

TOPICAL SESSION 5: FUTURE PROOFING NUCLEAR WASTE MANAGEMENT

ASTRA/FORSAFF



Co-funded by the European Union under Grant Agreement n° 101166718

AGENDA

16:30	Welcome/Introduction <i>Tim Schatz (VTT, FORSAFF)</i>
16:35	ASTRA scope and outputs/findings to date <i>Marja Vuorio</i>
16:45	FORSAFF scope and outputs/findings to date <i>Tim Schatz</i>
16:55	Facilitated Panel Discussion Panelists: <i>Virginie Wasselin (Andra, FORSAFF/ASTRA/WMO Rep)</i> <i>Nadja Železnik (EIMV, FORSAFF/ASTRA/TSO Rep)</i> <i>Gabriele Magugliani (POLIMI, FORSAFF/RE Rep)</i> Facilitator: <i>Vaidas Matuzas (EC)</i>
18:15	Closing <i>Marja Vuorio (COVRA, ASTRA)</i>



WP 3: ASTRA INTRODUCTION

ALTERNATIVE WASTE MANAGEMENT STRATEGIES

ASTRA/FORSAFF plenary
Marja Vuorio



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ASTRA

- Overview
- Participating countries and organizations
- Brief description of the technical tasks and their results

ASTRA INTRODUCTION

2 years

700.000 EUR budget

- **Strategic study** based on **ROUTES** suggestions
- Analysis of readiness, feasibility and challenges of alternative RWM solutions needed by many countries, in particular Small Inventory Member States (SIMS) to safely manage and dispose of their waste.

21 partners

3 associate partners

49 End-User/Stakeholder organizations

01 Management coordination

Lead Marja Vuorio, COVRA, WMO, the Netherlands

02 Knowledge management

Lead Wilfried Pfingsten, PSI, RE, Switzerland

Co-lead James Begg, EGIS, RE, France

03 RW long term storage

Lead Kateryna Fuzik, SSTC NRS, TSO, Ukraine

Co-lead Wilfried Pfingsten, PSI, RE, Switzerland

04 Deep borehole disposal (DBD)

Lead James Begg, EGIS, RE, France

Co-lead Steve Wickham, Galson Sciences, RE, United Kingdom

05 Alternatives for SIMS

Lead Barbara Horvat, EIMV, TSO, Slovenia

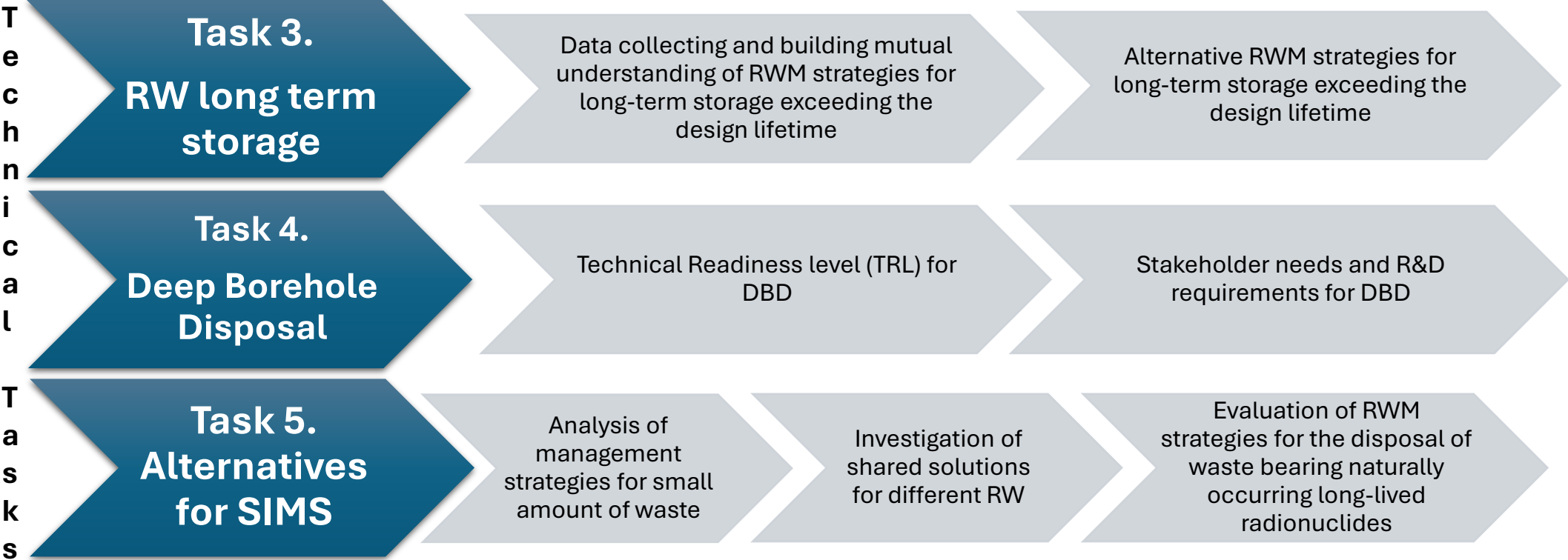
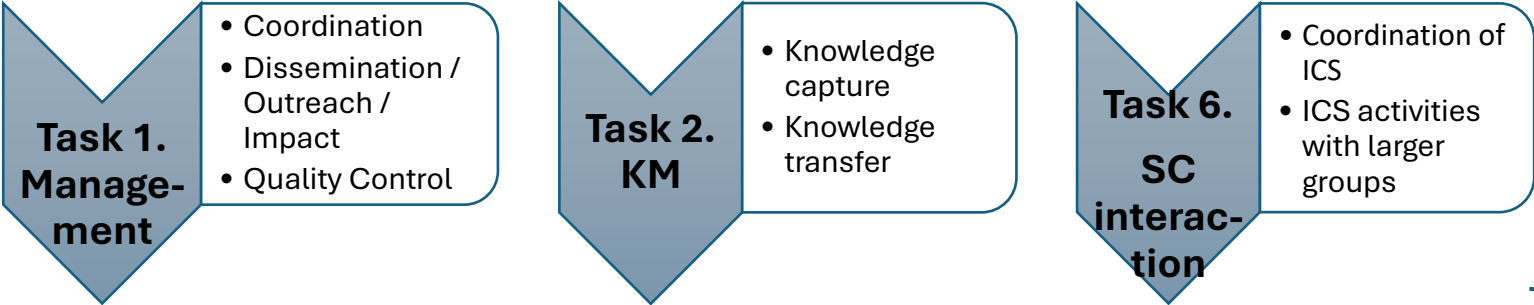
Co-lead Marie Charlotte Bornhöft, DMT, RE, Germany

06 Interaction with civil society

Lead Gabriele Mraz, NTW, TSO, France

Co-lead Alexis Geisler-Roblin, NTW, TSO, France

Cross cutting Tasks



Green and White papers, Outcome /impacts report

PARTICIPATING COUNTRIES AND ORGANIZATIONS

Country	Task 1 Management coordination	Task 2 Knowledge management	Task 3 RW long term storage	Task 4 Deep Borehole Disposal	Task 5 Alternatives for SIMS	Task 6 Interaction with civil society
Austria			NES		NES	
Bulgaria			TUS		TUS	
Czech republic			SURO	SURO	SURO	
Denmark			DEKOM	DEKOM	DEKOM	
Estonia			UTARTU	UTARTU	UTARTU	
Finland			VTT	VTT	VTT	
France	EGIS,NTW	EGIS,NTW	ASRN, NTW	EGIS , ANDRA, NTW	EGIS, ANDRA, NTW	NTW and all partners
Germany	DMT	DMT	DMT	DMT	DMT	
Greece			NCSR		NCSR	
Netherlands	COVRA , NRG	COVRA, NRG	NRG	TNO, COVRA	NRG	
Poland			INCT	INCT	INCT	
Portugal			IST-ID		IST-ID	
Slovenia	EIMV	EIMV	EIMV	ARAO, EIMV	EIMV , ARAO	EIMV
Ukraine	SSTC NRS	SSTC NRS	SSTC NRS , Energorisk	SSTC NRS	Energorisk, SSTC NRS	
Switzerland	PSI	PSI	PSI	PSI	PSI	
UK	GSL	GSL	NWS	GSL, NWS	GSL	
US			SNL	SNL	SNL	

TASK 3: RW LONG TERM STORAGE

Kateryna Fuzik, Wilfried Pfingsten



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TASK 3: RW LONG TERM STORAGE

2 Objectives

- **Building mutual understanding about RWM strategies for long-term storage exceeding the design lifetime**
- **Study of alternative RWM strategies** for situations in which the design lifetime of long-term storage is exceeded, considering safety, technical, and financial factors

19 organizations

- Structured survey gathered information from Task 3 participants on radioactive waste storage for periods exceeding the design lifetime of containers and/or facilities
- Data analysis was followed by a multi-stakeholder workshop that contributed to identifying and prioritising issues, comparing approaches, and identifying areas for collaboration in addressing long-term storage needs.
- Key challenges identified by survey and workshop: degradation of physical barriers, technical feasibility of extended operations, lack of up to date data and loss of historical records, waste acceptance criteria, unclear or missing lifetime definitions, climate change and reduced resistance to external events, emerging waste streams
- Minutes of the WS (MS38) is now in review and it will summarise the results of the WS and survey

TASK 4: DEEP BOREHOLE DISPOSAL

James Begg, Steve Wickham



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TASK 4: DEEP BOREHOLE DISPOSAL

2 interlinked objectives

- **State-of-the-art** report on Technology Readiness Levels for DBD
- Identification of **stakeholder concerns and R&D needed** to build confidence in the implementation of DBD
- => **Suggestions for R&D topics**

17 organizations

- Prior to Workshop 1, conducted a literature review and interviews with ASTRA participants to identify DBD knowledge gaps.
- Identified critical research tasks necessary to advance the technical basis of DBD: Deep Borehole Field Test (DBFT), Site Characterisation / Site Selection, Safety Assessment and Case and Strategic Context (cross cutting). These were specifically addressed during Workshop 1.
- Produced note for record of Workshop 1 (MS27)
- Fed outcomes from Workshop 1 into preparation for Workshop 2. The aim of this is to produce a generic DBD concept that will underpin the development of a comprehensive guidance framework for a safety assessment that will define the safety functions for all the key components in the disposal option.

TASK 5: ALTERNATIVE WASTE MANAGEMENT SOLUTIONS FOR SIMS

Barbara Horvat, Marie Charlotte Bornhöft, Kelvin
Browning



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TASK 5: ALTERNATIVE WASTE MANAGEMENT SOLUTIONS FOR SIMS

3 objectives

- Identification of management strategies for small amounts of waste
- Investigating of shared solutions for different RWs
- Evaluating of RWM strategies for the disposal of waste bearing naturally occurring long-lived radionuclides
- => Use the insights gained to guide the development of future initiatives and projects

20 organizations

- Based on the survey results Live Discussion Forums (LDF) on selected topics has been organized, so that one topic is more thoroughly discussed in one webinar/WS (1-2 hours long):
 - Conditioned waste:
initial inventory (predisposal),
characterisation (predisposal),
treatment (predisposal), conditioning methods
- There is broad interest across Europe (and beyond) in exploring shared solutions for radioactive waste management, particularly in knowledge sharing, training, maintaining competencies, and developing mobile solutions. Countries with different disposal strategies (DGR vs. non-DGR, dual-track, SMR/AR) emphasize different priorities, but common challenges are governance, financial sustainability, and long-term safety/security.
- The key disposal challenges survey highlighted that three general topics need further investigation: 'Practical Logistics', 'Assessment and Costs' as well as 'Volume and Timelines'. Additional collaboration between the member states should be continued to share and explore solutions to these problems.

TASK 6: INTERACTION WITH CIVIL SOCIETY

Gabriele Mraz, Alexis Geisler-Roblin



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TASK 6: INTERACTION WITH CIVIL SOCIETY

2 objectives

- Enabling interaction between technical partners and civil society partners
 - Identifying and elaborating topics of interest for ICS
- Direct collaboration of CS with technical partners in the tasks 3, 4 and 5 (= taking part in meetings, giving input and discussing)
 - Organisation of a pluralistic workshop (=3+1 workshop = 3 technical colleges plus civil society experts)
 - Identifying and elaborating topics of interest for ICS mainly based on outcomes of the ROUTES strategic study from EURAD-1, but also from UMAN and collaboration with EURAD technical WPs
 - Using methods that have been developed in EURAD:
 - Giving input and discussing with technical partners in the other tasks
 - Developing together methods for these meetings (f.e. using scenarios and discussing along them)
 - Using the PEP serious game
 - Giving feedback on inputs of the technical colleges
 - Contributing to reports
 - Organisation of a pluralistic workshop
 - Exchanging with larger civil society group in ICS meetings

WP4 – WASTE MANAGEMENT FOR SMRs AND FUTURE FUELS (FORSAFF)

Tim Schatz (VTT)



Co-funded by the European Union under Grant Agreement n° 101166718



FORSAFF OBJECTIVES

- The primary aim of FORSAFF is to identify knowledge gaps and provide recommendations for future research regarding SMR waste generation and waste management.
- Evaluate SMR waste inventories, including those related to the back end of the fuel cycle, and their main physico-chemical-radiological properties, and assess predisposal (treatment, conditioning, storage, transport) approaches and development needs in terms of anticipated waste generation across several reactor designs and operating conditions.
- Review management routes for SMR wastes over a range of needs will be reviewed, considering both conventional as well as more recent concepts.
- Examine national policies and regulatory frameworks in the context of SMR fuel cycle and waste management as well as stakeholder perceptions and concerns.

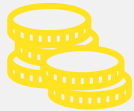
FORSAFF Overview



Strategic **S**tudy



2 years



~1 M EUR budget



25 partners

4 associate partners

01 Management/Coordination

Tim Schatz, VTT, Finland

02 Knowledge Management

Kateryna Fuzik, SSTC NRS, Ukraine

03 Waste Generation

Gabriele Magugliani, Polimi, Italy

Anne Saturnin, CEA, France

04 Waste Management

David Garcia, Amphos21, Spain

Virginie Wasselin, Andra, France

05 Policy & Regulatory Framework

Josef Brinek, UJV, Czech Republic

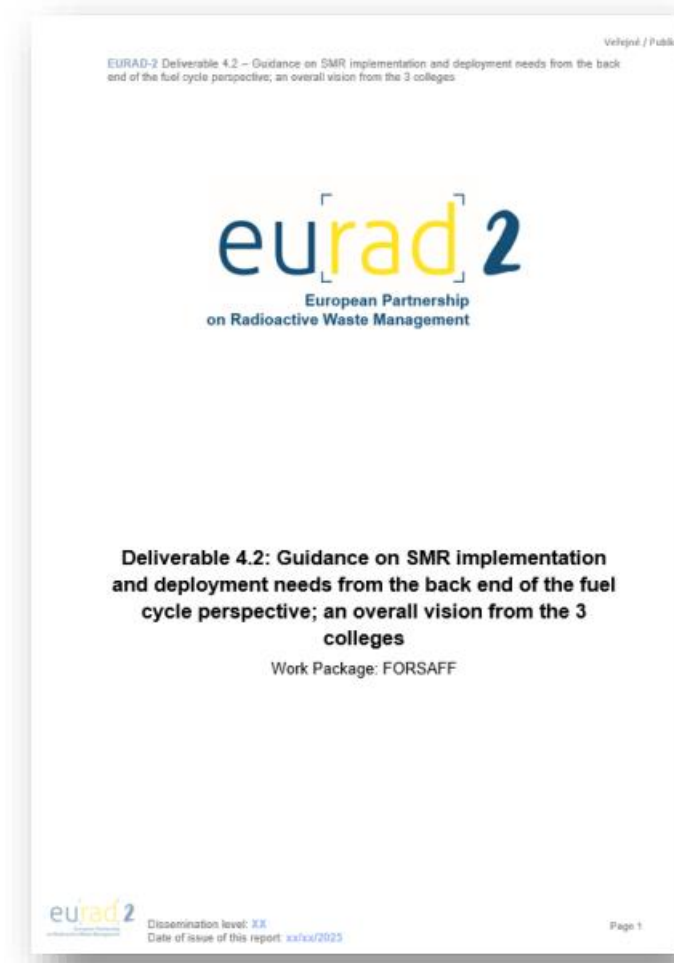
06 Stakeholder Engagement

Nadja Železnik, EIMV, Slovenia

Alan Tkacyyk, Utartu, Estonia

DELIVERABLE 4.2 - GUIDANCE ON SMR IMPLEMENTATION AND DEPLOYMENT NEEDS FROM THE BACK END OF THE FUEL CYCLE PERSPECTIVE

- **Green Paper**
 - What do we think should be done?
 - Challenges
 - Gaps
 - Uncertainties





STRUCTURE

- Overview of SMR/AMR Technologies and their Relevance to Future Nuclear Energy
- Waste Generation from SMRs/AMRs (FORSAFF Task 3)
- SMR/AMR Waste Management (FORSAFF Task 4)
- Regulatory and Policy Considerations (FORSAFF Task 5)
- Stakeholder Engagement (FORSAFF Task 6)
- International Actions
- Recommendations

KEY TECHNICAL CHALLENGES, GAPS, UNCERTAINTIES

- **Limited operational data:** major lack of knowledge regarding real-world waste generation and management.
- **AMR waste stream uncertainties :** e.g., for HTGRs, long-term behavior of TRISO fuel under disposal conditions, for LMFRs, feasibility of reprocessing MOX/actinide-rich fuels, for MSRs, long-term chemical stability of molten salts, conditioning of salt residues, volatile fission product behavior.
- **Treatment, conditioning and reprocessing technologies for AMR used fuels:** low maturity levels, no validated industrial-scale processes.
- **Material behavior:** limited data on SMR/AMR construction materials (e.g., composition, impurities) under irradiation affecting activation and waste estimates.
- **Scale Effects:** lack of reliable extrapolation to industrial scale operations.



KEY REGULATORY & POLICY CHALLENGES, GAPS, UNCERTAINTIES

- **Framework adaptation:** current licensing, transport, and decommissioning rules are designed for large LWRs, not for SMR/AMR-specific waste streams.
- **Classification gaps:** uncertainty on how to classify novel waste types (salt residues, TRISO particles, activated coolants, etc.) within existing categories.
- **Governance:** lack of clarity on roles/responsibilities if SMR/AMRs and waste management responsibilities are handled in decentralized fashion.
- **Economics:** limited information on the cost implications of SMR/AMR waste treatment, transport, and disposal.



KEY STALEHOLDER & SOCIETAL CHALLENGES, GAPS, UNCERTAINTIES

- **Public perception:** uncertainty regarding community reaction to decentralized waste disposal and storage, possibly increased transport frequency, novel waste types, etc.
- **Transparency:** confidentiality and limited public access to waste-related information hinder trust.
- **Engagement:** lack of tested methods for involving stakeholders in SMR/AMR deployment and waste governance decisions.



OTHER KEY CHALLENGES, GAPS, UNCERTAINTIES

- **Knowledge fragmentation:** multiple international initiatives exist regarding SMR/AMR waste management (e.g., EC, IAEA, NEA), but coordination is limited and risks duplication of efforts.
- **Standardization:** no globally harmonized standards for SMR/AMR waste management, most acutely for AMR technologies.



RECOMMENDATIONS

- Start waste planning early!
- Tailor characterization frameworks by technology.
- Focus R&D on unconventional waste treatment.
- Update regulations and foster international cooperation.
- Engage public proactively with transparency.
- *SMRs/AMRs are promising but pose waste challenges*
- *Collaboration, innovation, and trust are central to success.*
- *A unified European and global approach is needed/desired/essential.*



DELIVERABLE 4.4 - IDENTIFICATION OF KNOWLEDGE GAPS FOR FUTURE R&D ACTIVITIES

- **White Paper**

- How do we think it should be done?

- relative to addressing the challenges, gaps and uncertainties highlighted in FORSAFF Green Paper

- *in development*



FACILITATED PANEL DISCUSSION

- **Introductions**
- **Facilitated Discussion**
 - Themes (around SMR/AMR waste management)
 - Technical & Scientific
 - Regulatory & Policy
 - Strategic & Economic
 - International & Collaborative
- **Audience Q & A**



DESIGN STAGE INTEGRATION OF WASTE CONSIDERATIONS

How can waste management requirements (fuel composition, conditioning, packaging and disposal) be embedded into the earliest stages of SMR/AMR design to avoid downstream technical, regulatory and financial challenges?



LICENSING AND DISPOSAL PATHWAYS

Should approval of SMR/AMR projects be contingent on demonstrated disposal pathways and detailed waste management plans, including information on composition, heat output, volume and timing? What mechanisms can ensure that this information is provided early and kept updated as designs evolve?



INNOVATION IN RECYCLING AND FUEL CYCLES

What opportunities exist for integrating recycling or reprocessing into SMR/AMR fuel cycles to minimize waste volumes and recover materials? Closing the fuel cycle and employing Generation IV reactors could reduce waste volumes and radiotoxicities. Should advanced reactors be deployed alongside matching recycling infrastructure to achieve these benefits?



ROLES, RESPONSIBILITIES AND LIABILITY

In a landscape with multiple vendors and new actors, who should bear responsibility for ensuring that appropriate waste management technologies and infrastructure are in place before reactor deployment? How should liability be shared among vendors, operators, license holders, waste management organizations and governments to prevent unfunded liabilities and delays?



STANDARDISATION VS INNOVATION

Would standardizing multiple SMR/AMR designs help simplify the landscape for waste management organizations, and if so, what benefits could be expected? On the other hand, what trade-offs might such standardization impose on innovation and competition in the industry, and how could these competing interests be balanced?



OPTIMISATION OF THE WASTE MANAGEMENT SYSTEM

How should decisions be made between centralized repositories (which simplify safeguards and reduce costs but require more transport) and decentralized repositories (which minimize transport but require suitable geology at every site)? Are hybrid or regional solutions feasible, and how would site selection and community consent be managed?



GLOBAL COOPERATION ON R&D AND STANDARDS

How can countries effectively pool their resources to conduct research on SMR/AMR waste characterization, treatment, and disposal technologies? Would an international platform for data sharing and collaborative experiments on SMR/AMR waste be beneficial, and if so, how could it be established and operated to facilitate cooperation and knowledge sharing among nations?



SUPPORTING NEWCOMER COUNTRIES

How can international organizations assist newcomer countries or those with small inventories in developing competent waste management organizations and training personnel? Should funding mechanisms or partnerships be established to support their participation in shared disposal solutions?



ENGAGEMENT

How can the scientific and technical community effectively communicate the benefits and risks of SMR/AMR waste management to the public, and what role can they play in fostering transparency, trust, and informed decision-making?



THANK YOU!