

Capturing the state-of-knowledge in EURAD knowledge management

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Received: 14 April 2022 / Received in final form: 8 September 2022 / Accepted: 22 September 2022

Abstract. Knowledge about a wide variety of aspects is fundamental for the safe management and disposal of radioactive waste. This importance of Knowledge Management (KM) is also recognised by EURAD, the European Joint Programme on Radioactive Waste Management (RWM), which brings together over 100 organisations from different countries and backgrounds (Waste Management Organisations, Technical Support Organisations, and Research Entities). This vast resource of expertise and experience feeds into several dedicated EURAD KM programme activities. One of these activities, led by Work Package 11 State-of-Knowledge (WP11 SoK), is capturing experts' views on the current State-of-Knowledge on topics relevant to RWM and making this knowledge accessible through dedicated documents. For this, EURAD has developed the “Goals Breakdown Structure” (GBS), which provides a framework in which topics are structured thematically, as well as a hierarchy of documents that allows accessing knowledge on different levels of detail (see [EURAD Roadmap](#)). To make this knowledge available, EURAD is currently developing a Wiki (i.e., a web-based resource that allows access to knowledge and collaborative interactions) and is drafting a sustainable Knowledge Management System and other supportive KM-IT tools while already feeding the tools with content. This article gives an insight into the general EURAD KM concept, the approaches used, and the results obtained until EURAD's mid-term, after 2.5 years.

1 Introduction

The safe management and disposal of radioactive waste are urgent issues many nations face worldwide. It has been a matter of concern for many decades and will remain one for many decades or centuries. In addition to its long runtime, the safe management and disposal of radioactive waste is also a complex task, meaning that various aspects from different fields need to be considered for its successful implementation. Hence, a thorough understanding, i.e., knowledge, of many different aspects is crucial. This need for knowledge has been addressed through decades of R&D and also benefits from decades of practical experience, which has led to a vast resource of generated knowledge. The necessity to manage the already existing knowledge so that availability and usefulness can be ensured becomes increasingly pressing. As mentioned, this is even more evident considering the long lifetime of radioactive waste management (RWM) programmes, where knowledge needs to be managed over many generations. All in all, Knowledge Management (KM) is crucial

and will keep getting more important to achieve safe and feasible RWM.

The topic of knowledge management has been studied in various fields for more than 30 years, and its importance and acceptance are growing [1]. In nuclear sciences and specifically in the field of geological disposal of radioactive waste, KM is an extremely dynamic and fast-moving field that synthesises information from a wide range of disciplines. Several international organisations involved in the RWM are working to develop KM systems, e.g., the Japanese Atomic Energy Agency [2,3], the International Atomic Energy Agency [4,5], BGE [6], the EURAD programme (e.g., [7–9]), OECD-NEA [10], etc.

1.1 Knowledge Management in EURAD

The importance of KM is also recognised by EURAD, the “European Joint Programme on Radioactive Waste Management”, which aims to support the Member States with implementing the Waste Directive (EC 2011/70/EURATOM) [11]. It brings together 116 organisations from different backgrounds and countries that

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work jointly to advance safe and feasible RWM and disposal through (i) dedicated Research and Development (R&D) projects; (ii) Strategic Studies (StS), and, importantly, (iii) Knowledge Management activities. To achieve this, the ministries of 23 European countries (20 member-states + 3 associated countries) mandated 51 organisations to act as beneficiaries in EURAD. Furthermore, 62 organisations are associated as Linked Third Parties of beneficiaries, and also, there are three non-european international partners. The involved organisations are not only from different countries, but they also belong to three different organisation types, meaning that they have different backgrounds in their intrinsic tasks and responsibilities in the field of RWM. These three different categories are called the three colleges and are: (i) Waste Management Organisations (WMOs) (e.g., ANDRA, BGE, NAGRA, SKB etc.), (ii) Technical Support Organisations (TSOs) (e.g., BelV, GRS, SSTC-NRS, etc.) and (iii) Research Entities (REs) (e.g., HZDR, PSI or universities). The diversity of the ideas generated by the different colleges and their interactions are indispensable for the successful implementation of RWM. Hence, a sound mutual understanding and collaboration are highly beneficial. Having so many organisations from different countries and categories brings an enormous wealth of expertise and experiences to EURAD, a unique resource and opportunity. This combination of forces is considered as:

“A step change in European collaboration towards safe RWM, including disposal, through the development of a robust and sustained science, technology and knowledge management programme that supports timely implementation of RWM activities and serves to foster mutual understanding and trust between Joint Programme participants.” (Quote from EURAD Vision document [12])

The EURAD programme started in June 2019 with a runtime of 5 years (until May 2024) in its first funding period. It is a european joint co-funding programme, where a part of the funding is provided by the beneficiaries themselves, and the other part comes from the European Union’s Horizon 2020 research and innovation programme 2014–2018 (grant agreement N° 847593). These resources are put to work in a number of dedicated R&D projects, Strategic Studies (StS), and with a high priority, Knowledge Management activities [13,14]. Activities regarding Knowledge Management are organised in three dedicated Work Packages (WP). These Work Packages are:

- WP11 State-of-Knowledge – the work in this WP focuses on capturing and making available the experts’ views on the most relevant knowledge and associated uncertainties on topics that are important for safe RWM.
- WP12 Guidance – this WP works on developing guidance documents that are useful for national RWM programmes [15].
- WP13 Training & Mobility – WP13 deals with the development of a portfolio of training courses. For this, already available courses are taken into account and new courses initialised where gaps are identified.

Another part of the work is the realisation of a mobility programme that fosters exchange between different organisations [16].

Importantly, all three KM WPs work closely together, profiting from each other’s experiences, working in joint activities and benefiting from synergies where possible. Thereby, these KM WPs comprise the core of EURAD KM, which in turn is complemented by vital input and support by other WPs and actors, such as the Programme Management Office (PMO/WP1), the EURAD Bureau, the Chief Scientific Officer and the Civil Society Organisations in EURAD. Last but not least, the R&D and StS WPs provide an invaluable source of knowledge and experience, which is the crucial resource at the core of EURAD KM. Tapping into this resource and making it available in a useful and end-user-friendly way is the ultimate objective for EURAD KM and networking (and arguably for all KM activities). Should relevant knowledge on specific topics not be available within EURAD to a sufficient degree, this knowledge will be collected from other sources. For this, the EURAD community is again instrumental in identifying these gaps and signposting to the appropriate external sources.

The targeted end-users for EURAD KM are, in general, all persons that are involved in RWM, including generalists and non-specialists. This implies that the end-users will be from diverse backgrounds, which include, but are not limited to:

- people newly entering or transitioning to the field of RWM and/or a specific domain, such as employees of a Waste Management Organisation (WMO) or Technical Support Organisation (TSO). This can be from outside the RWM sector or moving within the RWM sector.
- The scientific community will be aided by EURAD KM in the identification of future research needs, as well as the training of new employees (see above).
- National programmes that are at an early stage and want to benefit from experiences made by advanced programmes.
- Advanced national programmes that face the challenges of generational change and need to capture the knowledge of the retiring experts.

First and foremost, EURAD KM shall serve the overarching goal of EURAD to support the safe and feasible implementation of RWM and disposal. If other end-users than the ones stated above are identified as relevant for this, they shall be considered in all EURAD KM activities. An overview of the knowledge management and networking in the EURAD programme is given in [13].

Importantly, KM in EURAD is not an isolated activity but accompanies and supports the rest of the programme. It is about creating a KM mindset within the whole EURAD community and beyond. Only by bringing in all EURAD members as contributors, not just as end-users, can the EURAD KM programme be successful. Then it has the potential to be a great success story for KM in RWM far beyond the runtime of EURAD-1 and, together with other KM initiatives, provide real tangible support for the national programmes and the implementation of safe management and disposal of radioactive

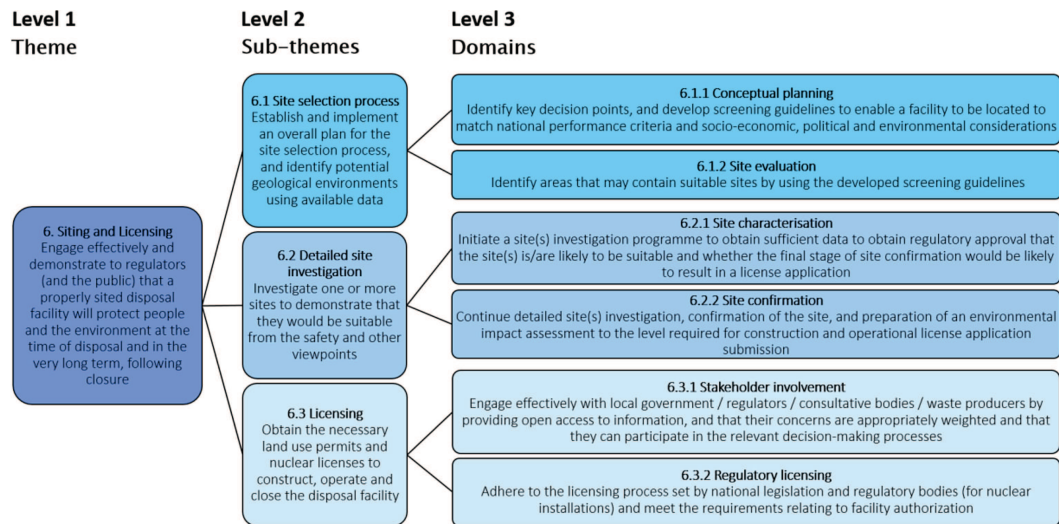


Fig. 1. Example for the breakdown of one theme (Theme 6 – Siting and Licensing) of the EURAD Goals Breakdown Structure (GBS) into the three levels (theme, sub-theme, domain) and the formulated “goals”.

waste. The contribution of the EURAD community to the EURAD KM programme can happen in a number of different ways. One important way is by participating in the production of specific documents, which capture the relevant knowledge on a certain topic and make it accessible. Participation in the production of these documents can happen, for example, as authors, reviewers, or editors and is coordinated by EURAD Work Package 11 – State-of-Knowledge (WP11 SoK). This article will give an insight into the work performed by WP11 SoK and describe the approaches, goals and first results after the half-time point of EURAD-1.

2 Capturing the State-of-Knowledge

As mentioned, many different topics need to be considered for safe RWM and disposal, such as geoscience, programme management, (radio-) chemistry, material science, civil engineering, and many more. For the work in EURAD WP11 SoK, documents for many different topics need to be produced. To do that, it is necessary to clearly define which topics need to be addressed. Furthermore, one needs to consider the scope of a topic because too broad topics cannot be handled appropriately in a single document while keeping the documents somewhat concise. This means that topics should also be broken down into suitable sub-topics. For this, EURAD has developed the so-called “Goals Breakdown Structure” (GBS). It serves as a thematic roadmap and fulfils the goal of organising and breaking down the topics relevant to safe RWM and disposal [17].

2.1 Structuring the Knowledge – the “Goals Breakdown Structure” (GBS)

The EURAD Goals Breakdown Structure is a valuable tool to structure and organise topics relevant to RWM

and disposal. It is especially important in the context of KM and other activities, such as RD&D or Strategic Studies. The development of the GBS was done in the first two years of EURAD-1 under the auspices of the EURAD Programme Management Office (PMO/WP1), with the strong involvement of EURAD internal and external experts. Topics in the GBS are formulated as “goals” rather than simple “buzzwords”, hence the name “Goals Breakdown Structure”. For example, the goal formulation for a topic, e.g., Domain 6.1.2, would be “Identify areas that may contain suitable sites by using the developed screening guidelines” instead of just calling the topic “Site evaluation” (see Fig. 1).

It should be emphasised that by design, the EURAD GBS is generic, it does not claim to be complete, and it is understood that topics and knowledge can be organised differently. Hence, the numbering and order of the topics are not a representation of their importance or temporal order. There are also inter-dependencies between topics, which need to be considered. National Programmes and individual organisations might find other ways of organising better suited for them, depending on their specific situations. This does not contradict the idea of the EURAD GBS since it is intended to serve as a useful tool in EURAD and beyond the programme, which can be used to spark discussions and encourage thoughts about how to organise and structure topics and knowledge relevant to RWM and disposal.

To achieve the breakdown of broader topics into smaller, more manageable “packages”, the GBS is hierarchically subdivided into three different levels. On the highest level, there are seven themes, namely: Theme 1 – National Programme Management; Theme 2 – Pre-disposal; Theme 3 – Engineered Barrier System; Theme 4 – Geoscience; Theme 5 – Design and Optimisation; Theme 6 – Siting and Licensing; Theme 7 – Safety Case.

On the next lower level, the 7 themes are subdivided into sub-themes, i.e., 27 sub-themes in total, and below

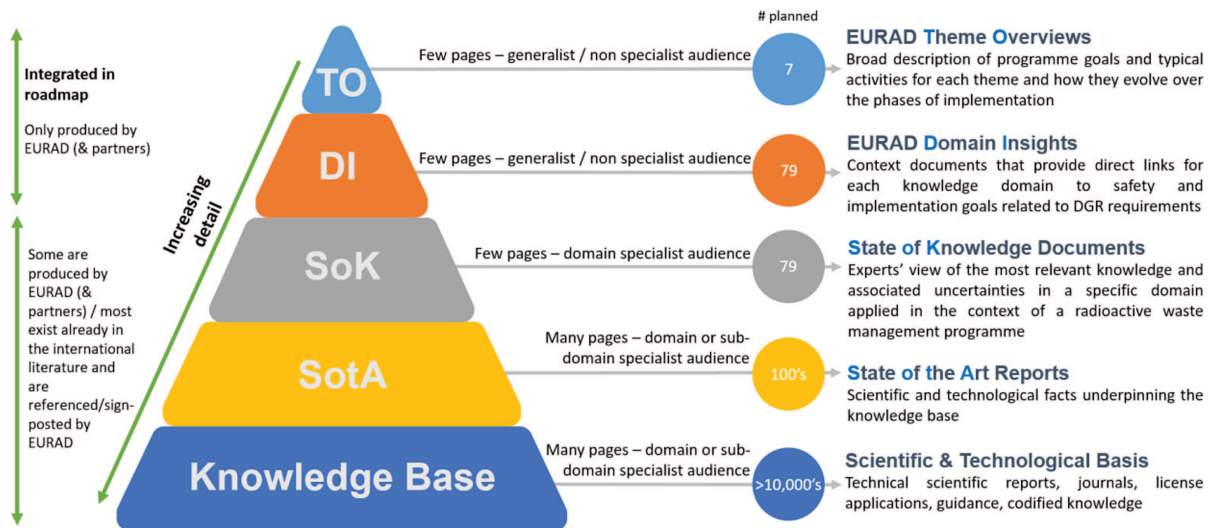


Fig. 2. Hierarchy of documents that are relevant for the work of WP11 SoK in the EURAD KM programme.

that, there are 79 domains. Hence, the domains are at the lowest level of the GBS. Should the need arise in the future, the GBS has the flexibility to add more levels or add further elements to the different levels.

The complete overview of all themes, sub-themes and domains can be found in EURAD Deliverable “D1.7 – EURAD Roadmap extended with Competence Matrix” [17]. With this GBS at hand, EURAD has a valuable tool that provides a common language and useful framework for KM. This framework now waits to be filled with content, such as the KM documents of WP11 SoK.

2.2 The types of KM documents

The EURAD KM programme can only be considered a success if it has a high level of end-user friendliness and provides a tangible benefit to the end-users. Hence, this guiding principle of end-user friendliness and benefit also applies to the documents produced within WP11 SoK. To provide the level of detail needed by different end-users, and thereby the best possible benefit, different types of documents will be produced within EURAD KM. These documents cover various aspects of one topic on different levels of detail while keeping the respective document concise. Therefore, end-users can tap into a topic on the appropriate level of detail. Beginners can start on the lowest level of detail and read their way through increasing levels, while advanced readers can start with the higher level of detail. As described in Section 2.1, the scope of the documents (i.e., the topics) is defined by the GBS.

For WP11 SoK, three different types of documents are relevant. These three types of documents are called: (i) Theme Overview documents, (ii) Domain Insight documents, and (iii) State-of-Knowledge documents. Although the documents vary in detail (with the level of detail increasing from theme Overviews over Domain Insight to State-of-Knowledge documents), scope and style, all of them have in common signposting to other existing resources and literature is fundamental. It should be noted

that other types of documents are produced in the framework of EURAD KM, such as Guidance documents, under the coordination of WP12 Guidance, Mobility Reports, under the coordination of WP13 Training & Mobility, and State-of-the-Art Reports by the R&D WPs, which all are an integral part of the EURAD KM programme.

The basic principle of the document hierarchy can be seen in Figure 2. The existing knowledge base (e.g., reports, scientific publications) is and remains crucial for thoroughly understanding RWM-relevant subjects. These EURAD KM documents can only aim at giving an overview, context and orientation to this knowledge base resulting from decades of hard work. The documents produced within WP11 SoK will also reference each other where useful, e.g., one Theme Overview will reference another Theme Overview or Domain Insight document to allow easier navigation and orientation for the end-user.

2.2.1 Theme Overview documents (TO)

The Theme Overview documents are located at the highest level of the GBS, the themes (level 1, see Fig. 1). They are designed to be concise documents (~20 pages) that give a very broad overview of the themes (see Sect. 2.1), focusing on typical programme goals and activities and their change over the different phases of a programme.

2.2.2 Domain Insight documents (DI)

The Domain Insight documents are located at the lowest level of the GBS, the domains (level 3, see Fig. 1). These short documents (10–20 pages) give information about the safety and implementation goals of the domain relevant to RWM and disposal. It further provides context and orientation to safety and implementation goals related to DGR requirements. This also includes providing links to other domains and knowledge documents. The main aim of the DI documents is to give a general overview of the domain.

2.2.3 State-of-Knowledge documents (SoK)

The State-of-Knowledge documents are located at the lowest level of the GBS, the same as the DI documents, the domains (level 3, see Fig. 1). This means they cover the same topics as Domain Insight documents but with a different scope and level of detail. Compared to DI documents, the SoK documents go into more detail about the scientific and technical aspects. They reflect the most relevant knowledge as well as uncertainties about the domain at hand, according to the expert's judgement. It should be noted that SoK documents are different from SotA documents. SoK documents are much shorter (a few dozen pages) and typically cover a broader topic, whereas SotA documents are much longer (possibly hundreds of pages) and go into more detail. Usually, a SotA will also cover a narrower topic, i.e., a specific aspect of a domain. SotA documents are an important part of the further knowledge base and are therefore signposted in SoK or DI documents.

2.3 KM document implementation procedures

All the documents discussed here have in common that they are written by recognised experts, who are asked to share their expert views on the knowledge relevant to implementing RWM. This allows us to benefit from the expertise of those who have worked hands-on in their respective fields for a long time and to capture scientifically sound content. The experts are also best qualified to judge what is most relevant, what needs to be included in the documents and to which level of detail. Defining the scope and level of detail is challenging, even with the help of the GBS. This is even more true when considering that the documents should be end-user friendly, i.e., despite their scientific excellence, they should be easy to read and concise. Hence, the availability and involvement of experts are crucial for the success of the work. This is where EURAD represents a unique opportunity due to the vast number of involved organisations and, by extension, of involved experts associated with these organisations. Identifying, involving, and supporting the appropriate experts are some of the core tasks performed by WP11 SoK, with the support of the PMO, Bureau, and the whole EURAD community. The documents undergo review by experts and the WP11 SoK team to assure factual quality and that the right level of detail and scope was found to provide end-user benefits. Furthermore, the WP11 SoK team conducts editorial work to ensure consistency between documents and end-user friendliness. The review process, editorial work, and publication (for the time being via EURAD channels like the homepage) are coordinated by WP11 together with the EURAD coordinator. For all these steps and particularly the content scope of the documents, defined quality assurance procedures and requirements are applied (EURAD, in prep.). As knowledge evolves, it is crucial to keep the documents up to date. For this, monitoring the progress in the individual topics is essential. Due to the high number of different themes and domains, the involvement of the whole community is needed to identify outdated knowledge.

3 Status of KM document production

The production of the EURAD KM documents is set up as an agile learning-by-doing approach. This means creating useful content and developing the necessary procedures in parallel. This approach offers the advantage that the results of work can be disseminated quicker than with an approach where processes and procedures are developed first and only put to work after that. By doing this, end-users should benefit as quickly as possible from work performed, increasing positive reception and participation. Furthermore, the approaches developed are put to work immediately, and therefore, problems and weaknesses can be identified immediately and rectified. This agile approach, of course, also has some downsides. Estimating schedules and resources becomes more challenging when downstream processes are not or only partially worked out.

Work on the EURAD KM documents started with producing SoK documents during year 1 of EURAD. First, a “pilot case” was conducted, followed by two “demonstration cases” (see Sect. 3.3). During the first two years of EURAD, it was realised that additional types of documents with a different level of detail than the SoK documents would be beneficial for the end-users. Hence, the concept of the Theme Overview and Domain Insight documents was developed by the PMO/WP1, considering input from experts and the EURAD community (see Sects. 2.2.1 and 2.2.2). The production of the Theme Overview documents was coordinated by the EURAD PMO/WP1. As with the other types of documents, experts were identified and involved as authors and reviewers to provide a high level of quality and relevance. The production of the Domain Insight documents was handed over to WP11 SoK in mid-year 2 (early 2021). Subsequently, efforts in WP11 SoK were to prioritise DI production over SoK production.

3.1 Theme Overview documents status

As of August 2022, six of the seven planned Theme Overview documents (one for each theme of the Roadmap GBS) were finalised and published on the EURAD homepage (<https://www.ejp-eurad.eu/roadmap>). These documents are Theme 1 – National Programme Management; Theme 2 – Pre-disposal; Theme 4 – Geoscience; Theme 5 – Disposal Facility Design and Optimisation; Theme 6 – Siting and Licensing; Theme 7 – Safety Case. The remaining seventh Theme Overview document, Theme 3 – Engineered Barrier Systems (EBS), is currently in the final phases of production, and it is anticipated that it will be published in 2022.

3.2 Domain Insight documents status

The production of Domain Insight documents was the last of the KM document types to go into production. Similar to the other types of documents, these will be written by experts. Therefore, the identification and engagement of

experts were and are at the core of the activities in the first steps. As of August 2022, experts for the production of 34 Domain Insight documents could be secured. For the domains in Theme 2 – Pre-disposal, a cooperation with the PREDIS (<https://predis-h2020.eu>) project was established, meaning that all DI documents in this theme will be authored by the PREDIS project and its associated experts. The first Domain Insight documents are planned to be available by mid-2022. However, five draft versions are already available in the EURAD internal Wiki, where they are open for comments and feedback from the EURAD community that will be invaluable input for their finalisation (see Sect. 4.2).

3.3 State-of-Knowledge documents status

For the State-of-Knowledge documents, it was decided at the start of EURAD to conduct a brief “pilot case” on Domain 3.1.1 – Spent Nuclear Fuel with EURAD internal experts available at the PMO. This pilot case was designed as a EURAD internal study and provided relevant insight into the concept and approaches to producing SoK documents. As the first fully-fledged documents, two so-called demonstration cases were planned to be conducted before the start of a broader implementation of SoK production. The two domains selected for the demonstration cases were: (1) Domain 3.1.1 – Spent Nuclear Fuel; and (2) Domain 3.2.1 – HLW and SF Containers. The rationale and the selection process of these domains were laid out in the EURAD Deliverable “D11.2 List of selected demonstration cases, criteria for final selection, proposal and estimation of effort and resources”, published in March 2020 [18]. In short, although the demonstration cases produce high-quality and highly-relevant SoK documents, it was also important that the production of the documents was feasible and relatively uncomplicated. For example, domains were to be selected where a sound scientific base exists, where multiple experts were anticipated to be available, and which were expected to be of high interest to EURAD members. As of November 2021, the SoK document demonstration case on Domain 3.1.1 – Spent Nuclear Fuel was finalised and published on the EURAD homepage [19]. The second demonstration case on Domain 3.2.1 – HLW and SF Containers is currently under production and is planned to be published by mid-2022.

3.4 Lessons learnt from KM document production

In line with the concept of agile learning-by-doing applied for KM document production, a number of insights have been gained during the production of the document types described above. These insights are not necessarily unexpected but come as a confirmation of anticipated challenges. The key lessons learnt are summarised below and are later discussed in the text:

- identification and engagement of experts for specific RWM topics are challenging.
- Integration of critical information from knowledge providers on key issues needs to display different views.

- KM implementation using the agile learning-by-doing approach requires adaptation.

Expert identification and engagement: one central pillar on which the successful production of high-quality KM documents relies, and by extension, the success of the whole EURAD KM programme, is the participation of experts as knowledge contributors, for example, as authors and reviewers. Securing the involvement of experts has proven to be challenging. The first step of this process is the *identification of experts*, which has been done mainly in two different ways (i) utilisation of networks and expertise of the WP11 members and the broader EURAD community (PMO, Bureau) to identify suitable experts (inside and outside of EURAD), and (ii) dedicated activities, such as presentations at events and a “Call-to-action” within the EURAD community, to motivate EURAD internal experts to actively volunteer as contributors.

At this step, it was realised that neither the personal networks nor the EURAD community covers the totality of topics displayed in the EURAD GBS. To overcome this, collaboration and exchange with organisations outside of EURAD needs to be extended.

Writing the KM documents requires not only in-depth scientific expertise in a given topic but also a broader view of putting things into the perspective of implementing RWM. Therefore, some researchers may not feel comfortable enough to cover the whole topic of a KM document. For these cases, it can be helpful to create expert teams that can cover different aspects of the topic, such as the scientific basis as well as the implementation perspective.

After identifying experts, the *engagement of these experts* and securing their participation follows. This step has also proved challenging, one reason being that top experts are highly sought-after persons by nature. Therefore, experts are, on the one hand, very busy, which can make it difficult for them to allocate the needed resources for this kind of work, especially if other work is prioritised for one reason or another. On the other hand, experts might choose or at least have a say in which kind of work they want to conduct. If the importance and benefit of the EURAD KM documents cannot be conveyed, this work will not be prioritised and is, therefore, unlikely to happen at all due to the tight schedules and high demand for other activities. These issues show once again what an invaluable resource and opportunity the EURAD community and its experts are. It offers the much-needed framework in which these issues of available resources and prioritisation of work can be addressed. Furthermore, having several documents ready and published is expected to trigger participation. The efforts of the experts involved as authors or reviewers need to be recognised.

To address this challenge, it is helpful to allocate resources (time and money) within EURAD Work Packages for internal experts and a sufficient budget for contracting external experts for full reimbursement of their work for the KM programme. If experts need to be contracted, as is the case of EURAD external experts, contractual challenges are not to be underestimated. Setting up a contract that satisfies the requirements of all parties involved can require a significant amount of time that

needs to be factored into the scheduling of activities. Furthermore, experts need to be provided with clear instructions on what is expected from them (e.g., what is the purpose, how does the structure of the Roadmap GBS look like, what is the benefit for RWM organisations and experts, and why should they contribute to the KM documents, what are the document contents, delivery dates and reimbursement rates, etc.) and be burdened with as few administrative tasks as possible to facilitate their willingness to contribute. The purpose of their work should be clear and well established. For this, active communication and promotion of the EURAD KM programme within the RWM community and beyond is necessary. It should also be realised that using personal networks can facilitate the involvement of experts and should be taken advantage of wherever possible. After all, it does make a difference if one is being approached by a familiar colleague or some completely unfamiliar person. Additionally, clear authorship and assignment of digital object identifiers (DOIs) would be beneficial, especially for experts from academia. If despite these efforts, an expert is not willing or able to contribute, it has proven to be a good secondary option to at least ask for suggestions for alternative experts. Usually, the experts will be able and willing to name other experts and maybe even act as the first contact to the other experts. Yet, overcoming all these issues still requires considerable effort and is not done easily. In this context, the enduring Covid-19 pandemic has not helped established networks and personal relationships across EURAD due to the cancellation of all physical meetings. Despite the size of the joint program, the EURAD community does not cover the required expertise in all domains. The domains in Theme 2 – pre-disposal are covered by experts from the PREDIS community. Further involvement of external experts is required in some other domains.

Integration of critical information from knowledge providers on key issues: other insights that were brought up during the KM document production are that there can and most likely will always be slightly different views on the scope and content of the documents. This is understandable and to be expected due to the vast number of different organisations and their different backgrounds. What might be relevant for one reader might be irrelevant to another. Consequently, it is important to collect broad feedback so all voices can be heard and a representative overview of opinions is formed when discussing specific issues and future work. At the same time, one should not assume that in all cases, a consensus can be found that satisfies everyone to a hundred per cent. Diverging or contradicting opinions are a reality in all big organisations and collaborations, which is also the case in EURAD. To mitigate this situation, it is essential to moderate the discussions and to remember to keep content on a somewhat generic level and/or cover all points of view. In this context, diverging and contradicting views should also be actively acknowledged. In fact, they can become a valuable resource of information since they might indicate a matter that needs to be addressed through R & D activities or an improved understanding of the diverging positions. Furthermore, the produced documents can

be followed by lectures from the same experts who wrote them. This would offer a discussion platform between the knowledge providers and end-users and enhance the quality of the feedback.

Agile learning-by-doing approach: it was also realised that the implemented agile learning-by-doing approach leads to its own challenges. This realisation is neither specific to EURAD KM nor surprising but should be considered for future work. Agility implies frequent and extensive exchange of concepts and progress and can make scheduling and planning of resources challenging due to the less defined nature of future activities and the higher degree of uncertainty. Undoubtedly, an agile approach brings many benefits with regard to flexibility and the time needed for first results. However, it also requires the appropriate mindset and tools, such as frequent exchange and flexibility in scheduling and budgetary questions.

Further lessons learnt will be assessed continuously, and the approach improved accordingly during the second half of EURAD until 2024. A more detailed analysis of findings will be reported in upcoming dedicated EURAD deliverables produced by WP11-SoK.

4 Making the State-of-Knowledge available

In addition to capturing knowledge through dedicated documents (see Sect. 2), these documents, i.e., knowledge, also need to be made available to the end-user easily and efficiently. To this end, one important, novel, and ambitious goal of WP11 SoK is the development of a Knowledge Management System (KMS), i.e., a systematic approach to transfer the captured knowledge to the end-users in the field of RWM. The aim of the envisaged KM system is to be not only a digital tool but also a lively instrument with which the participating actors can actively share and exchange their knowledge. To reach this target, a survey was carried out in which different organisations, all active in the field of RWM, participated and were asked about their current situation regarding knowledge management in their organisation [20]. The following 11 organisations participated in the survey: ANDRA (Agence nationale pour la gestion des déchets radioactifs, WMO, France); BelV (Belgian Agency for Radioactive Waste and Enriched Fissile materials, TSO, Belgium); CIEMAT (Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, TSO, Spain); GRS (Gesellschaft für Anlagen- und Reaktorsicherheit gGmbH, TSO, Germany); JRC (EC Joint Research Centre, RE, EU); Nagra (Nationale Genossenschaft für die Lagerung radioaktiver Abfälle, WMO, Switzerland); PURAM (Public Limited Company for Radioactive Waste Management, WMO, Hungary); RWM (Radioactive Waste Management, WMO, Great Britain); SKB (Svensk Kärnbränslehantering AB, WMO, Sweden); SSTC-NRS (State Scientific and Technical Center for Nuclear and Radiation Safety, TSO, Ukraine); SÚRAO (Správa úložíšť radioaktivních odpadů, WMO, Czech Republic).

4.1 Review of existing Knowledge Management Systems and tools

The above-mentioned survey [20] showed that many organisations already have a KMS in use. Based on already existing tools and available basic experience, these organisations are now in the process of combining these tools with new ideas to set up a suitable KMS. In this process, KMSs are based on a systemic approach involving interactions between people, processes, and technologies. However, there is a need to design such KMSs together with the respective target users and integrate them into existing systems of organisations. The KMS aim to provide assistance on how to manage distinct knowledge and information types for implementation and to ensure the sustenance and preservation of critical nuclear knowledge for safe and efficient management of radioactive waste.

All screened systems utilise methods to identify the holders of critical knowledge. Among the techniques enumerated for capturing critical knowledge can be found (D11.1 [20] Q14): On job training dialogue, Elicitation interviews, Mentoring/Coaching, Communities of Practice, Explicit capture (narrative documentation), Experience feedback, Decision tracking, Audio or video recording of “storytelling”, Annotation of existing documents, calculations, procedures, database capture, (see IAEA NG-T-6.10 [21] and references therein for a more detailed description of the methods). The document management system of those organisations contains relevant documentation (guidelines, standards, regulatory documents, project reports, publications etc.). Besides the documents, end-users try to get tacit and implicit knowledge from case studies, feedback, and other formats from internal and external sources. For this, organisations regularly implement pre-input screening and review processes, issues of updating the content, a quality check of content relevance and actuality, lessons learnt and surveys.

There is no clear tendency of how the surveyed organisations set up their KMS. Some are organised in a centralised way, others in a decentralised way, and some even describe it as a hybrid one. The contacts from outside are controlled by user access systems, and security here plays an important role. Already available modules of other organisations will be checked for suitability to become a useful component of such a EURAD KMS. In such a way, it is possible to act cost-efficient and rapidly adopt or adjust finished solutions into the prototype development. All interviewed organisations considered a written policy essential for implementing the KM strategy in their organisation. A clear policy and strategy in KMS development and implementation will avoid many traps and pitfalls and thus will increase the chances for high usage and sustainability.

The existing KM tools are diverse and adjusted to the respective organisational needs. The same has to be done within the EURAD programme. However, existing modules of KM tools could turn out to be useful. They could be adjusted to the EURAD needs and implemented into the EURAD KM programme. Since the EURAD KMS is planned to be generalised and web-based, the selected KM tools – which will support knowledge capture, storage,

sharing and transferring – are portal-KMS, Community of Practices (CoP) and Trainings (Lunch and Learn sessions series). Some further important findings of our survey are also in good agreement with the results of the anonymous benchmarking exercise conducted by the National Nuclear Laboratory (NNL) [22] to explore the KM activities and approaches of organisations from across the UK and internationally, are summarised below:

- the importance of KM is proven and shown by the continued interest and investment of organisations in KM.
- Knowledge management is implemented more effectively when it follows a top-down approach.
- The organisational culture is important to facilitate the knowledge exchange between people. KM is not only about transferring knowledge through documents (explicit knowledge) but through direct interaction between people, asking questions, and carrying out dialogues (tacit and explicit knowledge).
- Identifying critical knowledge and measures to preserve this knowledge is extremely important for organisations.

Key knowledge holders should be visible and active parts of the KM programme (e.g., debriefing, mentoring, coaching), and their efforts should be acknowledged.

In conclusion, organisational culture is extremely important for KM implementation. This addresses not only the access modalities but also the potential of interactive usage. The essential part of a successful KMS is knowledge sharing. The stronger the trust factor in an organisation, the more easily knowledge will be shared. Eventually, this strongly promotes the active usage of the KMS and, therefore, leads to the creation of a sustainable KMS.

4.2 The EURAD Wiki

One commonly used and, therefore, rather a familiar way for most people to retrieve knowledge is via a so-called Wiki, with Wikipedia undoubtedly the best-known example. In the field of RWM, the IAEA Nuclear Wiki is a good example of the usefulness of Wikis. The popularity of Wikis can be attributed to many attractive features, which have also led to the decision to set up a EURAD Wiki under the auspices of WP11 SoK. This Wiki is used to make the KM documents accessible to the EURAD community and provides some functionalities that are essential for successfully implementing the KM documents and the EURAD KM programme as a whole. Among these positive features is the relative ease with which a Wiki can be set up based on free software solutions. This allowed to quickly implement a useable EURAD Wiki without an overly long time for detailed specification of requirements and options or programming. The intention of the EURAD Wiki is in no way to duplicate or compete with the IAEA Nuclear Wiki but rather to complement it and possibly profit from synergies.

The Wiki was developed in 2021, and access was provided to all EURAD members in December 2021 to allow end-user feedback and real-life testing. For the future, it

is intended to have an area with restricted access, which would allow to discuss draft versions of documents that are still undergoing changes and have not yet been reviewed. Therefore, these documents do not fulfil the necessary quality standards for dissemination. Once reviewed and approved, these documents would then be made available in the openly accessible part of the Wiki. The Wiki will be developed further, taking into account the feedback gained from end-users and experts. As a further upside, Wikis have a built-in discussion function that allows users to comment on individual documents and the overall KM approach. The editing function allows users to participate easily as content creators or editors. As stated earlier, end-user feedback and engaging the EURAD community as active participants to KM via various functions is crucial (e.g., as authors, reviewers or by pointing out the necessity for updates for a document). For this, the exchange via the discussion functions can be highly useful. This high level of interactivity comes with the risk of “cyber-vandalism”, e.g., through deleting parts of documents or writing false statements. Therefore, it is highly beneficial that the Wiki provides control through adjustable access rights. This means there is a level of control regarding who can access the Wiki and with which rights, e.g., just to read without editing rights. These restrictions also have the advantage that documents can be shared internally in a defined user group in their draft status and can be scrutinised via the Wiki before broader publication.

5 Conclusions and outlook

Knowledge Management is crucial for the safe implementation of RWM. However, Knowledge Management also has specific challenges, e.g., useful structuring of knowledge into topics, providing knowledge on the needed level of detail, etc. The EURAD programme is an excellent opportunity to tackle these challenges by bringing together many organisations and highly qualified experts from different fields. With the support of this community, the EURAD KM programme can provide a real step change and tangible benefit for the implementation of RWM. As one integral part of the EURAD KM programme, WP11 SoK has taken important steps in the endeavour to capture relevant knowledge and make it accessible to end-users. With the Goals Breakdown Structure, developed by EURAD [17], we have a powerful tool to organise and structure knowledge. Based on this structure, the clear hierarchy and concept of dedicated documents (the Theme Overview, Domain Insight, and State-of-Knowledge documents) allow us to fill this structure with content that enables end-users to orient themselves in the topic at hand and access further Knowledge Base (reports, scientific papers, etc.) through signposting. Filling these documents with content, i.e., capturing relevant knowledge, is a task that relies on the participation of the whole RWM community. Of course, mere capturing of knowledge is not enough. This knowledge also needs to be made available. For this, WP11 SoK has developed a Wiki that already allows sharing and discussing documents and the approach as a whole. In parallel, the crucial ground-

work for the development of a broader Knowledge Management System (KMS)/IT Platform was laid through the survey of existing tools and approaches in different organisations. This work will be continued in the following years of EURAD and possibly beyond. Importantly, all of these activities need to and will consider end-user feedback. The EURAD KM programme, and KM in general, depend on end-user acceptance, so listening to the needs and wishes of the community has to be a central part of all efforts. This will also allow engaging the community not only as users but also as contributors, which is the prerequisite to a sustainable and useful KM programme extending beyond EURAD. Such a KM programme can overcome remaining challenges, such as keeping content up to date and adapting the overall approach to changing needs. The work described in this article is an important step toward achieving this goal and supports national programmes in implementing safe and feasible RWM and disposal.

Conflict of interests

The authors declare that they have no competing interests to report.

Acknowledgements

The authors are grateful to all EURAD KM programme members. We want to thank Paul Carbol, Tara Beattie, Bernd Grambow, Louise Theodon and Piet Zuidema for the fruitful discussions and support. We would also like to thank the anonymous reviewers for their comments.

Funding

The EURAD programme has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 847593.

Data availability statement

This article has no associated data generated and/or analysed.

Author contribution statement

T.K. and A.T. were responsible for the conceptualisation of the paper. T.K., A.T. and D.A. wrote the first draft. All authors have contributed to conducting the work, writing and reviewing the manuscript.

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Cite this article as: Tobias Knuuti, Alexandru Tatomir, Astrid Göbel, Carola Franzen, Dinara Abbasova, Thuro Arnold, Vinzenz Brendler, and Kateryna Fuzik. Capturing the state-of-knowledge in EURAD knowledge management, *EPJ Nuclear Sci. Technol.* **8**, 37 (2022)