

EURAD-2 SECOND WAVE

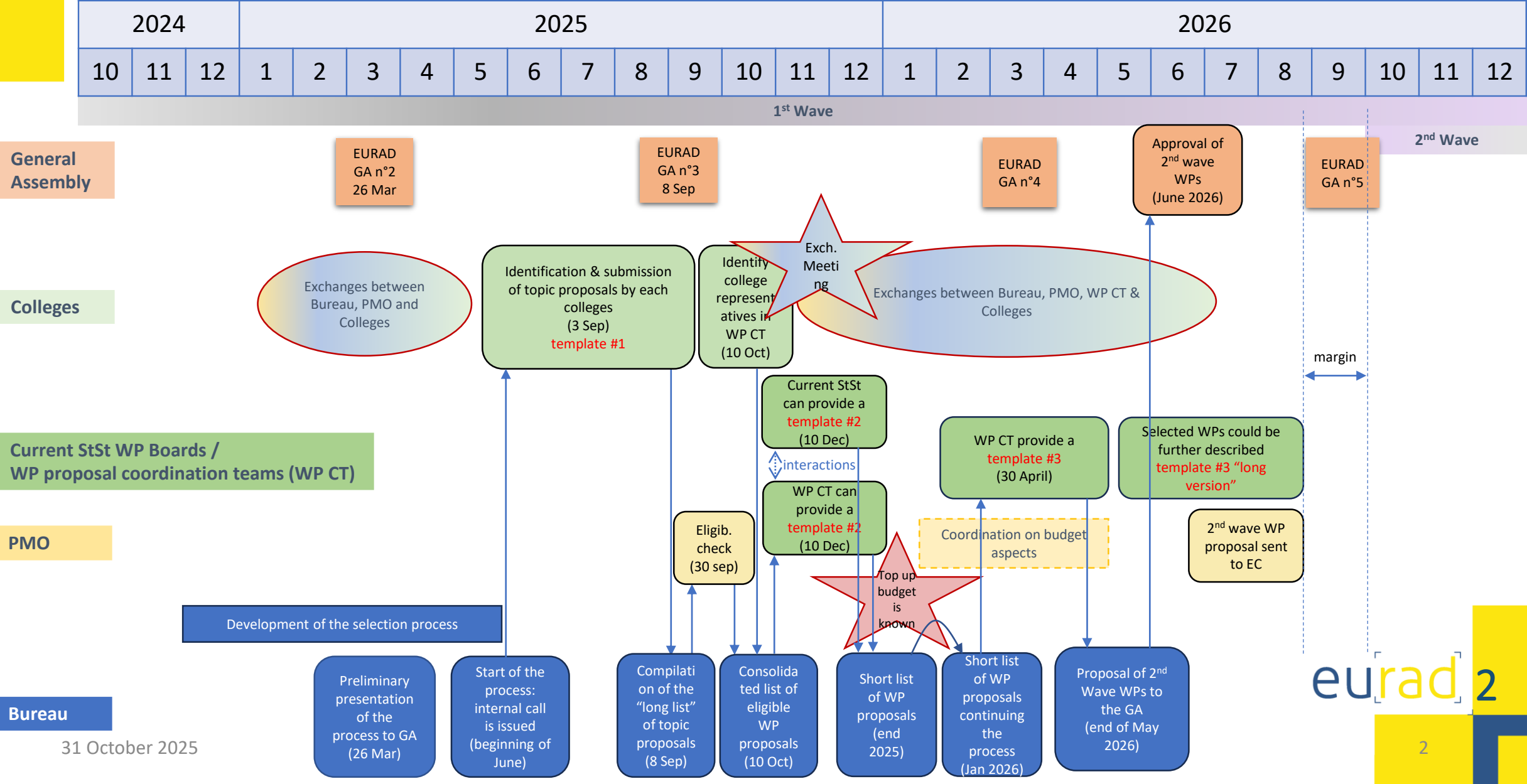
RD&D and StSt WP selection process

Webinars to assist templates #2 preparation



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

SELECTION PROCESS: OVERVIEW



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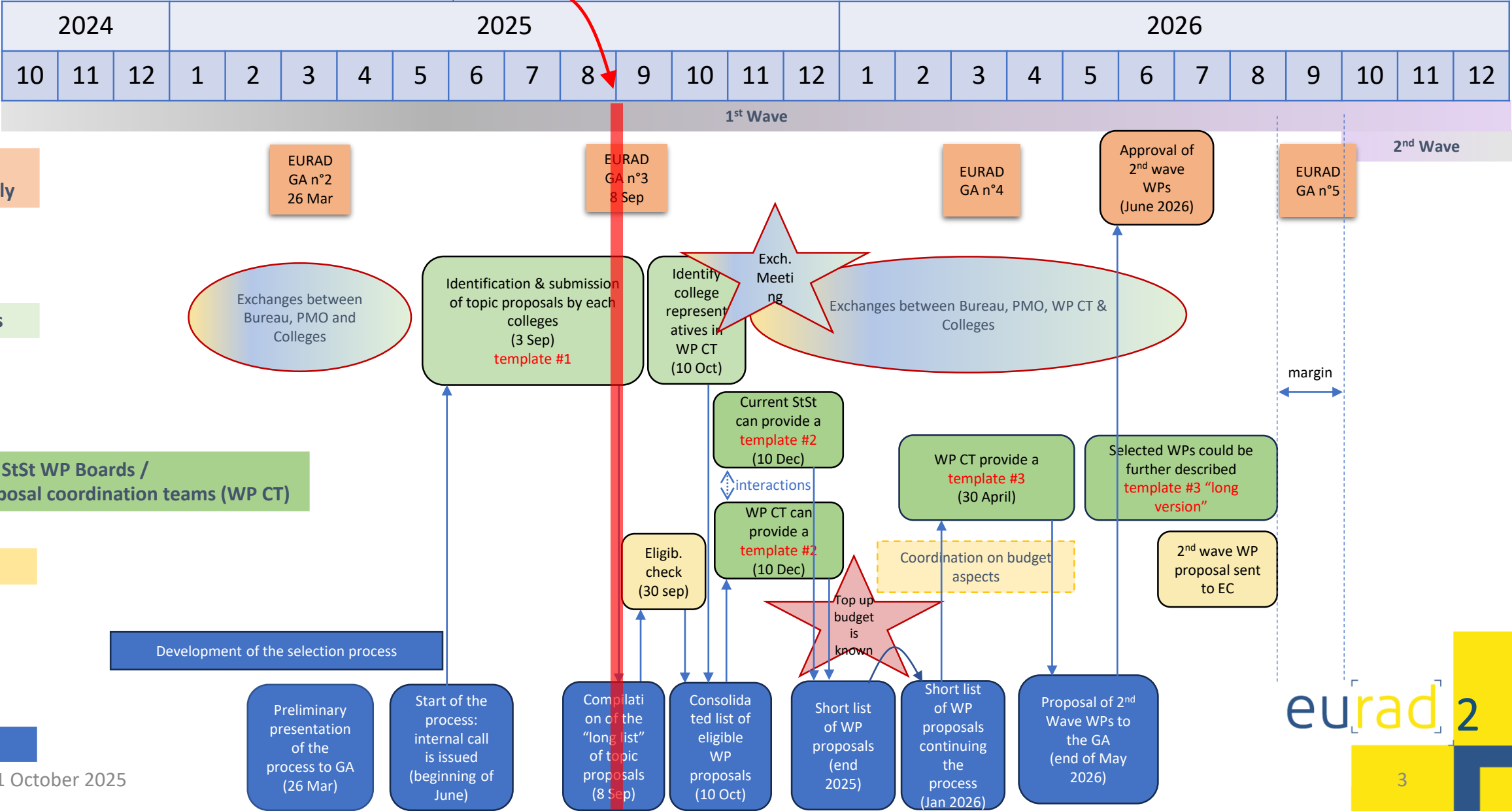
General Assembly

Colleges

Current StSt WP Boards / WP proposal coordination teams (WP CT)

PMO

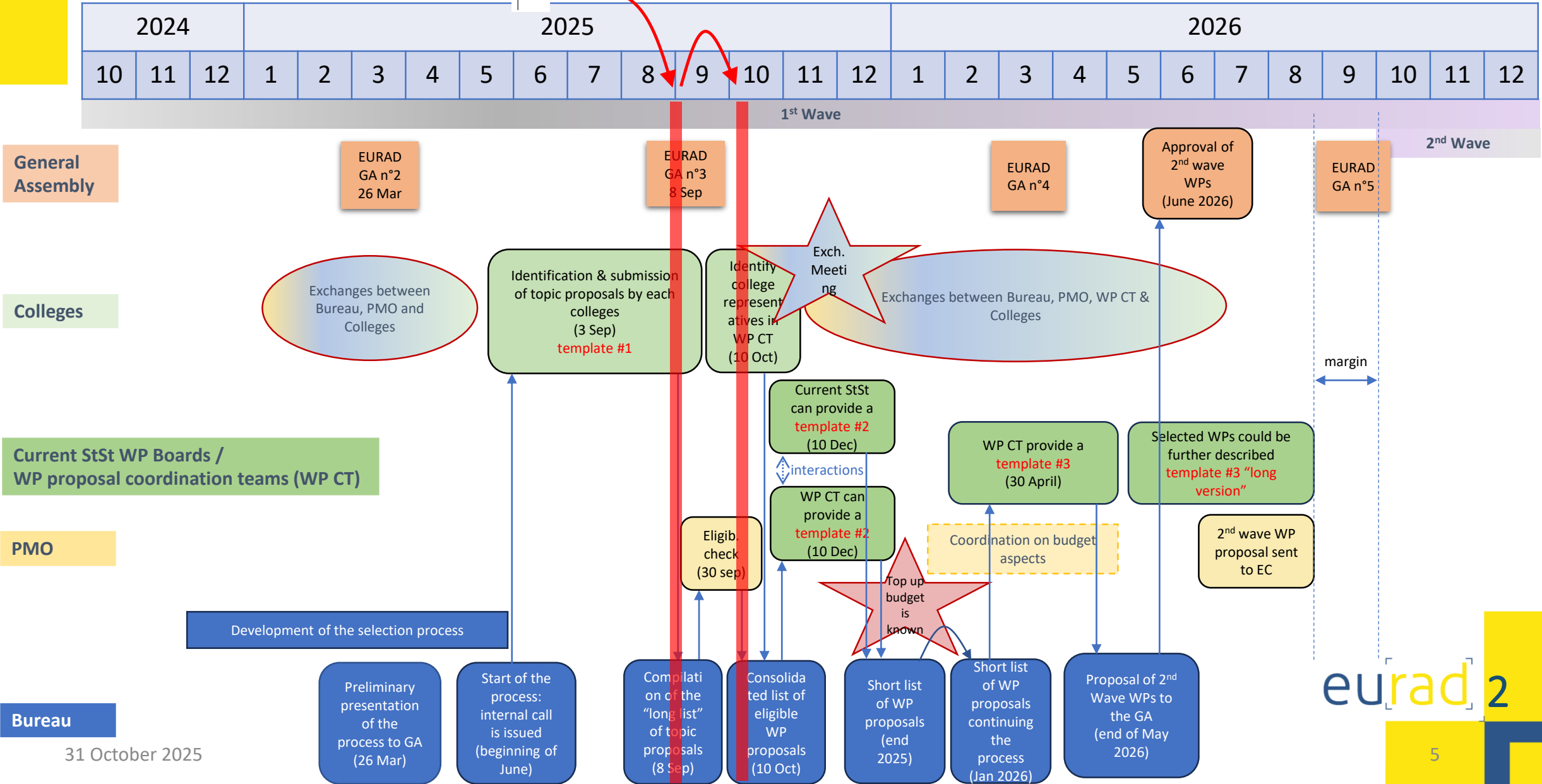
Bureau



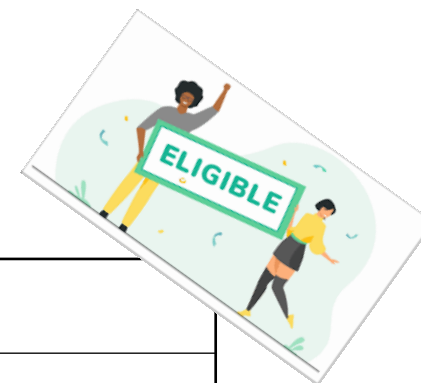
3/09/2025: LONG LIST OF TOPIC PROPOSALS

	From College			Title of the received template #1
	WMO	TSO	RE	
R&D Topics	X			Intelligence (AI) / machine learning for analysis of site characterisation data and other large datasets
	X			MOdelling of GAs behaviour and migration at the REpository scale storage/disposal
	X			Detection and Evaluation of Electrochemical and pH Conditions for Corrosion and HEterogeneous Monitoring
	X			Experimental investigation of nuclide composition in SF for post-closure criticality safety (expansion of WP-17 CSFD)
		X		Towards robust decision-making processes in RWM through participatory data analysis and co-creative development of scenarios
		X		Assessment of the long-term evolution and safety of bituminous radioactive waste (SAFEbit)
		X		Repository site flow and transport models
		X		Backfilling materials for disposal: ensuring long-term stability and performance
			X	Materials for enhancing passive safety and robustness of Engineered Barrier Systems
			X	Development of robust and versatile conditioning matrices for challenging waste streams
			X	Self-Powered Monitoring Systems for Radioactive Waste Repositories
			X	Developing site screening strategies and procedures for integrated site descriptive models
StSt Topics	X			Operational scientific data management
	X			Toxic substances/ chemicals
		X		Guidance for European (TE)NORM & DU enabled strategies for integrated stewardship
		X		Investigating analogues for trusted understanding of repository assessment
			X	Natural Analogues: Strategic review of holistic utilisation of NAs in radioactive waste disposal (NATSTRAT)
			X	THMC Host Rocks: Assessing the end user gaps and needs on THMC(B) properties of HR – defining a common strategy

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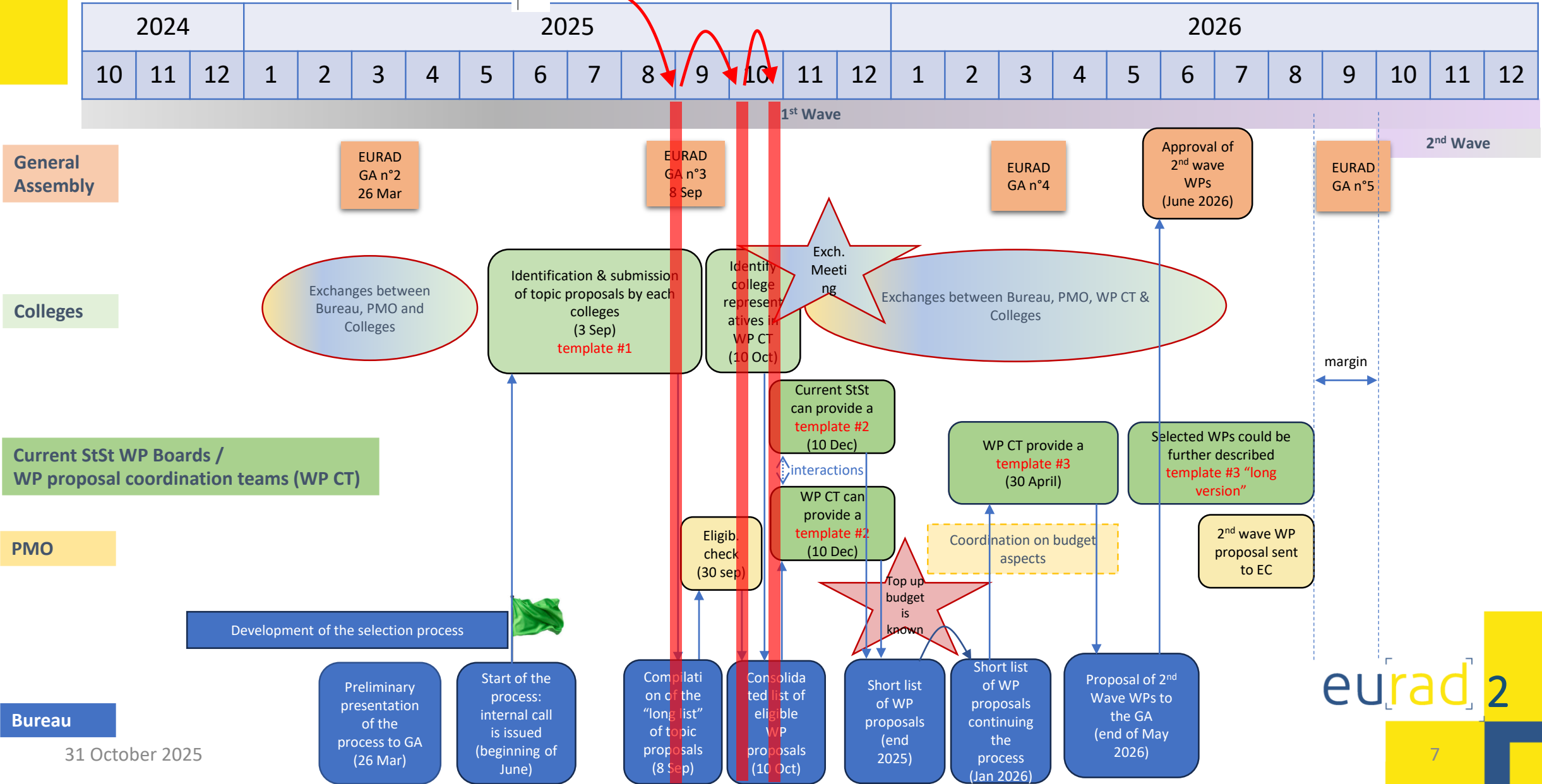


30/09/2025: ALL TOPICS IN THE LONG LIST ARE ELIGIBLE



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		X		Towards robust decision-making processes in RWM through participatory data analysis and co-creative development of scenarios
		X		Assessment of the long-term evolution and safety of bituminous radioactive waste (SAFEbit)
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			X	THMC Host Rocks: Assessing the end user gaps and needs on THMC(B) properties of HR – defining a common strategy

SELECTION PROCESS: OVERVIEW



CONSOLIDATED LIST OF ELIGIBLE WORK PACKAGE PROPOSALS

	WP #	Titles of the related templates #1	Template #1 from College			WP Coordination Teams (WP CT)		
			WMO	TSO	RE	WMO	TSO	RE
R&D Topics	R&DWP1	Intelligence (AI) / machine learning for analysis of site characterisation data and other large datasets	X			david.eastwell@nuclearwasteservices.uk	wpfingsten@pop.agri.ch	nikolaos.prasianakis@psi.ch
	R&DWP2	MOdelling of GAs behaviour and migration at the REpository scale storage/disposal	X			jacques.wendling@andra.fr	zakaria.saadi@asn.fr	luca.urpi@psi.ch
	R&DWP3	Detection and Evaluation of Electrochemical and pH Conditions for Corrosion and HEterogeneous Monitoring	X			johan.bertrand@andra.fr	charles.wittebroodt@asn.fr	c.boxall@lancaster.ac.uk
	R&DWP4	Experimental investigation of nuclide composition in SF for post-closure criticality safety (expansion of WP-17 CSFD)	X			anna.alvestav@skb.se	eva.leser@base.bund.de	mathieu.hursin@epfl.ch
	R&DWP5	Assessment of the long-term evolution and safety of bituminous radioactive waste (SAFEbit)		X		ian.rosdahl@skb.se	georges.matta@asn.fr	petr.vecernik@ujv.cz
	R&DWP6	Repository site flow and transport models		X		michael.schnellmann@nagra.ch	pirjo.hella@vtt.fi deputy: susan.britz@grs.de	jon.engstrom@gtk.fi
	R&DWP7	Backfilling materials for disposal: ensuring long-term stability and performance		X		jean.talandier@andra.fr	oliver.czaikowski@grs.de deputy: alexandre.dauzeres@asn.fr	janez.perko@sckcen.be
		Materials for enhancing passive safety and robustness of Engineered Barrier Systems			X			
	R&DWP8	Development of robust and versatile conditioning matrices for challenging waste streams			X	ilen@enresa.es	radouane.sghir@belv.be	Quoc.tri.phung@sckcen.be
	R&DWP9	Self-Powered Monitoring Systems for Radioactive Waste Repositories			X	renaud.fallourd@andra.fr	rita.plukiene@ftmc.lt	jl.garciasineriz@amphos21.com deputy: Susana.tunon@amphos21.com
	R&DWP10	Developing site screening strategies and procedures for integrated site descriptive models			X	No WP CT member identified yet	jeroen.mertens@belv.be	mirjam.kiczka@unibe.ch deputy: jon.engstrom@gtk.fi
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	StStWP5	THMC Host Rocks: Assessing the end user gaps and needs on THMC(B) properties of HR – defining a common strategy			X	No WP CT member identified yet	baksay.attila@gmail.com	arnaud.dizier@euridice.be

WHAT WAS CONSOLIDATED ?

- Potential for being merged first evaluated by the Bureau
- Decision about merging or not between WPs with such a potential on 30/09/2025, at a special Bureau meeting with College leadership organisations and representatives of corresponding templates #1



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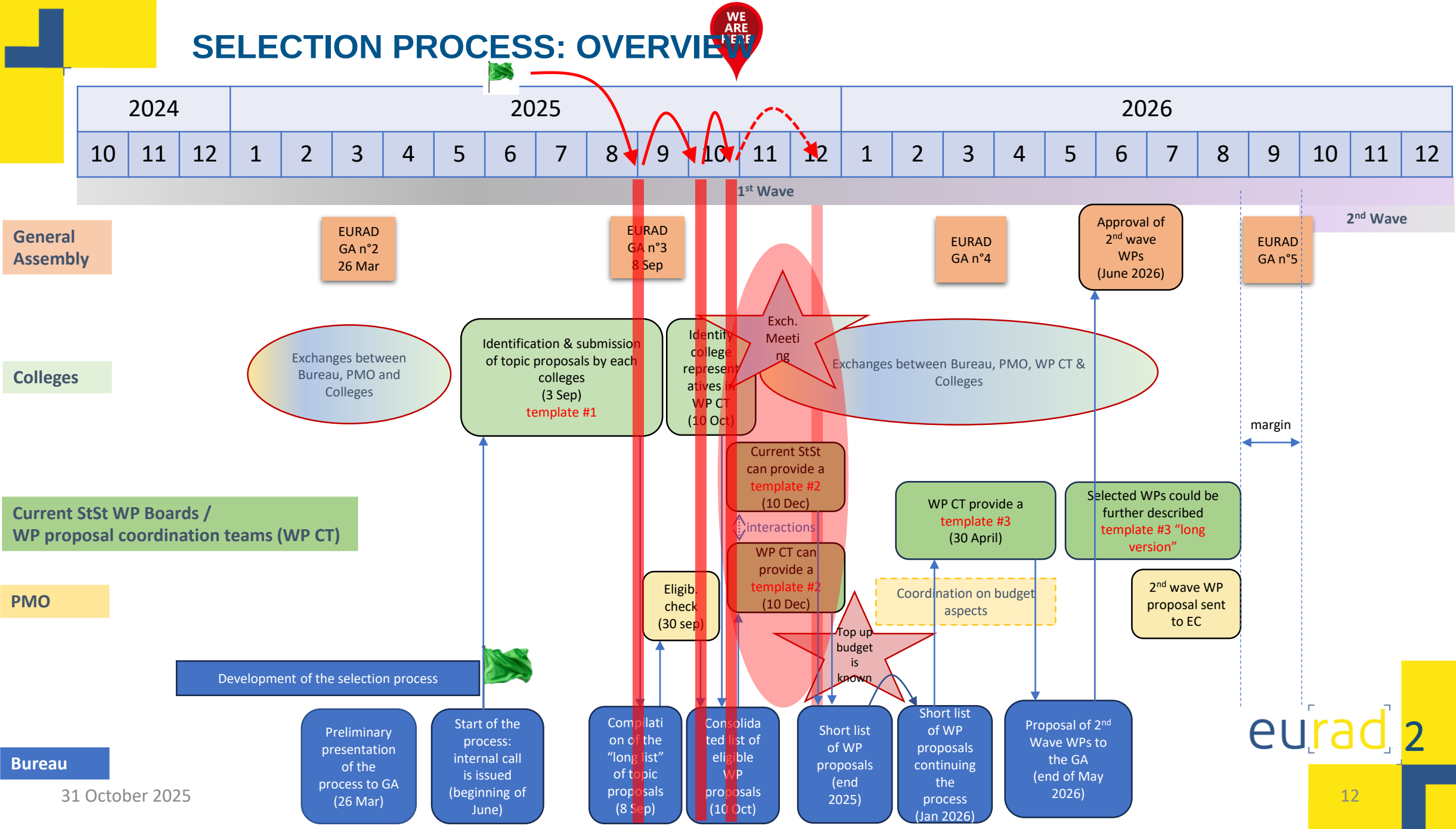
NOMINATED WP CTS

- You can start working on preparing templates #2.
- 2 WMO WP CT members still to be identified (discussion on going within the Bureau)



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SELECTION PROCESS: OVERVIEW



CURRENT STEP OF THE PROCESS

- **Preparation of templates #2, by the 10th of December 2025**
- **Who can submit a template #2?**
 - WP CTs of new WP proposals (see table on previous slides)
 - WP Boards of ongoing StSt WPs (only for a R&D WP connected to their scope)
 - DITUSC (Development and Improvement of Thermodynamic Understanding for use in Nuclear Waste Disposal Safety Case)
 - CLIMATE (Impact of climate change on nuclear waste management)
 - OPTI (HLW repository optimisation including closure)
 - DITOCO (Next generation Digital Twins to support Optimisation, Construction and Operation of surface and subsurface radioactive waste management facilities)
 - FORSAFF (Waste management for SMRs and future fuels)
 - ASTRA (Alternatives RWM strategies)

CURRENT STEP OF THE PROCESS

Important messages

- Interactions are essential between all WP CTs and WP Boards working on templates #2.
- Now, 2 processes (new WP proposals (i) by the colleges and (ii) by the WP Boards) come together.
- We need to build a global picture of what we propose in the templates #2 !
- The (preparation of) templates #2 should:
 - Be inclusive, be the result of a consensus building process between interested partners and the Colleges;
 - Provide added value to MS, the SRA is our guide but connect with end users to verify that there needs are addressed;
 - Be coherent, templates #2 have to tell a story together (avoid repetition of activities in several templates #2, create links between proposals if relevant...);
 - Promote scientific excellence.
- Be creative and avoid working in silos: new merges between WP proposals are still possible and, if relevant, encouraged by the Bureau.
- The task of the Bureau is to assist you in this process (e.g. by organizing the today's webinar)



WEBINARS OBJECTIVES & NEXT STEPS

- **Promote exchanges on the WPs currently being considered in the selection process by WP CTs and StSt WP Boards.**
- **Help assessing:**
 - Which aspects of the WPs proposals are the most important?
 - Is there a joint college interest in the proposals?
 - Could connections be made between the proposals? E.g. connections between the templates #1 and the intentions for new WPs from the WP Boards of the ongoing StSt WPs?
- **Help preparing the face to face EURAD-2 exchange meeting about 2nd wave**
 - Meeting on 26/11/2025 PM, Prague, aside of the IGD-TP exchange forum
 - Registration was closed on 12/10/2025
 - Agenda will be finalized and shared after the webinars
- **Templates #2 to be submitted after this meeting, by the 10/12/2025**

PRACTICAL INFOS FOR THE WEBINARS

- Webinar's agenda is organized in 2 sessions, and a conclusion at the end.
- WP proposals are distributed between the 3 webinars (agenda are thus different !).
- After a pitch (5 or 10min, see agenda) only 15 min for discussion. Use this time for important questions or remarks.
- The timing will be very strict !
- You are invited to fill in a survey during and/or after the webinars:
 - <https://ec.europa.eu/eusurvey/runner/4c3c2ee0-a138-a00a-0c4b-07fe4a30559f>
 - You can save your answers as a draft and continue filling in the survey later.
 - For each pitched WP proposal, 3 questions:
 - Do you think your organisation could be interested to participate to this WP (if selected) ?
 - Are you interested to contribute to the template #2 preparation?
 - Do you have any comment about this proposal?
 - Deadline = **before the 4/11/2025**
 - All answers will be shared with corresponding WP CT / WP Boards.
- **Webinars are recorded. Recording will be made available after the webinars.**

DEVELOPMENT OF ROBUST AND VERSATILE CONDITIONING MATRICES FOR CHALLENGING WASTE STREAMS

Quoc Tri Phung (RE) – SCK CEN

Jose Luis Leganes Nieto (WMO) – ENRESA

Radouane Sghir (TSO) - BelV



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

WHY THIS MATERS



Problem

Certain radioactive waste streams remain incompatible with conventional cement-based conditioning.



Impact

Without innovative solutions, these wastes pose long-term safety and cost challenges for disposal facilities.



Opportunity

The project is designed to benefit multiple Member States, regardless of their stage of advancement in RWM, and aligns with EURAD-2's goals of cross-border solutions.

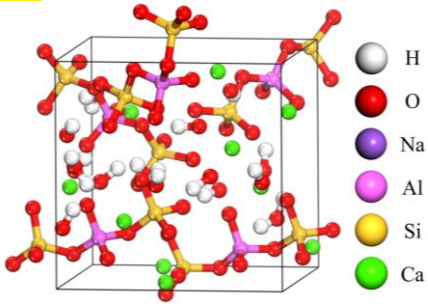
OBJECTIVES

- **Development of advanced matrices:** Focus on creating alkali-activated material and geopolymer matrices that are robust, versatile, and sustainable for waste conditioning.



- **Technology readiness and Scale-up:** Aim to elevate technology readiness levels and enable industrial-scale application of the new waste conditioning methods.
- **Ensuring long-term safety:** Commit to establishing standardized testing protocols and demonstrate compliance with generic WAC to guarantee safety and reliability in radioactive waste management.

INNOVATION AND ADDED VALUES



AAM/Geopolymers

Superior chemical resistance & durability vs. cement.

Higher waste loading capacity → reduced volume & cost.

Versatility

Handles diverse waste streams (e.g., spent ion-exchange resins, pyrolysis ashes, SMR-related waste).

Innovation leap

Builds on PREDIS and EURAD WP5–7 insights but pushes toward industrial-scale readiness.

Added values

Solutions for Member States struggling with incompatible waste streams.
Approaching wider partner interest

HOW WE'LL GET IT



Waste inventory:
Classification and identification of waste streams compatible with AAMs

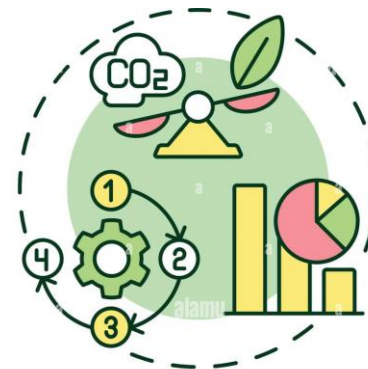
Develop & Optimize AAM-based matrices
using SCMs
(metakaolin, slag).



Robustness testing:
Ensure reliability across variable waste compositions.



Standardization:
Create common testing protocols with IAEA collaboration.



Modeling & LCA:
Validate long-term performance and sustainability.

WHY EURAD-2 NEEDS THIS

- Aligns with **Theme 2: Pre-disposal** and **Domain 2.2.3 Conditioning**.
- Supports **tailored solutions, scientific insight, and innovation & sustainability**
- Backed by **16 organizations across Europe** → strong collaborative base.



SCK CEN (Belgium), Tractebel (Belgium), VTT (Finland), SIIEG NASU (Ukraine), PSI (Switzerland), UniPi (Italy), HZDR (Germany), PSI (Switzerland), KIPT (Ukraine), KhPI (Ukraine), INCT (Poland), UAM (Spain), CSIC (Spain), RATEN (Romania), CV REZ (Czech Republic), EDF R&D (France)

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**Join us in shaping the future of
radioactive waste conditioning.**
Safer, more sustainable, and ready for
industrial implementation.

ASSESSMENT OF THE EVOLUTION AND SAFETY OF BITUMINOUS RADIOACTIVE WASTE (SAFEBIT)

TSO college:

Georges Matta, ASNR

Artūras Plukis, FTMC

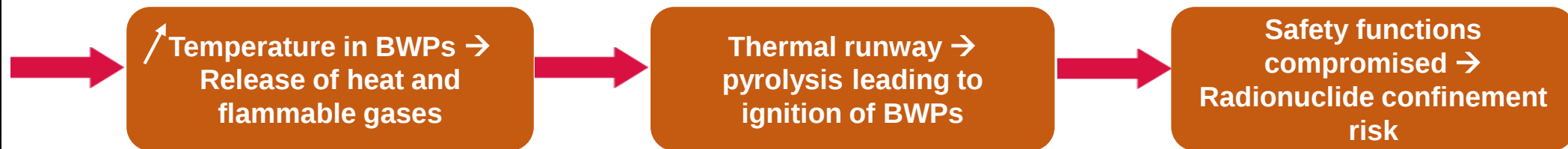
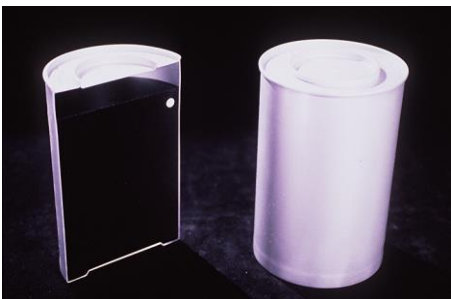
Oleksandr Soloviov, SSTC NRS



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CONTEXT AND EUROPEAN CHALLENGES

- Bitumen has been widely used for immobilising low- and intermediate-level radioactive waste, resulting in bituminized waste packages (BWPs) that now represent a management challenge across 13 European countries due to potential storage / transport / disposal risks
- Previous EURATOM projects (EURAD-1, PREDIS, CHANCE) identified key challenges related to BWPs management
- Challenges: complex chemical and physical evolution of bitumen over time; organic nature and oxidizing salts raise concerns, especially regarding chemical stability, and runaway associated to fire hazard



Fire risk management of BWPs throughout their lifecycle (transport, storage, disposal)

- Goal: evaluate BWP behavior and safety under storage/disposal conditions by studying thermal reactivity, gas generation, swelling, and leaching mechanisms → combine existing knowledge, conduct R&D, model key mechanisms, and provide safety analysis basis

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GOALS OF SAFEBIT

Inventory and knowledge base

- Review of existing **bituminous waste inventories** across Member States
- **Collection of data** on waste characteristics, conditioning methods, storage and disposal practices, and national management strategies
- Development of a **harmonised European knowledge base** related to bituminized waste, focusing on key safety aspects and factors affecting behavior under storage and disposal conditions

Safety-relevant mechanisms R&D

- **Conducting R&D based on experiments** to understand mechanisms:
 - *1. thermal reactivity,*
 - *2. gas generation,*
 - *3. swelling and leaching*

Modelling of scenarios

- **Mechanistic modelling** relying on fundamental physical and chemical mechanisms to describe BWP behaviour
- **Scenario modelling at larger scales** (BWP and disposal cell)
- Evaluation of system behavior under both normal and accidental conditions



**THANK YOU FOR YOUR ATTENTION !
ANY QUESTIONS?**

GUIDANCE FOR EUROPEAN (TE)NORM & DU ENABLED STRATEGIES FOR INTEGRATED STEWARDSHIP – GENESIS WP (StSt)

Konrad Lotter, Henriette Herzog	AGES	Austria	TSO
Kelvin Browning	NRG	Netherlands	TSO
<u>Yevheniia Kudriashova</u>	SSTC NRS	Ukraine	TSO
Nadja Železnik	EIMV	Slovenia	TSO



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(TE)NORM AND DU CHALLENGE: FROM A FRACTURED LANDSCAPE TO A UNIFIED STRATEGY*

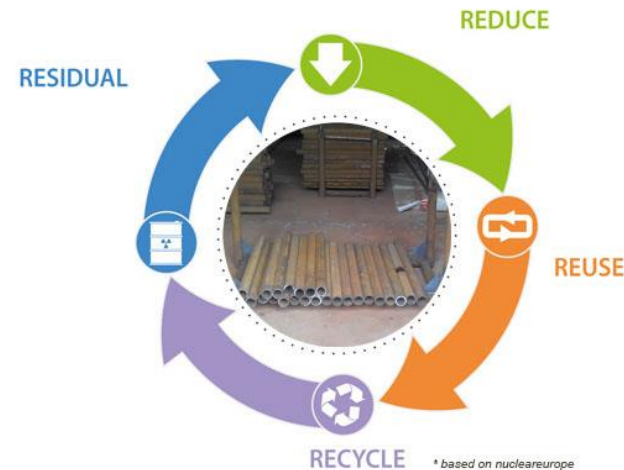
The shared challenge: a fractured European landscape

A deep divide

The foundation is inconsistent: **roughly 50% of EU countries legally define (TE)NORM as radioactive waste, and 50% do not.** This fundamental split makes a harmonised approach to transport, reuse, and the Circular Economy very challenging. Inconsistent practices and regulatory gaps create uncertainty for everyone, **especially SIMS**. A broad, economically viable uses for DU remain under development

A library of disconnected knowledge

We have a vast library of essential IAEA and EC documents (GSR Part 3, SSG-60, industry reports), but these are the foundational bricks, **not the architect's blueprint** needed to assemble them into a coherent European strategy.



The GENESIS solution: a strategic management template

Our objective:

To develop integrated strategies, tools, and knowledge bases for the safe management, reuse, and long-term storage/disposal of (TE)NORM and DU waste streams, tailored to SIMS needs and circular economy principles.

Expected added-value: GENESIS will answer the questions

"What technologies for recycle/reuse are actually applicable and available to us?"

"What are our real infrastructure and capacity needs for our specific inventories?"

"How do we develop the specifications for a robust safety case for nuclides like Ra-226?"

OUR STRATEGIC SCOPE: THE TECHNICAL HEART OF GENESIS

Task1 – WPM; Task 2 – KM

Task 3: Characterisation and predisposal optimisation

We will first establish the essential, harmonised evidence base by synthesising best practices for the characterisation of both complex NORM and heterogeneous DU wastes.

Task 4: Resource recovery and the circular economy

Next, we will define the complete technical, economic, and EU-specific pathway needed to transform (TE)NORM and DU from waste into safe, reusable materials. This includes a "Resource Potential Map" and a "Catalogue of Technological Solutions."

Task 5: Long-term storage and disposal

Finally, for all waste not destined for reuse, this task will define the state-of-the-art requirements for optimised stewardship of the wastes destined for final disposal, crucially specifying the requirements for a **robust, long-term safety case tailored for SIMS-relevant nuclides**.

Year 1: Green Paper (Mapping options and pathways).

Year 2: White Paper with R&D Roadmap to guide future EURAD projects.

Our consortium: CIEMAT, NTW, SSTC NRS, AGES, ASNR (+CEPN), SURO, EIMV, IJS, NRG, LEI...

Library of essential knowledge from key European projects like **EURAD (ROUTES, ASTRA, PREDIS), HARPERS, and RadoNorm**

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TOXIC SUBSTANCES & CHEMICALS

Benjamin FRASCA – ANDRA (WMO)

Anke NEUMANN-JENAL - PSI (RE)

Frederic COPPIN – ASNR (TSO)

Strategic Study



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OBJECTIVE

- **Context**

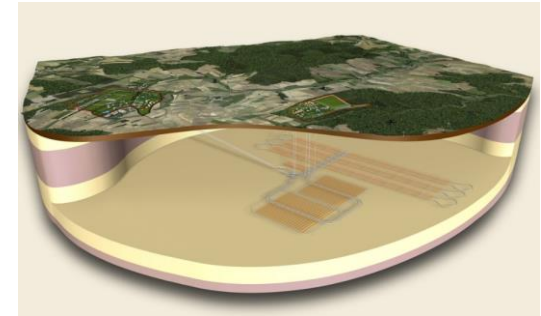
- Repositories are primarily intended to afford protection against radiological hazards
- The evolution of environmental regulations, including increasing focus on emerging contaminants such as forever chemicals

- **Objective**

- Analyse and identify the current issues about toxic chemicals for a strategic study
 - Identification of source terms,
 - Behaviour of toxic substances in engineered barriers and the geosphere,
 - Interactions with the biosphere (including impact to human)
 - Best practice in relation to environmental impact assessments in relation with environmental regulations



Surface disposal



Deep geological disposal project



EXPECTED ADDED-VALUE

- **Repositories are primarily intended to afford protection against radiological hazards,**
 - It is critical that the Safety Case also demonstrates the safe disposal of any associated toxic substances (both **organic** and **inorganic** substances).
 - Either **surface, near surface** or **deep geological repository**
- **The evolution of environmental regulations, including increasing focus on emerging contaminants such as PFAS and BPA,**
 - Need for greater confidence in the inventory of legacy waste streams.
- **Additionally, future waste streams, including those from Gen IV reactors, may contain significant amounts of toxic chemicals (e.g. Pb),**
 - Must be accounted for in safety assessments and disposal strategies.
- **Development of international best practice would help to ensure robust approaches in these areas and build regulatory confidence**
- **Define recommendations and highlight priority topics for future R&D studies**



SCOPE – OVERVIEW OF PROPOSED TASK

Task 1: Management & coordination / Task 2: Knowledge Management

Task 3 - Review of knowledge about the determination of the source term of toxic chemicals from different wastes

Task 4 - Review of knowledge about the behaviour (solubility, sorption, reactivity...) of toxic substances in rocks, materials and identification of knowledge gaps

Task 5 - Review of knowledge about the behaviour of toxic substances in the biosphere (impact to human and non-human biota) and identification of knowledge gaps

WP4 FORSAFF 2ND WAVE PROPOSAL PITCH

WP4 MT and Partners



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OBJECTIVE

- Perform research and development activities needed to achieve SMR/AMR waste management
 - finding solutions to SMR/AMR deployment challenges

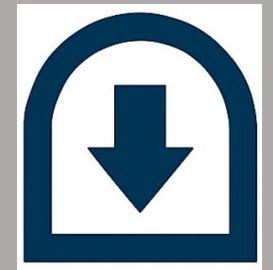




ANTICIPATED (ADDED) VALUE

- Develop (more) comprehensive understanding of SMR/AMR waste streams.
- Bridge gaps between SMR/AMR designs and waste management.
- Provide evidence-based guidance to support waste management decisions and licensing.
- Create collaborations with EURAD-2 activities and other initiatives, e.g., EURATOM, SMR Industrial Alliance, IAEA, NEA, as limited coordination risks duplication of efforts.
- Strengthen interactions between technology developers and end-users.

SCOPE



R&D NEEDS FOR SPENT FUEL AND WASTE CHARACTERIZATION

Radionuclide inventory and source-term calculations

- Determine the inventory of radionuclides in SMR/AMR spent-fuel under various burn-ups, enrichments and power densities. Perform full-core 3-D numerical calculations and validations with experimental data and improved nuclear-data libraries. Efforts to also include cross-verification of codes and uncertainty propagation studies.

Impurity and structural material effects

- Study the influence of impurities in SMR/AMR fuels, cladding and reactor structures on the activation products in spent-fuel. Similar work is needed to understand the effect of new cladding alloys and accident-tolerant fuels on radionuclide inventory.

Advanced fuels and coolants

- Characterise advanced fuels by microstructural and chemical analyses; determine long-term stability under air ingress, humidity and heat loads; analyse coolant activation products (e.g., Po-210 in lead–bismuth coolants). Characterise halide-rich molten-salt waste to mitigate matrix effects and improve analytical accuracy.
- Develop methods to quantify radionuclide inventory within TRISO kernels and graphite layers, assess PyC/SiC integrity and determine contamination heterogeneity in bulk graphite. Complementary studies to optimise dissolution techniques for TRISO fuels using molten KOH or HF/HNO₃ and perform micro-deposition/ alpha-spectrometry for trace-level isotopic analysis.

R&D NEEDS FOR FUEL TREATMENT AND REPROCESSING

Advanced separation techniques

- Develop actinide/lanthanide separation methods to enable partitioning and transmutation; optimize extraction of uranium and thorium from HTGR reprocessing and demonstrate the process at scale; adapt existing reprocessing plants for new SMR waste forms by predicting feed isotopic compositions.

On-line/off-line reprocessing of molten salt fuels

- Further develop technologies for implementing on-line (gas sparging, cold traps, electrochemical polishing and sorbents) and off-line (salt drainage to shielded hot-cells for batch pyrochemical separations) reprocessing of MSR Th-breeder and actinide-burner fuels.

Pyrochemical reprocessing of fast breeder fuels

- Develop dry pyrochemical technologies for sodium-cooled fast-breeder reactor fuels, including characterisation of resulting waste streams and immobilization methods.

Access to TRISO kernels

- Further develop techniques (e.g., plasma-aided etching, molten-salt dissolution) to remove PyC and SiC coatings from TRISO particles and to manage volatile fission products and C-14 contaminated graphite.

R&D NEEDS FOR PREDISPOSAL

Stabilization, immobilization and encapsulation

- Develop cementitious matrices to immobilize TRISO particles and irradiated graphite while ensuring criticality safety and assessing chemical interactions between graphite and cement. For MSR spent fuel, develop stable waste forms with low leach rates and experimentally demonstrate radionuclide containment; for liquid-metal fast-reactor fuel, develop waste forms that handle residual coolant and large volumes while ensuring criticality safety

Decontamination and conditioning of structural waste

- Investigate the decontamination and cement-based conditioning of metallic (and SiC) structural waste materials exposed to corrosion and irradiation.

Graphite handling

- Optimize steam-oxidation decontamination to reduce activity and enable reclassification of graphite waste; evaluate the need for treatment and assess nuclide migration if graphite is disposed of without treatment.

Routes for metal-coolant wastes

- Devise conditioning treatments to stabilize metallic coolants (Na, Pb, Bi) and demonstrate leach behavior of toxic elements from conditioned waste forms. Study conditioning of caustic NaOH solutions arising from sodium neutralization, including sustainable matrices for direct conditioning and removal of Cs/Sr.

Management of chemo-toxic and volatile species

- Develop approaches for managing aggressive species (Cl, F, Na) in waste and trapping volatile fission products such as I, Te, Xe and Kr using sorbents.

Recycling

- Investigate technologies to recycle Pb, Cd, Bi and other metals used in advanced fuel cycles to reduce waste streams. Evaluate recycling Cl-37 in fuel salt waste to reduce enrichment costs and Cl-36 generation.



R&D NEEDS FOR PACKAGING AND STORAGE

Canister design and loading

- Investigate canister designs and loading strategies for LWR SMR spent fuel, including stacking short assemblies and assessing criticality.

Packaging materials

- Characterize and qualify materials for packaging irradiated graphite that resist galvanic corrosion; assess materials for packaging molten-salt waste and consider chemical conversion before disposal.

HTGR fuels and graphite

- Optimize interim storage and packaging of HTGR fuel pebbles and prismatic blocks to improve cask utilisation; develop disposal concepts that accommodate large volumes of irradiated graphite and manage H₂ and C-14 gas generation..



R&D NEEDS FOR DISPOSAL

Adaptation

- Assess whether existing deep geological repository concepts can accommodate SMR spent-fuel with non-standard geometries, higher heat loads and different isotopic compositions. Develop alternative disposal concepts (e.g., deep boreholes).

HALEU fuel

- Evaluate disposal of HALEU fuel, considering thermal limits, long-term degradation and post-closure criticality.

TRISO and graphite wastes

- Develop disposal concepts for bulk graphite from prismatic blocks and pebble-bed fuels, including co-disposal with fuel compacts or separate disposal.

Sodium coolant

- Investigate near-surface disposal of sodium-coolant processing effluent and compatibility with regulatory frameworks.



CROSSCUTTING R&D NEEDS

Siting

- Investigate whether multiple, dispersed disposal facilities are needed for widespread SMR deployment.

Safeguards and accounting

- Establish procedures for radioactive-material accounting in liquid-fueled reactors; develop data-recording systems and safeguards for pebble-bed fuels to comply with accountancy and disposal requirements.

Lack of data and conservative assumptions

- Recognise that the largest uncertainty in several topics is the lack of input data from vendors and design developers; i.e., conservative assumptions and sensitivity analyses should be used until proprietary data become available.

Governance and accountability

- Models for licensing new operators, ensuring long-term waste responsibility in decentralised SMR systems; addressing geopolitical implications of cross-border waste transport.

Societal

- Research on risk assessment regarding RWM of decentralised SMRs/AMRs. Development of transparency and dialogue frameworks to improve societal trust. Design of SMR/AMR-specific participation frameworks, comparative studies of public engagement across EU member states, and analysis of cross-institutional mechanisms. Scenario assessment design.

PRIORITIZATION OF EFFORTS



Assessment of radioactive waste management and disposability technology readiness level (TRL) by reactor type (CoRWM, February 2024).

- Preparation for the back-end fuel cycle of non-LWR SNF (AMRs) will require considerable time and effort.
- LWR designs appear most likely for first deployments because they are more mature, with existing regulatory precedent (fuel, safety, operations).
- R&D focused on waste management for LWR-type SMRs can have the highest near-term impact but should target specific challenges.

ASTRA R&D WP

ASTRA Board



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

SUMMARY OF ASTRA R&D TOPICS IDENTIFIED

Long-Term Storage

- **Setup of a knowledge exchange**
 - E.g. end-of-life considerations of storage facilities and waste packages (direct exchange and support in between SIMS and LIMS countries)
- **Setup of a decision support system for end-of-life considerations of storage facilities and waste packages.**
 - developing and validating models and tools to predict waste package degradation, container alteration, and storage barrier performance over extended timeframes

Deep Borehole Disposal

- **Develop a generic Safety Assessment for operational safety**
- **Understanding impacts of heat sources on low flow environments.**
- **Guidance Framework to establish mutual trust with CS**

Alternatives for SIMS

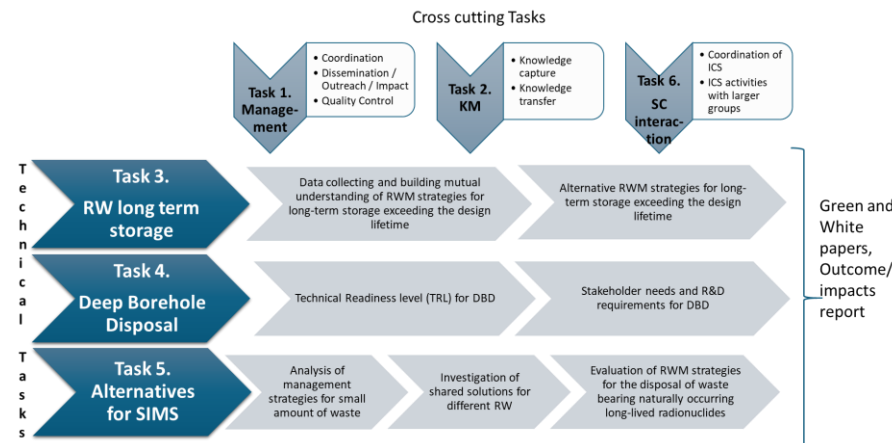
- **(TE)NORM and DU**
 - Reuse and Recycling
 - Waste Management Options (Pre-treatment, Conditioning, Cementation)
 - Disposal Programme and Site Selection
- **Damage State- and Damage Rate-Based Remediation Prioritisation for RWM**

KM

- **Live Discussion Forum: Continuation of direct communication (knowledge management) between SIMS-LIMS**
- **Setup of a demonstrator partnership of SIMS and LIMS partners (from all colleges WMO, TSO, RE, CS) to show how knowledge exchange should be organised in between SIMS and LIMS**

PROPOSAL FOR ASTRA R&D

- **The objective:** Continue research on alternative RWM topics interesting to SIMS
- **The expected added-value:**
 - Through live discussion forums (LDF), webinars and WSs ASTRA has created very active community including partners, associated partners, stakeholders and end-users, we would like to continue to utilize this in the follow up project
 - We already have established good working relations with the CS group involved in ASTRA. Their topics of interest fit well together with topics presented in this pitch, continuation of work would be easy.
 - We have good connections with existing projects working with similar topics (e.g. IAEA CRP on DBD, OECD-NEA MIRA, DG ENER pilot project), it is easy to avoid overlapping work and utilize networking
 - Present organization and way of working could continue



KM TOOL CREATED, AND THE NEED FOR A TOOL IDENTIFIED IN ASTRA

- **KM:**

- **Life Discussion Forum (LDF)**
Continuation of Live Discussion Forum (LDF) to support knowledge transfer expressed by SIMS and LIMS, offering a direct communication between both, building on the results from ASTRA Task 5.1 (Bornhöft's matrix), and having each year 6 technical and 1 civil society LDF, 1 workshop, and 1 survey resulting in a new Bornhöft's matrix to form topics for the next year, which will be cyclically performed every year and allow smooth transfer to, e.g., EURAD-3. Each year's deliverable will capture the knowledge created in LDFs.
- **SIMS–LIMS Pilot Demonstrator**
The SIMS–LIMS Demonstrator is a 3-year collaborative exchange designed to tackle practical SIMS radioactive waste management (RWM) challenges. Its goal is to solve selected SIMS issues with the help of MS with more advanced programmes (MAP) by analysing solutions, identifying best practices (across the whole waste management lifecycle) through targeted, problem-focused exchanges.





LONG-TERM STORAGE R&D TOPICS IDENTIFIED

- Setup of a **knowledge exchange partnership on waste characterisation, conditioning methods: database for use of tested and/or to be developed recipes for special (research, “historical”, ... wastes) end-of-life considerations of storage facilities and waste packages** (monitoring, repackaging options, ... as direct exchange and support in between SIMS and LIMS.
- Support of **end-of-life considerations of storage facilities and waste packages by digital twins for waste packages** to model/simulate waste package evolution (a follow-up activity of PREDIS WP7) – of interest for SIMS and LIMS. Subtasks include of **developing and validating models and tools to predict waste package degradation, container alteration, and storage barrier performance over extended timeframes, while also considering support legacy waste management aspects.**



DEEP BOREHOLE DISPOSAL R&D TOPICS IDENTIFIED

- **Develop a generic Safety Assessment for operational safety.** Including research into:
 - Overpack materials
 - Emplacement requirements (e.g., lift heights, shielding requirements)
 - Retrievability operations

Includes foundational Civil Society (CS) contribution.

- **Understanding impacts of heat sources on low-flow environments.**
- Use hydrogeological modelling to quantify the limits, in terms of maximum heat flow and hydraulic conductivity that would be acceptable, for deep borehole disposal.
- **Guidance Framework to establish mutual trust with CS,** especially with respect to a deep borehole field tests:
 - Strategies to include CS from the outset of the process
 - Transparent presentation of technical information

Research to include:

- Analysis of analogous case studies (e.g., geothermal, mined DGR) to identify successful / unsuccessful approaches.
- Enquiries and interviews with stakeholders.

ALTERNATIVES FOR SIMS R&D TOPICS IDENTIFIED

TE-NORM and DU

- **Waste Management Options (Pre-treatment, Conditioning, Cementation)**
Develop and compare waste management processes for TE-NORM and depleted uranium wastes across LIMS and SIMS to **establish unified procedures**. The work will evaluate **performance aspects** such as **strength, durability, longevity, leach resistance, and radiation stability** upon the **mixtures**) for final disposal, supporting technology transfer and harmonisation of waste treatment practices between countries
- **Safety Case Development and Post-Closure Assessment**
Develop **tailored safety case frameworks** and long-term **assessment tools**. This includes adapting **international safety methodologies**, creating **validated radiological models** for oxidising environments, and developing **generic scenario catalogues** (e.g., intrusion, erosion, climate change) to support Member States with limited modelling capabilities,
- Reuse and recycling: advancing the valorisation of waste streams, traditionally regarded as unusable, by developing **scalable decontamination and measurement methods** that enable their reuse and recycling in light of European sustainability ambitions. The goal is also to strengthen European expertise through collaboration, **modelling, experimentation, and standardisation**.

- **Damage State- and Damage Rate-Based Remediation Prioritisation for RWM**
Developing a **protocol for radioactive waste management in slow-developing catastrophic scenarios**, including the development of time-dependent response strategies for diverse events, integrating historical lessons, site remediation urgency graded classifications, and sustainability assessments (sLCA, LCCA, LCA) to **prioritise remediation actions**, including the shared solutions, particularly **supporting SIMS in planning and resource allocation**. CS will be integrated into the task to contribute a solution to the **ethical questions** dealing with “**acceptable collateral damage**” caused by negative scenarios.

EXPERIMENTAL INVESTIGATION OF NUCLIDE COMPOSITION IN SF FOR POST-CLOSURE CRITICALITY SAFETY

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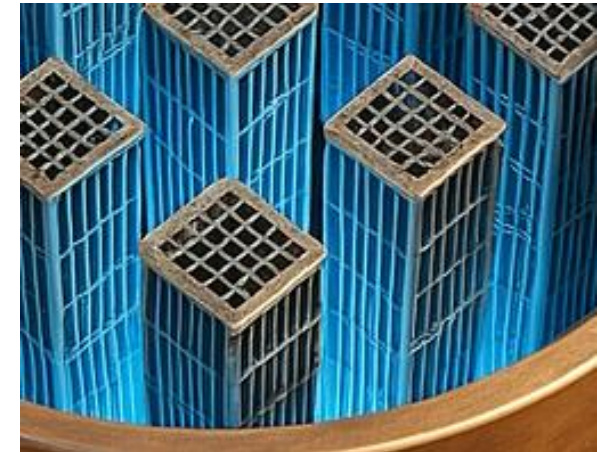
Alexander Vasiliev, PSI, RE



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OBJECTIVE

- Demonstrating the criticality safety of a final disposal concept over very long timescales, in the post-closure phase, is a complex and difficult endeavour.
- One challenge relates to the validation of models and assumptions related to material properties and behaviour
 - Results in large uncertainties
 - And difficulties knowing if the safety margin is appropriate or if there are unnecessary conservatisms
- **SNF in PCCS**
 - Large variation in build-up of nuclides due to operation
 - Many nuclides in high-burnup fuel - difficult to do and find experiments that targets all
 - Composition after 100 000 years
- **Nuclides also in:**
 - Radiation shielding and decay heat measurements
 - Fuel characterisation by neutron and gamma measurements
 - Fuel dissolution
- *Nuclide composition is a fundamental in several assessments – more data, better knowledge*





THE SCOPE

- Method development and non-destructive measurements
- Develop underpinning theories
- Understand how different types of investigations related to fuel characterisation can be used also for criticality assessments
- **Most important aspects:**
 - Develop methods for the targeted use of experimental data in validation for PCCS by
 - Investigate if and how other databases could be used for validation for criticality assessments
 - How to select experiments suitable for PCCS
 - Review current ND libraries with focus on PCCS

THE EXPECTED ADDED-VALUE - OUTCOMES

- Expand the experimental basis
- Understand variations and reduce conservatisms in criticality assessments
- Continue previous work in EURAD:
 - WP8 - SFC: Spent fuel characterisation and evolution until disposal:
 - “A non-destructive method to determine the neutron production rate of a sample of spent nuclear fuel under standard controlled area conditions”, JRC TR 2020
 - “*..can be applied for more innovative applications ... to determine non-destructively the nuclide vector of a SNF sample*”
 - WP10 - UMAN:
 - The aspects with the largest uncertainty and high safety significance were related to the conditions of the fuel, e.g. *irradiation conditions, burnup and respective isotopic composition in case of burnup credit.*
- WP8 SAREC
 - Criticality, BUC: nuclides that remain in the fuel matrix
 - Radionuclide release: nuclides that are dissolved from the matrix
- Seek to further combine the areas that rely on SNF characterisation

**THANK YOU
FOR YOUR ATTENTION**



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