic studies and KM activities at international conferences and workshops, thus placing EURAD as an actor on the international RWM landscape.
- Having DG-RTD, DG-ENER, DG-JRC as observers in the EAB, providing the possibility to discuss and interact also with the Coordinator and the CSOff being involved.

4.2 Added value by using the EURAD platform for interaction

The platform provided by EURAD for interaction and networking was used, though with different 'intensity':

- Interaction through the Strategic Studies-WPs (especially ROUTES) was an excellent platform for the SIMS / early-stage programmes to get an overview and to build up a network.
- Interaction through the Strategic Studies-WPs and R&D WPs was an excellent platform for the interaction between Civil Society and the other participants of EURAD.
- Interaction with end-users within some WPs would be an excellent opportunity to interact but was not used as much as wanted.
- Interaction between the different WPs was not everywhere as strong as wanted, as it was not included in the programme of work of the first wave WPs. Nevertheless, some excellent interaction and cooperation did take place, especially for the second wave WPs.
- The interaction with international organisations (EC, IAEA, NEA) and the invitation to some of their meetings and to participate in some of their groups allowed to cooperate on several issues. Several of the interactions took place on an 'ad-hoc' basis (also taking advantage of personal contacts); this should be better and more formally planned in future.
- The meetings of the EAB with the observers from DG-RTD, DG-ENER and DG-JRC were an excellent opportunity to exchange information and ideas also with the coordinator and the CSOff being involved. However, time often did not allow to discuss the different issues in more detail.
- The possibility to participate in EC meetings (e.g., the 'Euratom Scientific and Technical Committee (STC)', the 'Programme Committee of the Research and Training Programme of the European Atomic Energy Community', the 'Atomic Group', the 'Nuclear Back-End Financial Aspects expert group (NuBaFA)) allowed to raise the profile of EURAD and to make the added value of EURAD better visible.

5. Added value provided by EURAD

5.1 Achievements and added value for the EURAD communities

Below, the input and comments applying to all communities (Colleges, and Civil Society) are summarised in the format of bullet points:

- With EURAD, the European Commission has created a highly visible and potentially long-lasting programme of European research, development and knowledge management in the area of radioactive waste management.
- The established framework provides added value as it clearly defines the roles of each of the Colleges. Above all, it allows beneficiaries to steer the programme, form a view on issues / to take a decision on issues, agree on a EURAD Strategic Research and Knowledge Management Agenda (SRA), etc. This is an important change in the EC-supported RWM strategy and a cornerstone for the functioning of EURAD.
- EURAD has shown, that with adequate governance, joint activities are possible with the TSOs and the WMOs maintaining their independence (as independence does not mean isolation); this 'lesson learned' could probably also be applied to regulators wanting to participate in joint programmes.
- EURAD has shown to be able to integrate both more and less advanced national programmes for mutual benefit. It supports EU Members States in their responsibilities relative to the European Council Directive 2011/70/EURATOM.
- The instrument of having the Bureau to manage the interaction of the WPs and the Coordinator/PMO with the Colleges has proven to be effective; with this, the actual interaction

and cooperation has become possible. It should be checked if some modifications could make the management easier.

- The integration of Civil society has been possible, with Civil Society applying the ‘double wing’ model for their involvement. A clarification on the representativeness of civil society representatives might be useful.
- To have different views and perspectives by working together provides a lot of added value – EURAD has successfully brought the Colleges together, and also included the Civil Society in the interactions.
- However, in future one should try to develop some joint position papers by the Colleges together to better position radioactive waste management and especially deep geological disposal.

For example: there is agreement that ‘there are solutions for DGRs, but this conclusion is site- and system-specific and needs a case-by-case assessment’. There is agreement that this message should get better visibility.

Position papers should not only address the waste management community but as well general public and/or scientific audience at large etc.

- Bringing the Colleges together gives more resources (EURAD experts together see more), including access to each other’s infrastructures and avoids duplication of work.
- An integrated programme gives ‘added value’ (applying different instruments (RD, StSt, KM), the step from competition to cooperation is beneficial for all,
- There is broad agreement on the importance of knowledge management that includes education of new people, the preservation and accessibility of information (incl. SotAs.), training to transfer knowledge, etc. with the importance of State of Knowledge (SoKs) documents to provide the big picture being broadly acknowledged.
- Knowledge management cannot cover everything; it is important to explicitly decide about what should be included. But the question of prioritisation remains.
- Knowledge transfer between countries needs to be organised, considering the complementarity and needs, i.e. choosing between someone involved in EURAD or a commercial consultancy (based on a transparent business model).
- It is important and useful to have a platform to prepare thoughts about the future (next programme, long-term strategy); can this be integrated in a joint programme? Is something separate needed (like JOPRAD)?

5.1.1 Colleges – WMO

Below, the specific input and comments by the WMO are summarised in the format of bullet points:

- EURAD supports the national programmes and the discussions at the national level. It provides information for licensing, for planning the R&D, etc.
- EURAD helps to set priorities and to learn from others.
 - using the SotAs with providing input to the ‘*how good is good enough?*’
 - with the possibility to compare and to benchmark the national programme with information available from the interactions,
 - with optimisation becoming a key issue that profits from information exchange, potentially leading to joint activities,
 - and supporting both advanced / less advanced programmes with these and other activities.

- Overall improvements and optimisation are of growing importance in future programmes:
 - the usefulness (and the need) to share facilities ((URL, hot labs, light sources...) experiments also to be open for small/less advanced countries) is an issue that deserves more attention,
 - with the WMO having a central role in optimisation (not only for R&D, but also for other issues (e.g. feasibility of implementation)); their involvement in EURAD is central.

5.1.2 Colleges – TSO

Below, the specific input and comments by the TSO are summarised in the format of bullet points:

- The TSO put a strong emphasis on ensuring the involvement of civil society, which has worked out well in EURAD (UMAN, ROUTES and participation in several of the R&D WPs).
- For the TSO, Strategic Studies and knowledge management (including the SotA reports from the R&D WPs) are at least equally important as the new findings by the R&D WPs.
- For the TSO, a follow-up of EURAD is needed, that takes the lessons learned from EURAD into account. This has to happen carefully as the system of 'joint programming' is considered to be fragile (budget availability, positive participation and respectful interactions, sharing infrastructures).
- The involvement of TSO as a representative of the regulator addressing regulators issues (e.g. verification and validation of R&D, modelling) was limited and a stronger visibility of this function would have been appreciated.

5.1.3 Colleges – RE

Below, the specific input and comments by the RE are summarised in the format of bullet points:

- EURAD produced a lot of excellent science / research outputs (including SotA reports).
- There is a need to reflect more on how the results are being used and to confront them with end-users: as input for the future, learn about the needs of end-users – this provides an opportunity for the REs to be better embedded and focussed with their work at the European level.
- EURAD is more than 'DGR', it is important that a follow-up continues to look at legacy waste; integration of pre-disposal activities (as an interlinked chain) shared solutions; new nuclear, with that high amount of RWM expertise should be able to author position papers, heading for a competence hub etc. For new nuclear, what should / could be the role of EURAD?
- Knowledge management: How to organise? First and foremost, the information should not be lost and should stay accessible. Then, transfer of tacit knowledge (persons to person) makes the difference. Finally, education and getting new PhDs is essential.
- Nuclear infrastructure is a precious resource; this may need a coordinated effort to ensure its availability.
- 'Specialists' and 'generalists' are both are needed, especially as specialists get more specialized.
- 'How good is good enough?' – to be addressed, taking into account:
 - scientific findings (parts with good understanding, with only limited/insignificant uncertainties),
 - scientific findings (e.g. identification of issues in themes addressed where remaining uncertainties (aleatory, epistemic) could be critical,
 - system-specific interpretation / decision-making about scientific findings, taking remaining uncertainties into account.

5.1.4 Civil society (CS)

Below, the specific input and comments by the CS representatives involved in EURAD are summarised in the format of bullet points:

- Civil society successfully used the ‘double wing model’ with experts and larger group.
- CS representatives organized 16 workshops, participated in 28 other events, contributed to 13 deliverables and to many milestones and provided support to training and Lunch-and-Learn.
- Based on the experience made, the CS participants concluded that the Aarhus Convention can be implemented; involving the CS works for the full knowledge chain (creation, use, conclusions). Making the CS concerns and views visible is important as this leads to an improved mutual understanding.
- CS participants conclude that openness and transparency exist within EURAD.
- Involvement of CS is considered a critical element by the CS participants, also to express issues that are critical for society (e.g. safety culture).
- Replacements of CS participants in the course of EURAD turned out to be a critical issue.
- Involving CS works, for EURAD-2 a stronger involvement and better linkage to ‘local’ is planned.

5.2 Member States

The input presented below is a direct extract from the presentations made during EURAD final event. During this event a strategic session about the main achievements and concrete examples of how EURAD help Member States gathered speakers from different Member States.

5.2.1 Member States – general

Below, the general input and comments by the Member States are summarised in the format of bullet points:

- EURAD supports national programmes and national discussions by providing information for licensing, input to the planning of R&D (provides input to focussing), etc.
- Even if there is a natural division of MS needs depending on the phase they are in, some guidance could be helpful by dividing the MS in early, middle and advanced programme (one could use the Roadmap and pinpoint what is missing the MS), thus more efficiently and optimally use the scarce EURAD resources.
- It is important and of high value to have results through EURAD that are broadly discussed and reviewed.
- The interaction with and hearing from others by participating in EURAD gives confidence to be on 'right track'.
- Being part of such a big network, as provided by EURAD, gives confidence also at the political level.
- EURAD supports the interaction at the national level (mandated actors, linked 3rd parties – but concept of 3rd linked parties increases the administrative burden for the mandated actors)
- EURAD also contributes to an organisational culture of collaboration and of mutual sharing of information at the national level.
- WPs broadly discussed within EURAD are of direct relevance, but this still needs discussions at the national level (within the different organisations).

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- EURAD should strengthen the involvement of end-user (also as reviewer).
- Differences in needs exist (and should be acknowledged) but this does not prevent to agree on having all needs on the list and to work together.
- The role of training courses & networking provided by EURAD to hear and to learn (also about the deliverables) is very important, and also supports the students by providing them with contacts.
- The transfer of knowledge (from advanced programmes to the other) is not limited to KM activities, but it also occurs through involvement in WPs (learning by doing); this, however, must allow newcomers to participate in corresponding WPs.
- EURAD is also important for the regulators to get the information as it helps to maintain / develop their needed skills, competences and attitudes.
- The continuation of EURAD is important; continuity provides stability for planning (as source of knowledge), continuity is essential for knowledge transfer (young generation) and gives confidence to the public.
- It is important that the future EURAD programmes are focussed on R&D, StSt and KM, but also on future methodologies and techniques, such as artificial intelligence, deep learning, machine learning, digital twins and virtualisation of processes, to promote disposal implementation and attracting the young generation to RWM and retain them.

5.2.2 The special situation of the small inventory Member States (SIMS)

Below, the specific input and comments by some 'small inventory' Member States are summarised in the format of bullet points:

- SIMS need (and have to develop) safe solutions for all elements of waste management and this has to be managed by small organisations; thus, taking advantage of existing information and knowledge is essential.
- It is not clear at the creation of the programme what the SIMS expect from EURAD and what they directly need from EURAD. This should be addressed and clarified on a high-level (ministry) prior to engage in EURAD.
- The SIMS also have to manage the change in focus (decommissioning → interim storage → managing legacy waste → disposal solution): managing personnel and competencies in such an environment is a challenge. Again, taking advantage of existing information and knowledge is essential.
- For SIMS it is important to have advanced WMOs in EURAD; this provides valuable input / support when exploring technical disposal solutions.
- For SIMS it is important to learn about and have access to competence clusters (strength of having the Colleges). Networks (like ROUTES) are highly valuable, e.g. for investigating solutions as SIMS often have only a very limited workforce.
- Efficient knowledge transfer to SIMS will to some extent rely on services provided by the advanced programmes; to accomplish this in a fair and balanced manner.
- DGRs are often not the dominating issue for SIMS, the priority is with shallow/medium depth disposal. Disposal at depth (for very minor amounts of SF/HLW, 'special waste') should ideally be done through a shared solution or otherwise by deep boreholes.
- Shared solutions are also highly important for pre-disposal management.

- EURAD is highly relevant for SIMS as platform for exchange of information for sharing of information. However, as many things go in parallel, it can be difficult for smaller programme to follow everything. Then comes also the question: How to find the relevant information?

6. Conclusion

Step Change in European Cooperation

Joint delivery of research, strategy development and KM activities within EURAD is a huge step forward in facilitating collaboration, exchange, learning and dissemination. Joint programming supports a balanced prioritisation of work addressing common needs identified through the joint strategic research and knowledge management agenda. Implementing the three Colleges, together with a coordinating Bureau with equal membership across the Colleges, has enabled the perspectives of different Actors involved in waste management, including Waste Management Organisations, Technical Safety / Support Organisations, Research Entities, and Civil Society Organisations to be explicitly represented in a balanced manner. This also included cooperation with the complementing PREDIS project involving the waste generators (NPP owners) and international organisations such as the IAEA and the OECD/NEA. The breadth of national programmes involved has increased compared to previous EC projects, including Small Inventory Member States (SIMS) and Early-Stage Programmes (ESPs). Joint programming has helped to maximise the value of EC co-funded work to these programmes, by facilitating cross-cutting participation. Representation of SIMS and ESPs on the Bureau alongside Large Inventory Member States and More Advanced Programmes promotes a balance of viewpoints informing joint programme governance.

Implementation of radioactive waste management activities in EU Member States

EURAD has contributed to the responsible and safe management of radioactive waste in Europe, including advanced programmes, which will soon start operation of the first geological disposal facilities for high-level and long-lived radioactive waste / spent nuclear fuel. The advanced disposal programmes have set clear leadership in communicating their expectations as end users and have actively contributed to delivery and following work and using outputs as well as advising on improvement, innovation and development of science and technology for the management and disposal of other radioactive waste categories.

Public confidence and awareness in radioactive waste management

The diversity of viewpoints contributing to key scientific challenges in waste management has been strengthened further by increasing links to regulators via the TSO College, reaching out to nuclear fuel producers and/or waste generators through the sister EC PREDIS project, and broadening the participation of non-EU partners with associated countries (Switzerland, Ukraine, United Kingdom) and other countries (Japan, Canada, Australia). Communicating and exchanging on EURAD scientific results across the different work packages, as well as translating the scientific output with appropriate context on how the work fits into wider radioactive waste management (RWM) perspective has been seen as a positive development. The impacts of this have extended to working closely with civil society organisations, fostering transparency, credibility and wider engagement on scientific excellence.

Innovation and optimisation

EURAD has supported the development of solutions for different waste streams and types with results available that can support the continuous improvement and optimisation of waste management routes and disposal solutions, including identifying needs and technology options specific to small inventory programmes with their particular challenges with respect to access to critical mass of expertise in developing appropriate disposal options. Through the establishment of EURAD as a platform for

networking and a marketplace for all key actors operating in radioactive waste management, organisations have provided feedback on how engagement with EURAD has supported development of personnel, impacting their agility to respond to national programme needs.

Scientific excellence

Across all the work undertaken it is reinforced that scientific excellence, not only excellence in scientific research, but also in all the activities implemented through Joint Programming, will support the credibility of results and contribute to the advancement of radioactive waste management in Europe. The governance structures of EURAD have strengthened the quality of European funded R&D outputs through a robust quality assurance and peer review process applied to all deliverables. The implementation of a Chief Scientific Officer who is an industry figure head with a wide breadth and expert knowledge to provide independent assurance across all work activities, has added greatly to the oversight of the work being delivered against EURAD objectives and the needs of national programmes. The outputs of the EURAD work packages have made a major impact on their research areas beyond the immediate programme, which has been demonstrated by the large number of conference proceedings, journal publications and technological advancements, resulting in an increase in the international profile of European radioactive waste RD&D.

Challenges and evolving regulatory concerns

Strategic studies in EURAD have provided a valuable forum for exchange and learning from experience. These, and other, forums for exchange on dedicated topics (including the planning of future work and development of a joint Strategic Research Agenda and Roadmap) have helped consensus building exercises to prioritise future work that will contribute to emerging needs.

Knowledge management

EURAD has provided an opportunity for less advanced programmes, and particularly those in an early stage of geological disposal programme implementation, to benefit from the cross-European fertilisation in radioactive waste management. EURAD, through the Roadmap, has signposted to existing knowledge that can be accessed internationally by capturing tacit knowledge of industry experts and building Communities of Practice across multiple domains, many of which may be sustainable beyond the lifetime of the joint programme itself. Through the training and mobility programme the efficient use of the RD&D resources at the EU level has been fostered, enabling peer-to-peer mentoring, benchmarking of toolkits, and sharing and advancing existing knowledge, facilities and infrastructure rather than repeating and duplicating efforts. Most importantly, the EURAD programme has fostered a better transfer of knowledge across generations of experts, with over 140 PhDs, post-doc and MSc students and 300 hours of training, 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 timespans.

Ongoing evaluation of EURAD results by EU Member States and Programme Owners

Finally, EURAD has not intended to replace National Programmes, rather it has demonstrated successfully that 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' National Programmes are organised and funded independently, and their participation in EURAD (and in EURAD-2 which will start in October 2024) is the responsibility, and at the sole discretion, of each national RWM programme owner. By mandating organisations to participate, Member States demonstrate that the European Joint Programme has an EU-added value beyond their National Programme. As the final deliverables of EURAD are now completed, it is the responsibility of the National Programmes to evaluate outputs and results with respect to their own needs (towards implementation).

The added value of EURAD can be summarised as follows:

- providing a framework and a platform ...

- with the **Member States** with their experts taking advantage of having a platform to interact and learn about possible work to be done (documented in an **up-to-date SRA**).
- where the **Member States** with their mandated actors jointly propose and **develop the WPs** to be addressed with the help of the **Colleges** and their experts (sometimes in cooperation with **international organisations**) and where appropriate with involving **Civil Society**
- making existing knowledge available and **generating needed new knowledge** (excellent science & the insights by strategic studies), made possible by bringing Europe's experts & actors together.
- facilitating the **use of the preserved available & newly generated knowledge**:
 - the knowledge providing the '**building blocks**' to be used by the Member States
 - the importance of **proper documentation** of the knowledge generated, e.g.:
 - qualification (significance, applicability ('operating window'), ...)
 - context
 - uncertainties (aleatory, epistemic) and its management
 - storing and maintaining the **accessibility** of this knowledge
 - with **Member State generalists and specialists** as a team having the needed scientific **competence** to understand the knowledge to assess its usefulness and to put the knowledge to be used in context to ensure its **correct use**
 - using a **suitable approach** (for early-stage programmes made available by **appropriate guidance**, that was developed in cooperation with end-users)
- contributing to the **education** by **maintaining the competences** needed:
 - PhD students, Post Docs, participating in the work (RDD / StSt / KM) – learning by doing,
 - taking advantage of training and mobility,
 - coordinated actions to ensure the availability of the needed infrastructure:
 - hot labs & analytical tools
 - light sources
 - computer centres
 - experiments in underground laboratories (URLs)
- providing a RWM platform for the young generation, to convey their involvement and general outcomes from R&D and StSt packages to the coming generations.

Appendix A. List of mobility arrangement used

Categorie	Total ▼	2020	2021	2022	2023	2024
Conferences or Workshops	34	0	0	6	10	18
Intra WP	32	2	4	8	13	5
Training courses	23	0	0	9	13	1
Cross WP mobility actions	9	0	0	3	5	1

Appendix B. List of trainings provided

	Date	Location	# attendees
EURAD Training on Multiphysical couplings in geomechanics	January 20 – 24, 2020	University of Liège, Belgium	75
Introductory course on EURAD and Radioactive Waste Management	September 14, 2020	Online	260
WP FUTURE Education & Training Event on the scientific basis and safety relevant aspects of radionuclide transport and retention	November 17, 2021	Online	50
EURAD Training Course on Safety Case Development and Review	November 28 – December 2, 2022	SURO, Prague, Czech Republic	19
Information session and discussion on the Spent Fuel State-of-Knowledge document	January 18, 2023	Online	54
Geochemical and Reactive Transport Modelling for Geological Disposal	February 6 – 10, 2023	University of Bern, Switzerland	30
EURAD Training course on Uncertainty Management	February 14 – 16, 2023	BelV, Brussels, Belgium	24
Information and discussion session on the SoK document on Containers	June 5, 2023	Online	67
Multiphysics and multiscale coupled processes in geomaterials – Focus on thermal effects and gas transfer impact on the behaviour of geomaterials	August 28 – September 1, 2023	University of Liège, Belgium	48
EURAD-PREDIS Summer School on Waste Acceptance Criteria	September 4 – 8, 2023	Rez Research Centre, Czech Republic	39
Workshop – Ukrainian experience from exercising radioactive waste management under exceptional conditions	October 16, 2023	Online	106
EURAD Training course on application of Requirement Management Systems	January 16 – 18; 2024	Mercure Budapest Castle Hill, Hungary	22
EURAD Training course on Monitoring in Geological Disposal facilities of radioactive waste	January 22 – 26, 2024	Online	95
EURAD Information & Discussion Session on IDKM	April 8, 2024	Online	71
EURAD Training course on the state-of-the-art of container corrosion phenomena under disposal conditions	April 26, 2024	Pullman World Trade Centre Hotel	2

Appendix C. List of Training materials produced by the EURAD R&D WPs.

Title	Produced by EURAD Work Package	Link to EURAD publication	Link to CORDIS database
Summary of training materials produced during the SFC WP	SFC	Link	
Education and training materials on radionuclide transport and retention	FUTURE	Link	Link
Updated training materials by the ConCorD Work Package	ConCorD	Link	
Training materials by the ConCorD Work Package	ConCorD	Link	Link
Multiphysical Couplings in Geomechanics, a focus on thermal effect and gas transfer impact on the behaviour of geomaterials	GAS & HITEC	Link	Link
Geochemical and Reactive Transport Modelling for Geological Disposal - ACED	ACED & DONUT	Link	Link
Geochemical and Reactive Transport Modelling for Geological Disposal - DONUT	ACED & DONUT	Link	Link
Training materials by WP CORI	CORI	Link	Link
Training materials of the 2nd GAS/HITEC Joint training course	GAS & HITEC	Link	Link

Appendix D. List of ‘Lunch-and-learn’ provided

Title	Date	# live attendees	# views
Synergies of EURAD with the PREDIS project addressing pre-disposal waste treatment	28 October 2020	30	101
News from the German Site Selection Procedure	25 November 2020	19	100
Celebrating 20 years of the IGSC	27 January 2021	45	46
Knowledge Management in Nuclear Organizations	24 February 2021	22	42
The IGD-TP: European waste management organisations coordinating international R&D activities	31 March 2021	19	70
The next-generation scientific research for safe radwaste management - EURADSCIENCE	28 April 2021	75	30
The ERDO Association - Steps for Sharing	26 May 2021	44	24
The SITEX Network	30 June 2021	53	29
European Commission’s Joint Research Centre activities on RWM and decommissioning	29 September 2021	51	42
The US Nuclear Waste Management and Disposal Strategy: Status and Possible Futures	6 October 2021	107	53
News on the siting process in Italy	27 October 2021	57	25
Methods of information and knowledge transfer regarding final disposal of radwaste	23 February 2022	133	40
Deep Borehole Repository of high-level radioactive waste - State of knowledge	19 May 2022	99	37
Implementation of the world’s first GDF for SNF – Status update from Finland	22 June 2022	82	39
Knowledge management in the German WMO - Origin, approach & practical implementation	29 June 2022	50	29
A pluralistic tool of dialogue on RWM: the Pathway Evaluation Process (PEP)	28 September 2022	40	62
The NEA Forum on Stakeholder Confidence	2 November 2022	47	27
The role of Knowledge Management in Civil Society	30 November 2022	23	72

EURAD Deliverable 1.17 – Evaluating the impact of EURAD

Guidance on Cost Assessment and Financing Schemes of Radwaste Management Programmes	23 January 2023	70	17
Introduction to EC projects HARPERS and HARMONISE	25 January 2023	23	24
Mission (almost) completed. Swiss proposal for a combined repository in clay rocks	22 February 2023	185	61
OFFERR - eurOpean platForm For accEssing nucleaR R&d facilities	31 March 2023	36	7
Submission of the application for authorization to create Cigéo (France)	14 June 2023	86	22
UK GDF Programme update	21 June 2023	73	14
IAEA On-Going Activities on Nuclear Fuel Cycle Options and Spent Fuel Management	28 June 2023	51	18
Beyond conventional methods: The role of ANN in nuclear waste management	27 November 2023	79	1
Tailoring the digital transition to the challenges of geological disposal in Japan	29 November 2023	26	1
Update by the CORI Work Package	12 December 2023	77	8
Plus minus what? - Uncertainty in destructive spent nuclear fuel inventory analysis	14 February 2024	53	2
Advisory Board Committee (ESK)	28 February 2024	27	5
Sensitivity Analyses in Safety Assessments for Geologic Disposal Facilities	27 March 2024	80	4

References

- [1] EURAD Vision, <https://www.ejp-urad.eu/eurad-vision>