

EURAD-2 SECOND WAVE

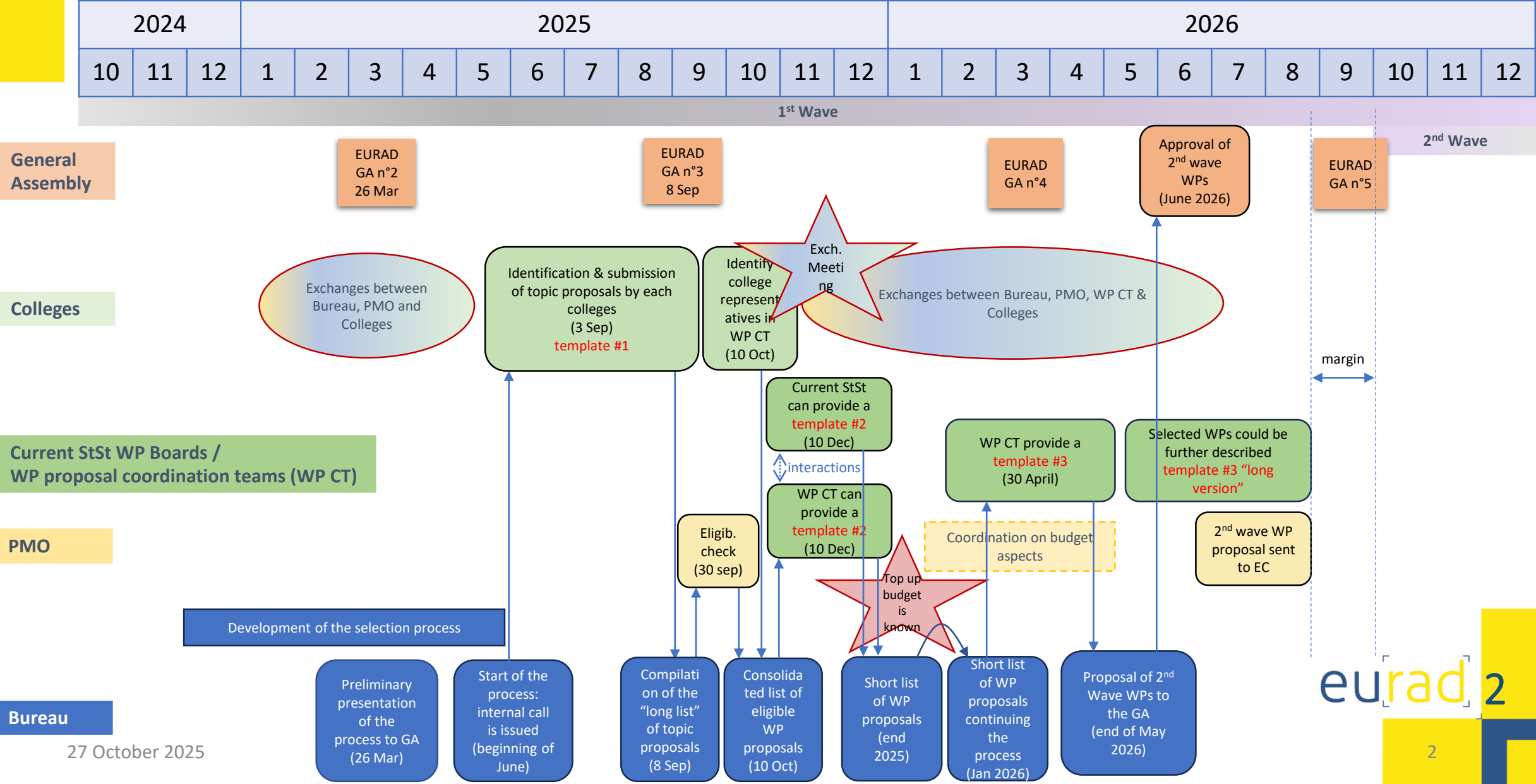
RD&D and StSt WP selection process

Webinars to assist templates #2 preparation

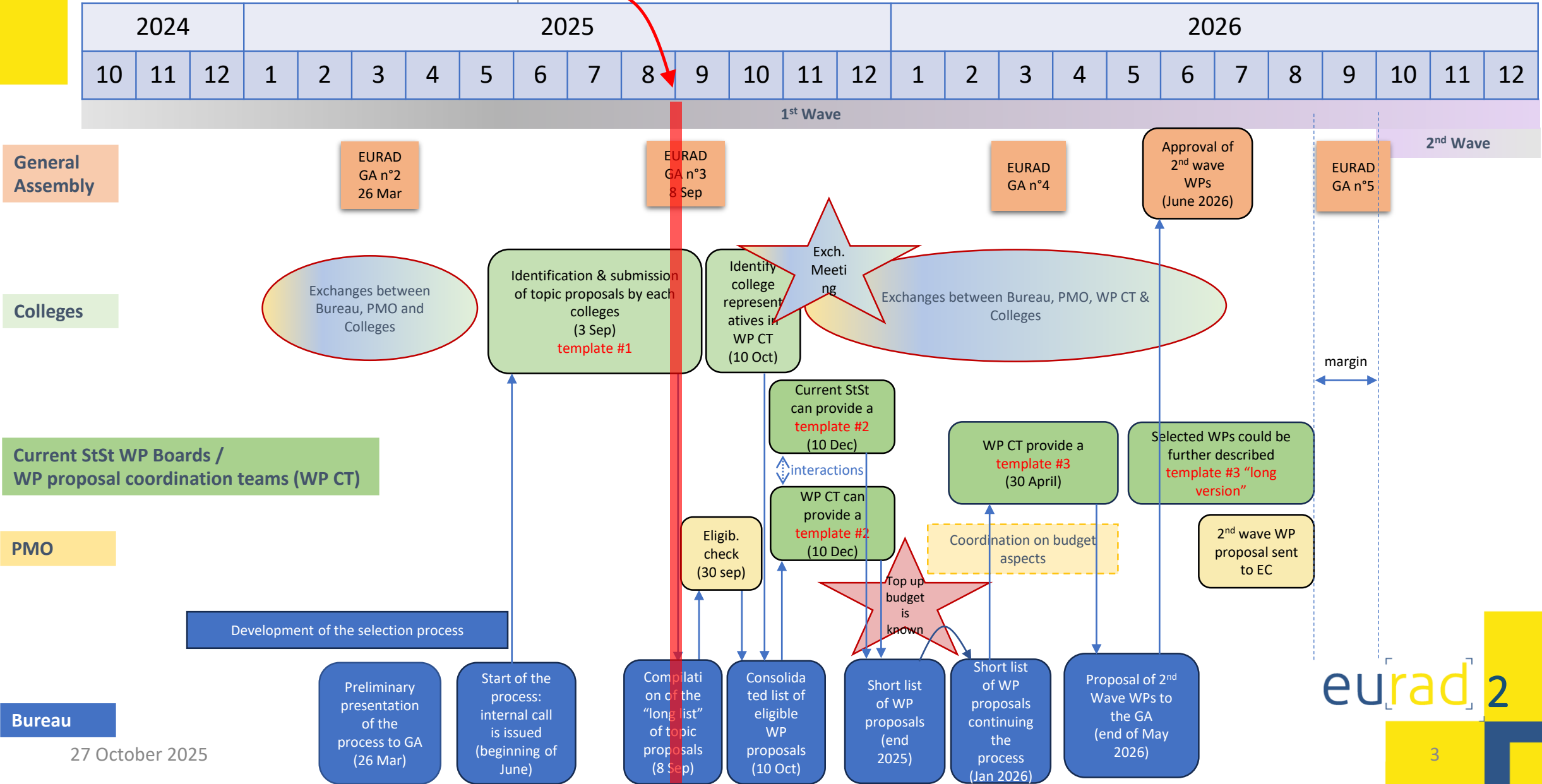


Co-funded by the European Union under Grant Agreement n° 101166718

SELECTION PROCESS: OVERVIEW



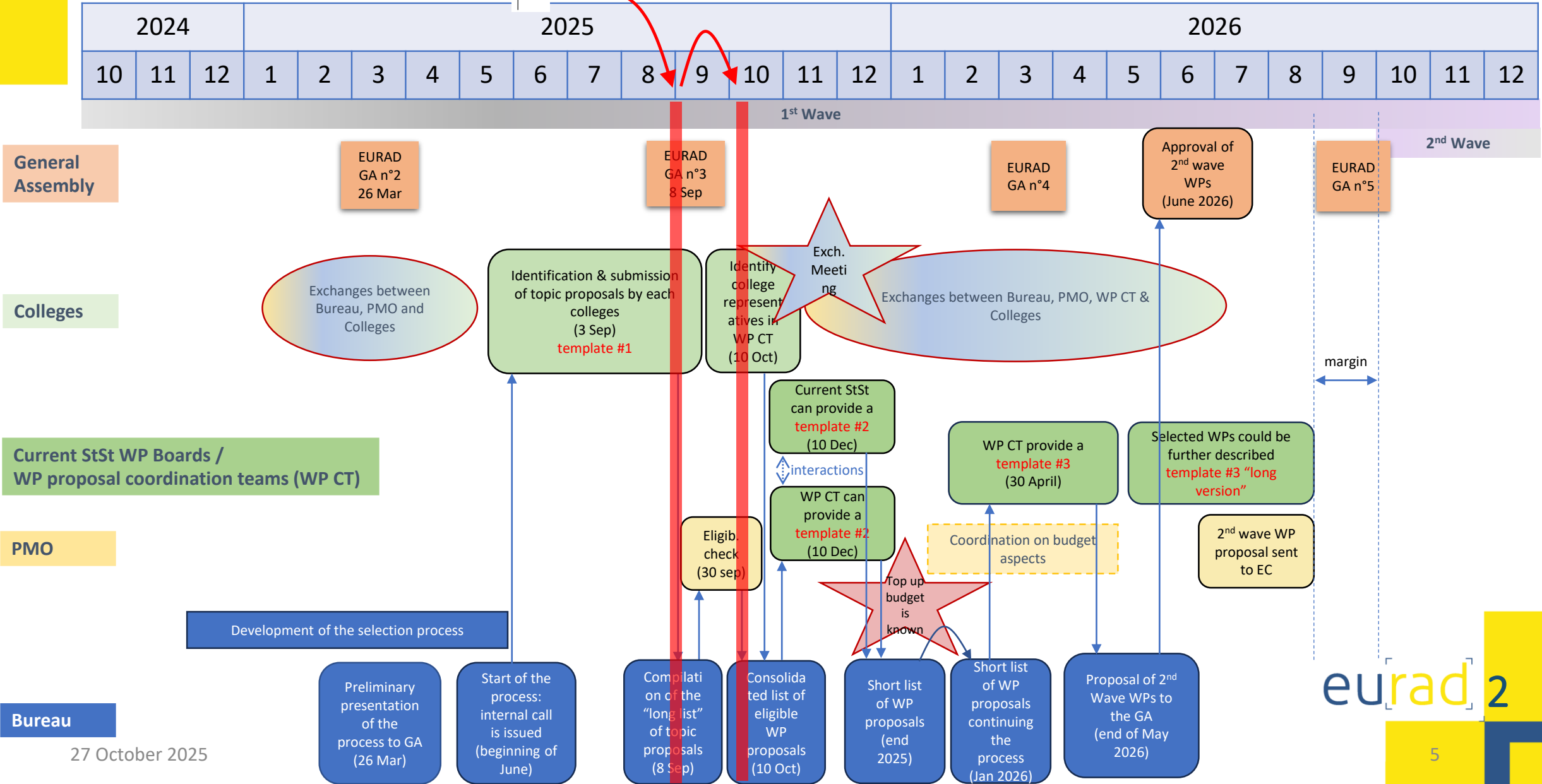
SELECTION PROCESS: OVERVIEW



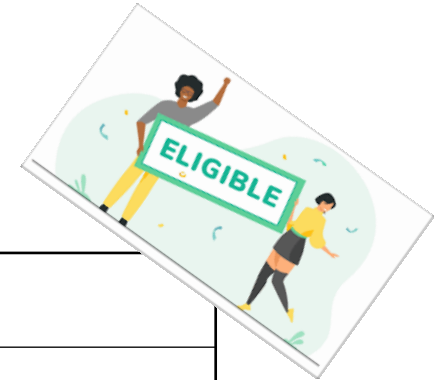
3/09/2025: LONG LIST OF TOPIC PROPOSALS

	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

SELECTION PROCESS: OVERVIEW

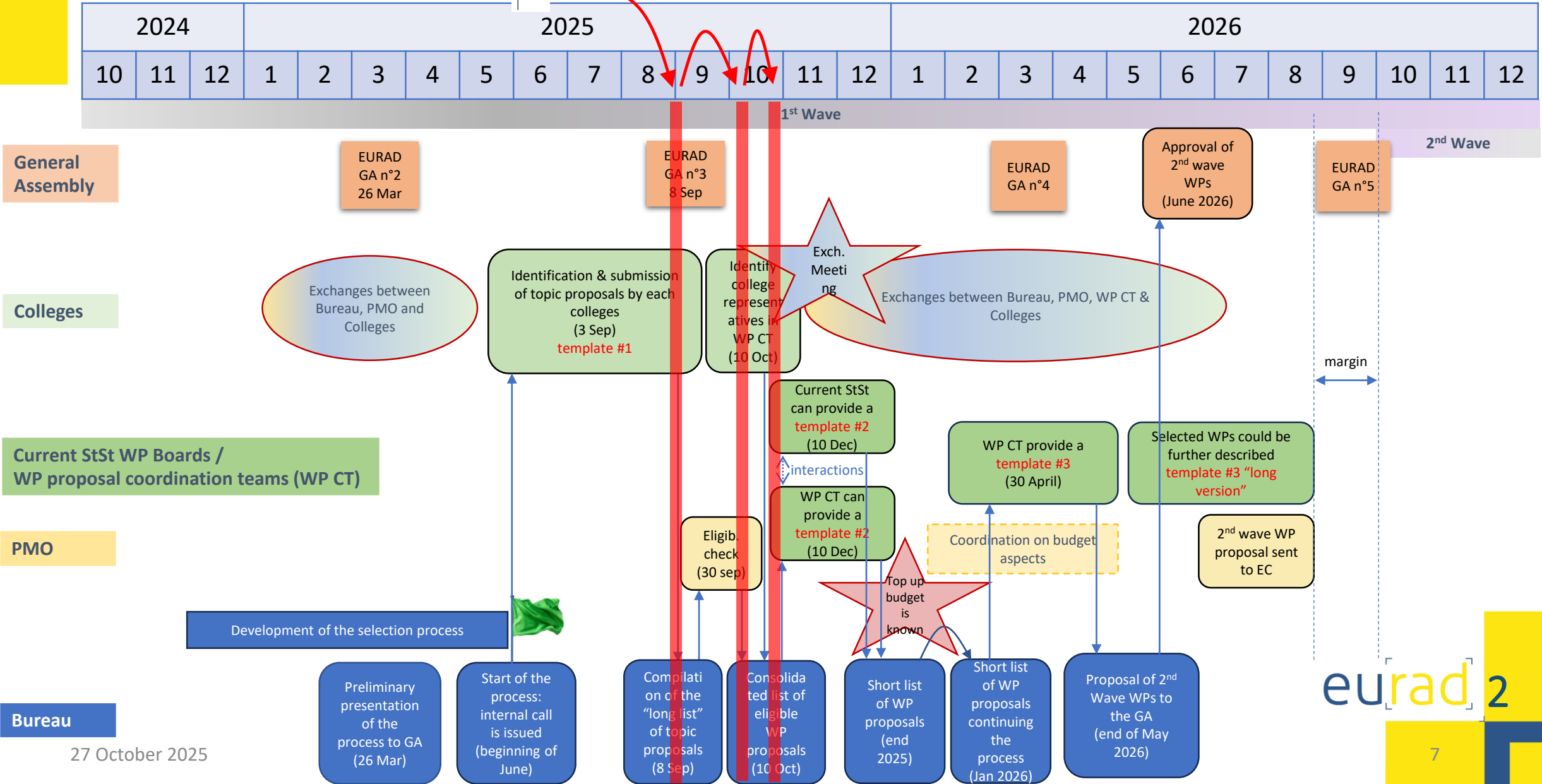


30/09/2025: ALL TOPICS IN THE LONG LIST ARE ELIGIBLE



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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)
		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

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
StSt Topics	StStWP1	Operational scientific data management	X			simone.tillmann@bge.de	nadja.zeleznik@eimv.si deputy: nataline.simon@asn.fr	camelia.ichim@nuclear.ro
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	StStWP3	Guidance for European (TE)NORM & DU enabled strategies for integrated stewardship		X		enga@enresa.es	yv_kydrashova@sstc.ua deputy: konrad.lotter@ages.at	fidel.grandia@amphos21.com
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		Natural Analogues: Strategic review of holistic utilisation of NAs in radioactive waste disposal (NATSTRAT)			X			
	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 30/11/2025, at a special Bureau meeting with College leadership organisations and representatives of corresponding templates #1



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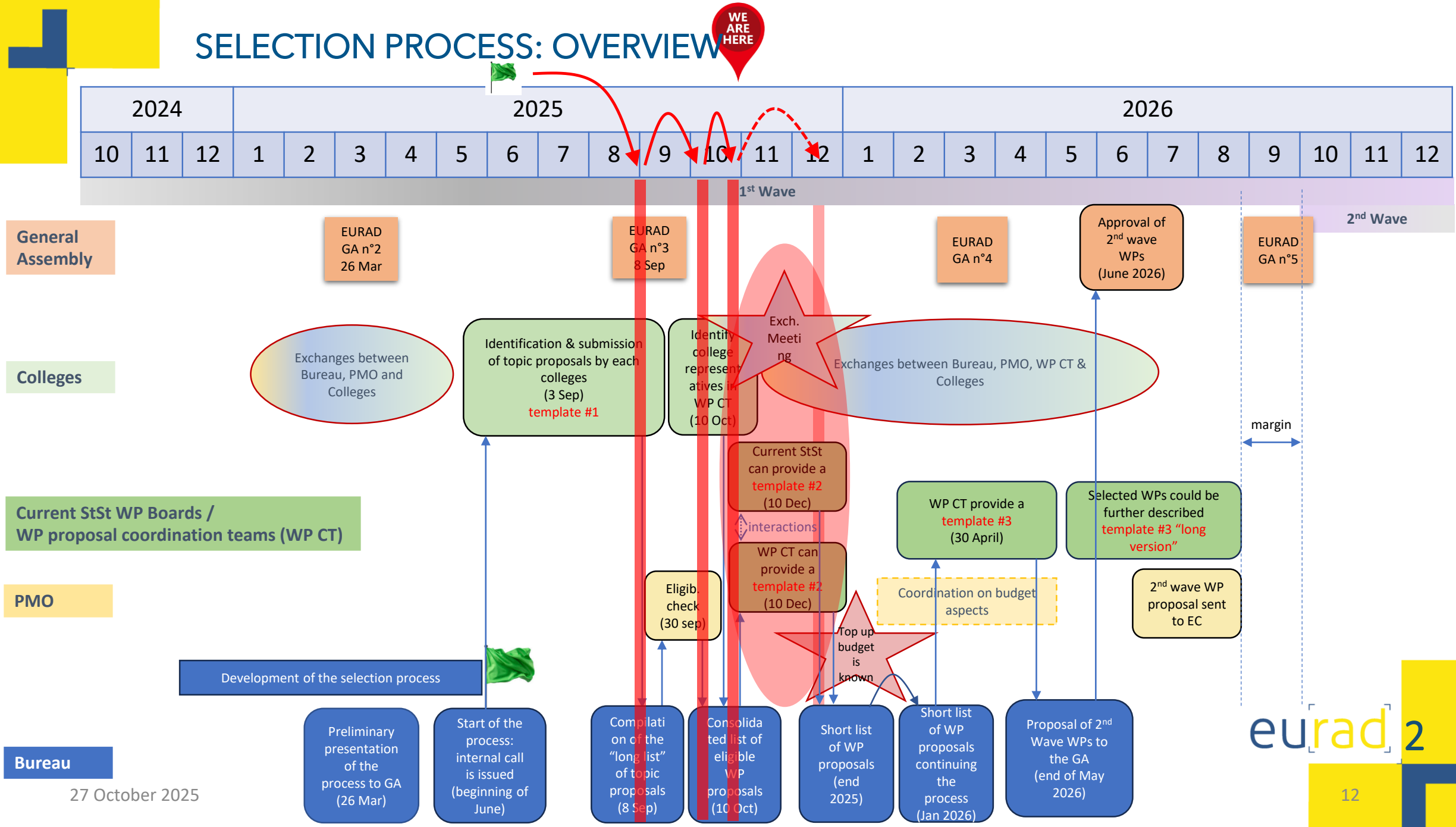
NOMINATED WP CTS

- 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.

EBS MATERIALS

RE: Janez Perko, SCK CEN

TSO: Oliver Czaikowski, GRS (deputy: Alexandre Dauzeres, ASNR)



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



EBS MATERIALS

- Objective: Finding innovative solutions that promote **sustainability, robustness and long-term safety** of radioactive waste disposals
- Approach for the selection of topics
 - Main topic is about materials
 - Finding solutions for existing challenges with radioactive waste disposals
 - Study of possible solutions for future steps in disposal related to materials
- Merging of RE and TSO proposals
 - RE: Materials for enhancing passive safety and robustness of engineered systems
 - TSO: Backfilling materials for disposal

Indicators and assessment of sustainable EBS

- Identification of criteria and **indicators** for assessing the **sustainability** of EBS materials and approaches
 - Economic
 - Social
 - Environmental
- Stakeholder and expert validation of the framework
- Monitoring of indicators along the execution

Applying advanced industrial techniques to improve durability of metallic disposal containers

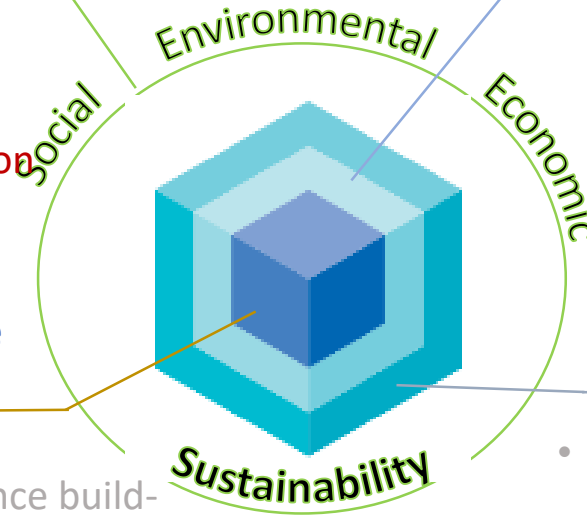
- Application of industrially available high-performance build-up welding processes
- Investigation of improved manufacturing techniques for producing non-metallic protective coatings (ceramics, enamel)
- Development of radiation-resistant concretes that can be used under conditions of simultaneous exposure to ionizing radiation and elevated temperatures.

Develop sustainable innovative backfill materials to allow for waste matrix swelling and gas generation

- Development of innovative cementitious composite backfill materials to accommodate for expansive processes including gas production and passive -protection of other engineered barriers from mechanical degradation.
- Development of backfill material that reduces stresses on barriers in case of gas generation

Reuse and repurposing of closure/backfill material

- Reusing of endogenous material after long term exposure to environmental conditions or introducing exogenous materials.
- Potential impact of the material on the environment during the surface storage period.
- Repurposing of excavated materials for its use as EBS material (liners, components,...)



Indicators and assessment of sustainable EBS

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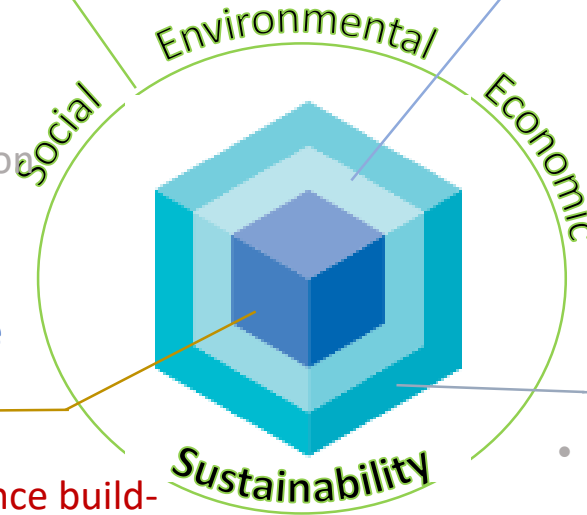
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Indicators and assessment of sustainable EBS

- Identification of criteria and indicators for assessing the sustainability of EBS materials and approaches
 - Economic
 - Social
 - Environmental
- Stakeholder and expert validation of the framework
- Monitoring of indicators along the execution

Applying advanced industrial techniques to improve durability of metallic disposal containers

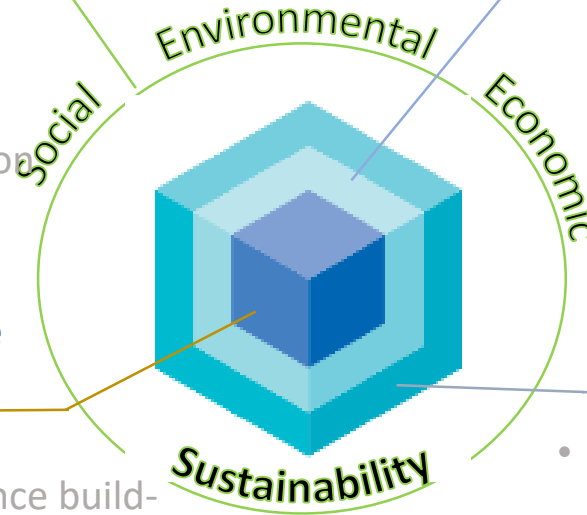
- Application of industrially available high-performance build-up welding processes
- Investigation of improved manufacturing techniques for producing non-metallic protective coatings (ceramics, enamel)
- Development of radiation-resistant concretes that can be used under conditions of simultaneous exposure to ionizing radiation and elevated temperatures.

Develop sustainable innovative backfill materials to allow for waste matrix swelling and gas generation

- Development of **innovative** cementitious composite **backfill materials** to accommodate for **expansive** processes including **gas** production and passive -protection of other engineered barriers from mechanical degradation.
- Development of backfill material that **reduces stresses on barriers** in case of gas generation

Reuse and repurposing of closure/backfill material

- Reusing of endogenous material after long term exposure to environmental conditions or introducing exogenous materials.
- Potential impact of the material on the environment during the surface storage period.
- Repurposing of excavated materials for its use as EBS material (liners, components,...)



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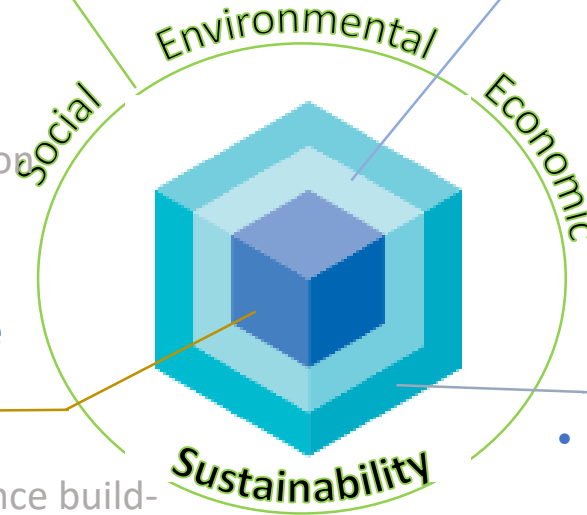
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Reuse and repurposing of closure/backfill material

- **Reusing of endogenous material** after long term exposure to environmental conditions or **introducing exogenous materials** with the evaluation of impact of the material on the environment during the surface storage period.
- **Repurposing of excavated materials** for its use as EBS material (liners, components,...)



Indicators and assessment of sustainable EBS

- Identification of criteria and **indicators** for assessing the **sustainability** of EBS materials and approaches
 - Economic
 - Social
 - Environmental
- Stakeholder and expert validation of the framework
- Monitoring of indicators along the execution

Applying advanced industrial techniques to improve durability of metallic disposal containers

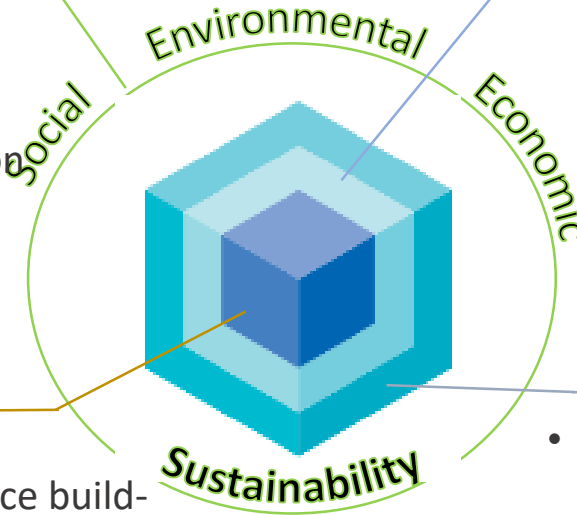
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DEVELOPING SITE SCREENING STRATEGIES AND PROCEDURES FOR INTEGRATED SITE DESCRIPTIVE MODELS

Proposal by the Research Entities College:

Kiczka, M.¹; Engström J.²; Kuehn, M.³; Kolditz, O.⁴; Bucur, C.M.⁵; Levizzari, R.⁶; Trinchero, P.⁷; Zlobenko, B.⁸; Peetermans, S.⁹; Griffiths, J.¹⁰; Haines, T.¹¹; Poskas, G.¹²; Ziefle, G.¹³

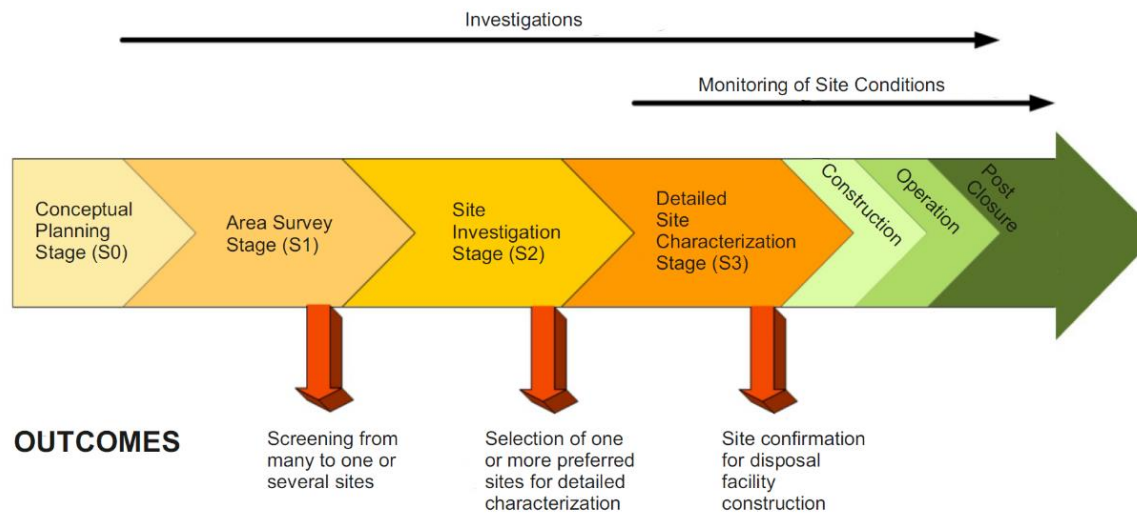
¹ UniBern, Switzerland; ² GTK, Finland; ³ GFZ, Germany; ⁴ UFZ, Germany; ⁵ RATEN ICN, Rumania; ⁶ ENEA, Italy; ⁷ Amphos21, Spain; ⁸ SIIEG NASU, Ukraine; ⁹ Tractabel-engie, Belgium; ¹⁰ UKNNL, UK; ¹¹ Galson-Sciences, UK; ¹² LEI, Lithuania; ¹³ BGR, Germany



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

OBJECTIVES AND ADDED VALUE FOR NATIONAL PROGRAMMES

Guidance on developing site descriptive models based on siting criteria catalogues and by providing robust workflows that i) integrate various disciplines, ii) improve the models as the siting process progresses through its successive stages and iii) include the long-term evolution of a site



- **Compilation and improvement of best practices** for siting strategies, criteria and site descriptive models
- **Reference framework** with workflows for progressive development of site descriptive models and long-term evolution models
- **Strengthening credibility** of site-specific management of uncertainties and ensuring continuous improvement and adaptability of models to new data and interpretation

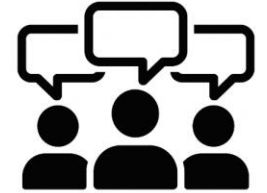
SCOPE OF WP – PRELIMINARY DEFINITION OF TASKS

Task 1) Development of policies and best practices for

- Site screening strategies (e.g. GIS based analysis processes)
- Geoscientific, environmental and socio-economic siting criteria
- Communication



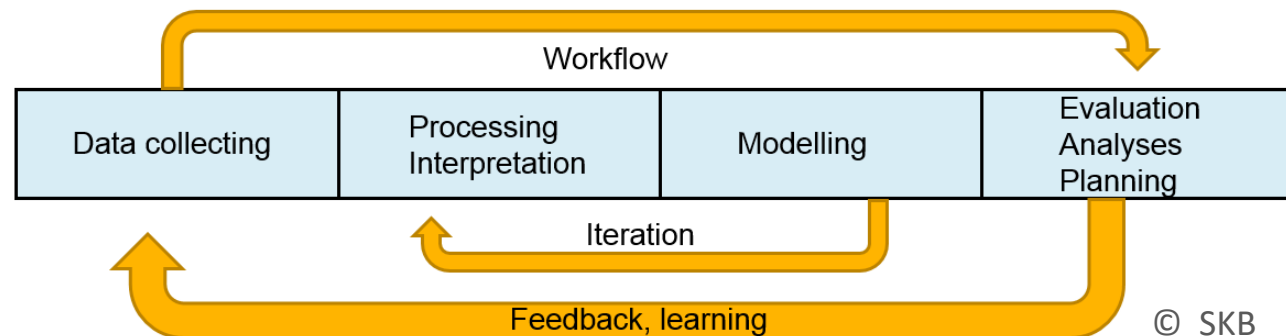
**LITERATURE
REVIEW**



**EXCHANGE
WITH
END-USER ENTITIES**

Task 2) Development of progressing site descriptive models in connection to siting stages and conditions

- Predictive-outcome approaches
- Feedback loops
- Stepwise and iterative modelling approaches

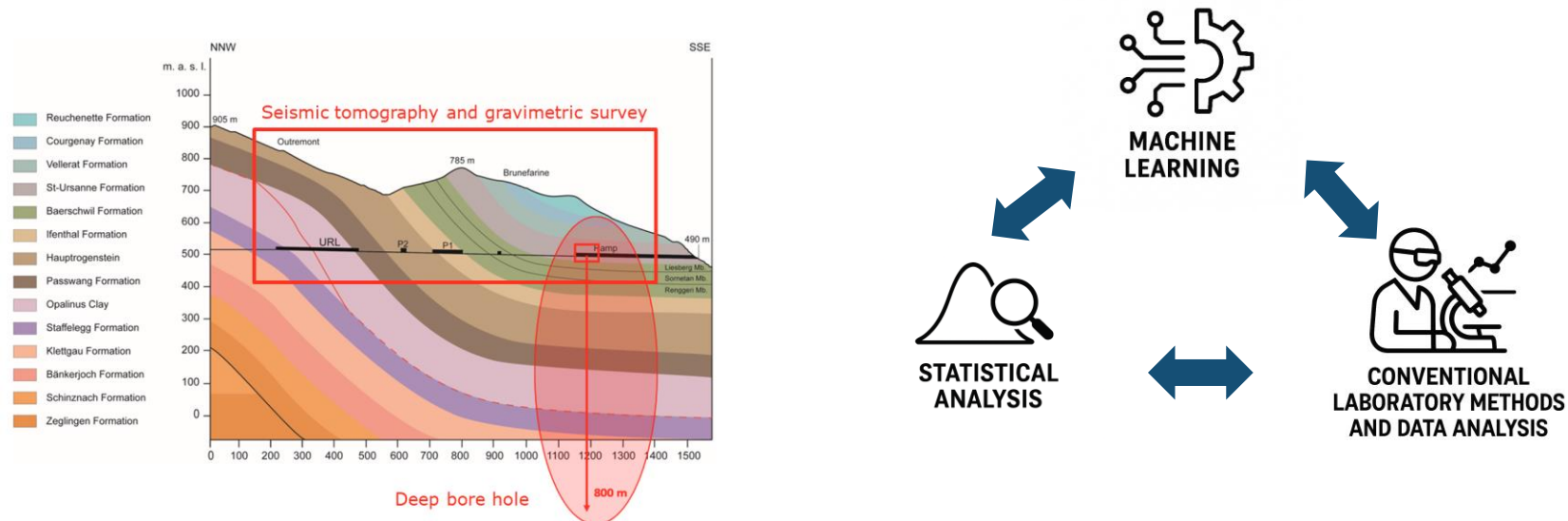


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SCOPE OF WP – PRELIMINARY DEFINITION OF TASKS

Task 3) Comprehensive set of methods for fast and efficient evaluation of borehole data

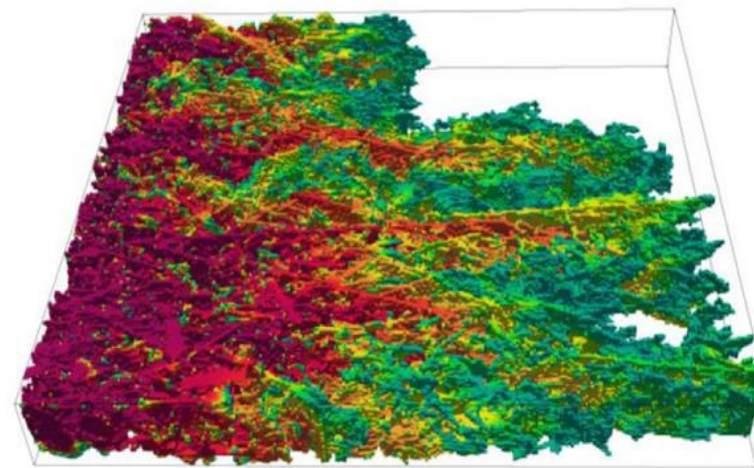
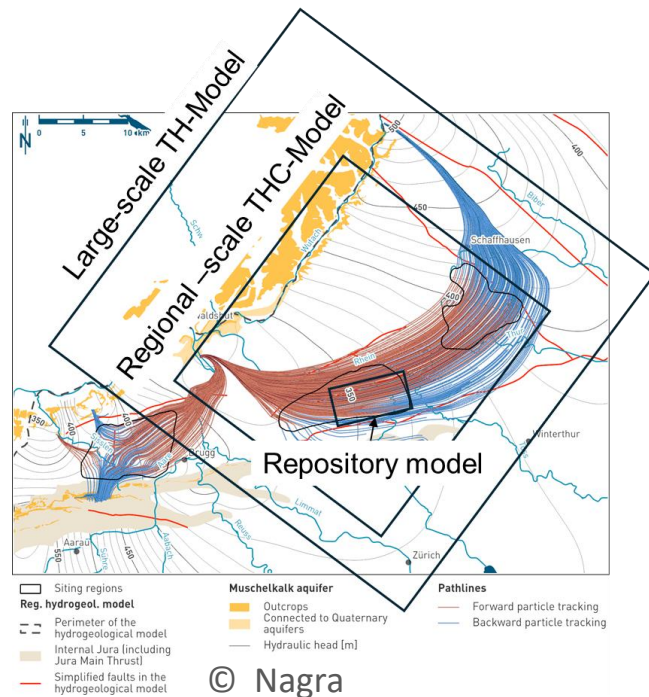
- Machine learning methods
- Statistical approaches
- Comparison of new methods with conventional data analysis methods
- Developing tools for upscaling and sensitivity analysis
- Definition of required parameter sets for different siting stages



SCOPE OF WP – PRELIMINARY DEFINITION OF TASKS

Task 4) Tools and workflows towards integrated models for assessment of long-term evolution of disposal facility and surrounding geosphere

- Enhancement of numerical tools for coupling of subsidiary models
- Building of integrated geosphere models
- Palaeo -hydrological models as key for understanding long-term solute transport



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KEY SCOPE & OUTPUT FOR WP ON SITING

- Benchmarking best practices for siting strategies
- Framework for the progressive development of site descriptive models during all siting steps
- Improving credibility and robustness of site-specific data management and mitigating uncertainties

THANK YOU FOR YOUR ATTENTION AND LOOKING FORWARD TO QUESTIONS

ASSESSING THE END USER GAPS AND NEEDS ON THMC(B) PROPERTIES OF HOST ROCK – DEFINING A COMMON STRATEGY

RE college

A. Dizier, E. Jacops, N. Maes - SCK CEN

R. Cuss - BGS

H. Reijonen - GTK

C. Bucur - RATEN

M. Kiczka - UniBern



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

CONTEXT

- 40+ years of studies to characterise THMC(B)+GAS behaviour of clayey rock formations and clayey EBS materials
 - Past and current EURAD projects: EURAD GAS / HITEC and EURAD-2 ANCHORS
 - Past EC projects + national programmes
- All these programmes investigate phenomena from small-scale (mm to cm) to in situ experiments (dm to dam)
- A systematic upscaling to repository-scale implementation is still missing



MAIN QUESTIONS

- Does the existing THMC(B) + GAS knowledge base fully support understanding of the long-term performance of a geological disposal facility (GDF)?
- What are the main uncertainties?
 - Where does our understanding remain insufficient with respect to the different disposal concepts (clayey host rock / clayey EBS materials)?
 - How can uncertainty reduction (knowledge / intrinsic variability) help improve the robustness of safety cases?
- What do we actually need to upscale and how can we proceed from the perspective of the large scale safety analyses (relevance, sensitivity)?

STRATEGIC STUDY – GOALS

- The objective is to systematically identify knowledge gaps and prioritize research needs related to the upscaling of THMC(B) processes and gas transport, and to understand how properties can be derived in clayey host formations and clay-based engineered barrier systems (EBS)
- Ensure mutual benefits across all programmes
 - Engagement with end-users of national programmes will take place at all stages to incorporate the needs of both early-stage and advanced countries

Link to EURAD SRA \ Themes

Engineered Barrier Systems (Theme 3)
Geoscience (Theme 4)
Disposal facility design and optimisation (Theme 5)
Safety Case (Theme 7)

EURAD Roadmap insight

4.2 Perturbations
4.4 Geosynthesis
7.1 Safety strategy

SRA Drivers

Scientific insights

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TASKS OF THE STRATEGIC STUDY

TASK 1 Management

TASK 2 Knowledge management

Develop a comprehensive and uniform synthesis of the state of the art of THMC(B) coupling in clayey host rocks / clayey EBS materials by integrating previous projects (EC and national projects)

TASK 3 Identification of Knowledge Gaps in THMC(B) Behavior in the perspective of upscaling

Use the review process of Task 2 to identify gaps and link findings with ongoing projects and national programme needs to ensure relevant upscaling

TASK 4 Proposal of a common strategy

Translate defined THMC(B) gaps into actions to define and develop a strategic framework from early-stage to more advanced research programs



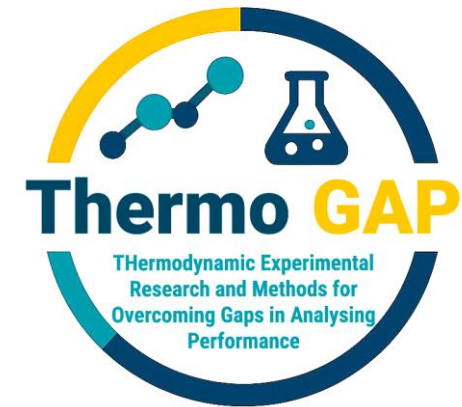
Already 17 interested partners over 11 countries

- SCK CEN (Belgium)
- BGR(Germany)
- BGS (United Kingdom)
- CNRS/Navier (France)
- CNRS/ULorraine (France)
- EURIDICE (Belgium)
- EPFL (Switzerland)
- GTK (Finland)
- LEI (Lithuania)
- RATEN (Romania)
- TU Delft (Netherlands)
- TU BAF (Germany)
- UFZ (Germany)
- UKNNL (United Kingdom)
- ULiège (Belgium)
- UniBern (Switzerland)
- UPC/CIMNE (Spain)

Pitch DITUSC StSt WP (Development and Improvement of Quality Assured Thermodynamic Understanding for use in Nuclear Waste Disposal Safety Case)

Xavier Gaona (KIT-INE), Stéphane Brassinnes (ONDRAF/NIRAS), Jenna Poonoosamy (JFZ), Eli Colas (Amphos21) and George-Dan Miron (PSI)

ThermoGAP: Thermodynamic Experimental Research and Methods for Overcoming Gaps in Analysing Performance



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

OBJECTIVE AND TARGETS

Technical content – to be further developed

- Strong interest from the partners to prepare a Wave 2 R&D proposal: ThermoGAP
- OBJECTIVE: Development of thermodynamic data and understanding in support of radioactive waste disposal Safety Cases and beyond. Focus on experimental and estimation approaches
- Scope to be defined collectively on the basis of data gap analysis and subsequent prioritization (done with interested END-USERS and WPLs at the 2nd DITUSC workshop, on 19-20.11, Nantes)
 - => Inputs for DITUSC White paper => First full draft scheduled for 12.2025
- Relevant aspects:
 - FOCUSED: much narrower scope than DITUSC (3 years, priority-driven)
 - Input from END-USERS (especially WMOs) is key to success (!)
 - => CSO @ Bologna's meeting: *"What the end-users don't use, we should not be doing ..."*
 - => Strong EUG in DITUSC: Andra, Nagra, SKB, NWS, COVRA, ENRESA, NWMO, KORAD, IFIN-HH, DSA, Swedish Radiation Safety Authority, ...
 - Continued interest of TSOs and REs

OBJECTIVE AND TARGETS

Technical content – to be further developed

- List of potential high-level topics (subject to Prioritization at DITUSC 2nd workshop → establishment of a shortlist !):
 - Solubility products of relevant phases (including geo-technical barriers, new materials such as new cement-based, ...)
 - Relevant complexes (organics, Si-based, ternary)
 - RN & Chemotoxic elements
 - Perturbations: Temperature (attention to SOTA NEA-TDB), saline systems
 - Kinetics: solid phase transformation, inorganic redox disequilibrium
 - Incorporation in solid-solutions
- What we do NOT plan:
 - Modelling, beyond the development of the thermodynamic models themselves
Need to stay focused (!), limited time and funding
- Instead => synergies with modelling initiatives in on-going R&D WP

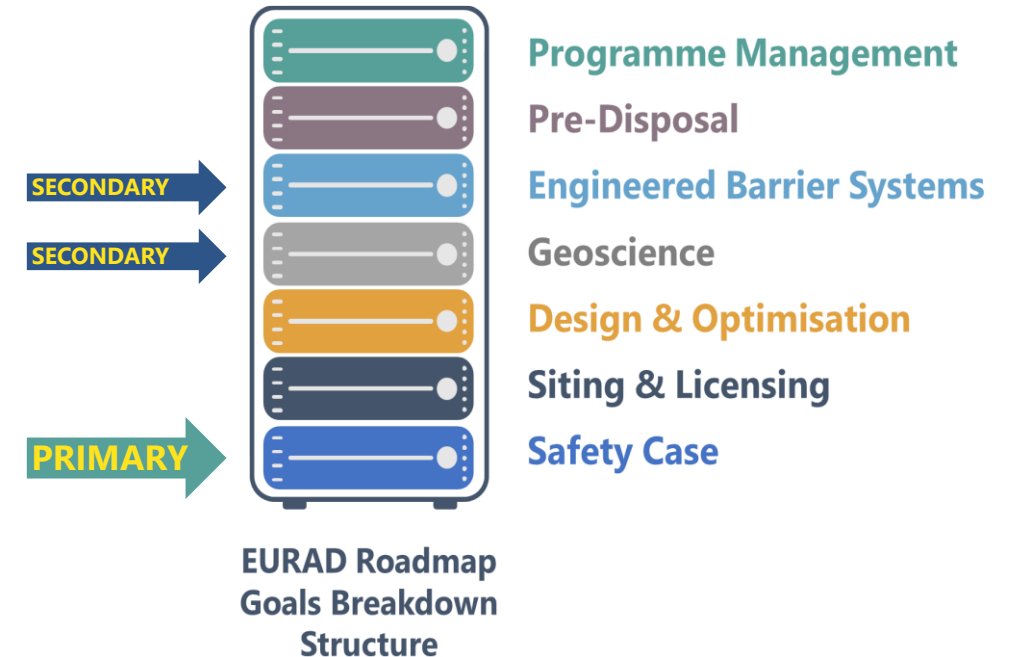
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REQUIREMENTS AND ADDED VALUE FOR CONSORTIUM AND EUROPEAN RADWASTE COMMUNITY

Maximisation of value and use for the radwaste community

- Links with EURAD SRA and Roadmap =>
- Links with IGD-TP SRA
- Synergies with on-going EURAD-2 WP: on-going contacts with RAMPEC, SAREC, HERMES, InCoManD: Datagaps from WPs; Inputs to WPs modelling activities
- Synergies with main EU TDB's, from low (ThermoChimie, NAGRA-PSI) to high (THEREDA, Thermoddem / PhreeScale) ionic strength systems
- Needs of Small Inventory Member States => 2nd DITUSC workshop (!)
- Links with Civil Society => 2nd DITUSC workshop (!)
- Strong international interest in DITUSC: US, Japan, Korea as AP and EUG
- Education of young researchers and training events



2ND OPEN WORKSHOP

NANTES

DEVELOPMENT AND IMPROVEMENT OF THERMODYNAMIC UNDERSTANDING FOR USE IN NUCLEAR WASTE DISPOSAL SAFETY CASE

19-20 November 2025

- (i) Feedback survey
- (ii) Prioritization of knowledge/data gaps in relation to the Safety Case

REPOSITORY SITE FLOW AND TRANSPORT MODELS

R&D WP6

Pirjo Hellä (VTT, TSO), Susan Britz (GRS, TSO)

Michael Schnellmann (NAGRA, WMO), Jon Engström (GS Finland, RE)

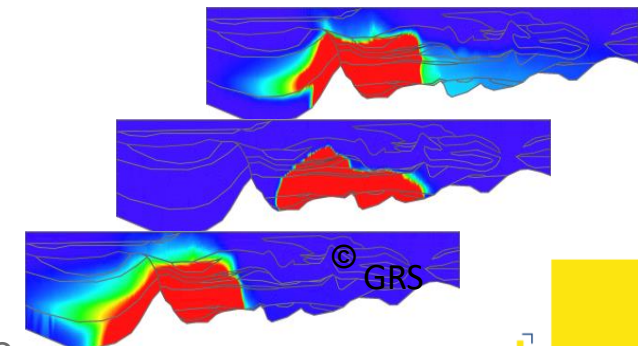
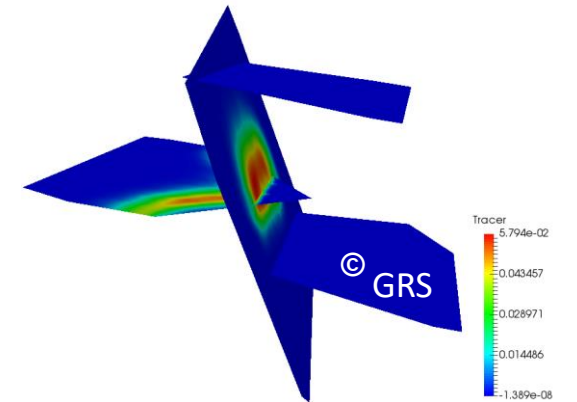
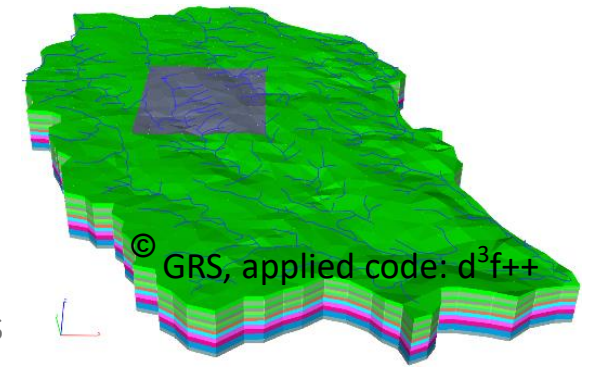
Interested organisations: ASNR, SKB, EDF R&D as an affiliated entity of CEA, SSM as end user



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

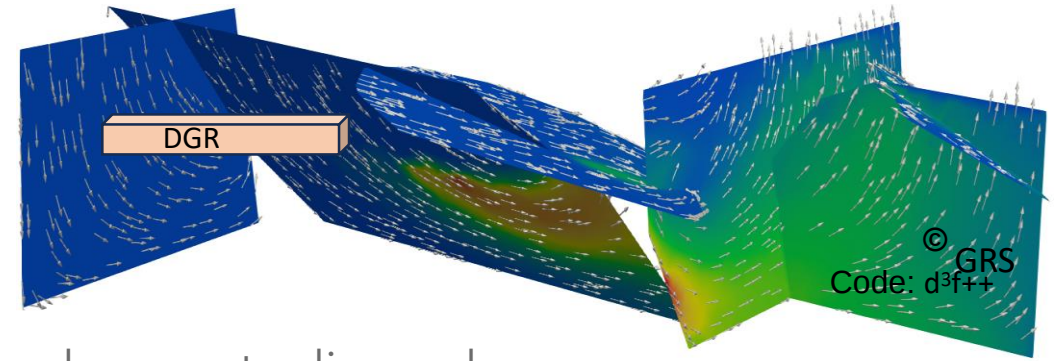
MOTIVATION

- Advanced and complex groundwater flow and transport models for DGRs make the assessment of confidence in modelling results challenging
 - How can we **trust** the outcome of our models?
 - **How** do we improve our modelling results?
 - What kind of **data** is essential for my needs?
 - Would more data **improve** my modelling results? If yes, what kind of data should we include?
 - Which model is **suitable** for my unique question I want to tackle?
 - Which **codes** are available? What are their advantages?
- It is no about whether the available codes produce trustworthy results rather than which code to pick and how to assess the confidence of these results.



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ENVISIONED SCOPE



- **Improvement of confidence** in long-term safety of nuclear waste disposal
→ Show/develop ways to better demonstrate that our models have a prediction capability over the safety relevant timescale, e.g. reproducing the geological past and current state with the same models as future prediction)
- **Development of a benchmark study** to get a bird's eye view on the modelling process
→ Recommendation of modelling approaches that **balance model complexity, data needs, computational costs and accuracy** of the models
- Support selection of **innovative modelling approaches** and design recommendations of tools to answer unique questions

Far field
processes of a DGR

Relevant processes
(data acquisition, hydrodynamic flow fields, permafrost, large scale, chemistry, density-driven flow, computational costs etc.)

Design of benchmark using **case studies** and/or **generic approaches**

Reveal undiscovered questions, highlight advantages of available codes

APPROACH: UNDER CONSTRUCTION AND OPEN FOR DISCUSSION

- Cooperation with interested institutes to involve pioneer and cutting-edge codes for groundwater flow and transport problems
- Definition of suitable case studies/benchmarks
- Review and comparison of existing groundwater flow and radionuclide transport codes
- Benchmarking the modelling process not the codes
- Identifying gaps/advantages in the representation of processes
- Data worth analysis to determine the role of key data requirements
- Uncertainty analyses
- Evaluation of how these codes/models handle evolving boundary conditions
- Assessment of the robustness, adaptability, and transferability of current modelling practices
- Utilization of advanced innovative computing technologies

MOGARE (MODELLING OF GAS BEHAVIOR AND MIGRATION AT THE REPOSITORY SCALE)

WMO college:

J. Talandier, J. Wendling, Andra

L. Kegel, ARAO

W. Rühaak, BGE

J. Bartol, COVRA

A. Papafotiou, NAGRA

S. Levasseur, ONDRAF

M. Laszlo, PURAM

M. Rasmusson, S. Hedström, SKB



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

CONTEXT

- Predicting the fate of gases is a crucial element in assessing the long-term safety of a repository
- In the recent past, two European projects were devoted to the issue of gases in deep underground radioactive waste repositories:
 - [FORGE \(2009-2013\)](#)
 - [EURAD-GAS \(2019-2024\)](#)
- However, in these projects, the tasks dedicated to performance assessment at the repository scale were designed to arrive downstream of the experimental results produced by the other tasks
- These projects therefore did not focus on the development of performance evaluation programs at the scale of a complete repository

Link to EURAD SRA / Themes:

- [Engineered Barrier Systems \(Theme 3\)](#)
- [Disposal facility design and optimization \(Theme 5\)](#)
- [Safety case \(Theme 7\)](#)

EURAD Roadmap Domain Insight

- [3.4.1 EBS System](#)
- [5.1 Design](#)
- [7.3.1 Performance assessment and process models](#)

SRA Drivers:

- [Implementation Safety](#)
- [Scientific Insight](#)
- [Knowledge management](#)

OBJECTIVES AND ADDED-VALUE

The main objective of this WP is to [provide new advances](#) (compared to the one provided in EURAD-GAS) for better consideration of gases in the long-term safety and in the [optimization of the EBS](#), which could be used by WMOs to [optimize repository concepts](#) and could [increase the confidence of the various stakeholders](#) (TSO and public) regarding gas considerations.

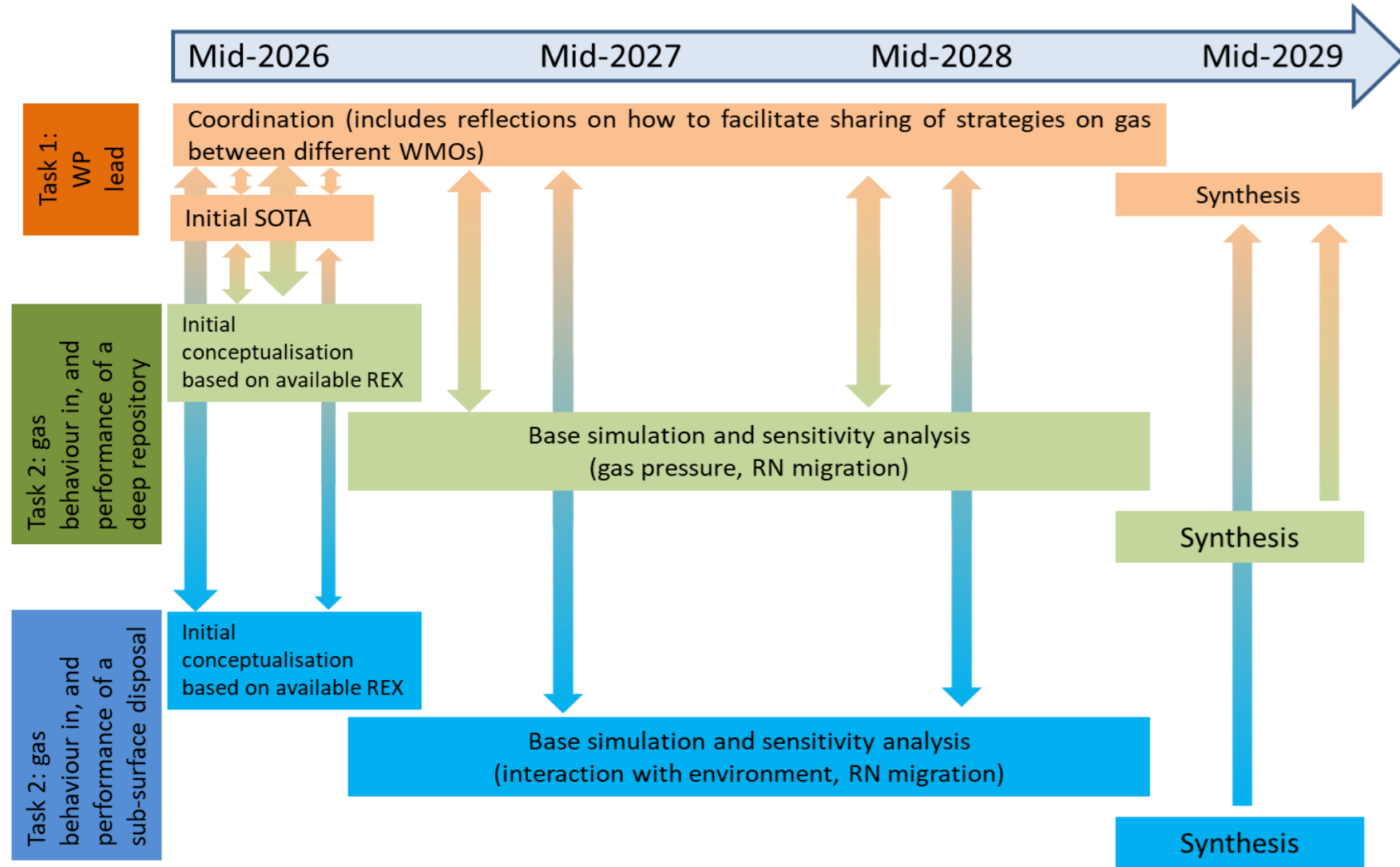
These objectives will be achieved by:

- consolidating the choices and models used to represent gas transfers at repository scale for deep underground facilities
 - based on the extensive data acquired and models developed in previous projects
- Developing specific models for (near)surface repositories
 - migration of radioactive gases (particularly H-3 and C-14...)
 - interaction with the natural environment
- Benchmarking simulations to gain confidence in the long-term evolution of the repository
- Training activities, to improve the ability of all partners to model gas migration at the repository scale
- Promoting reflections on how to facilitate sharing of strategies on gas between different WMOs
 - Development of workflows for model calibration, validation and strategies for valid model simplifications ...

This WP will not address

- *Gas source terms*

GENERAL STRUCTURE AND PLANNING OF THE WP



ARTIFICIAL INTELLIGENCE (AI) / MACHINE LEARNING FOR ANALYSIS OF SITE CHARACTERISATION DATA AND OTHER LARGE DATASETS

D. Eastwell (NWS), WMO, R&D, Geoscience (Theme 4)



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

PROBLEM STATEMENT

- **Data Diversity Challenge:**

- Geological Disposal Facility (GDF) siting relies on vast, varied subsurface datasets—ranging from quantitative logs to qualitative images—each with differing formats, resolutions, and quality levels.

- **Integration Complexity:**

- Current workflows struggle to integrate these disparate data types, often relying on manual interpretation and long-form reporting, which limits scalability and consistency.

- **AI/ML Opportunity:**

- Convolutional AI/ML models can unify and analyse diverse data types (e.g. core photos, seismic data, wireline logs) by learning relationships across formats, enabling probabilistic predictive and generative capabilities.

- **Unique Dataset Advantage:**

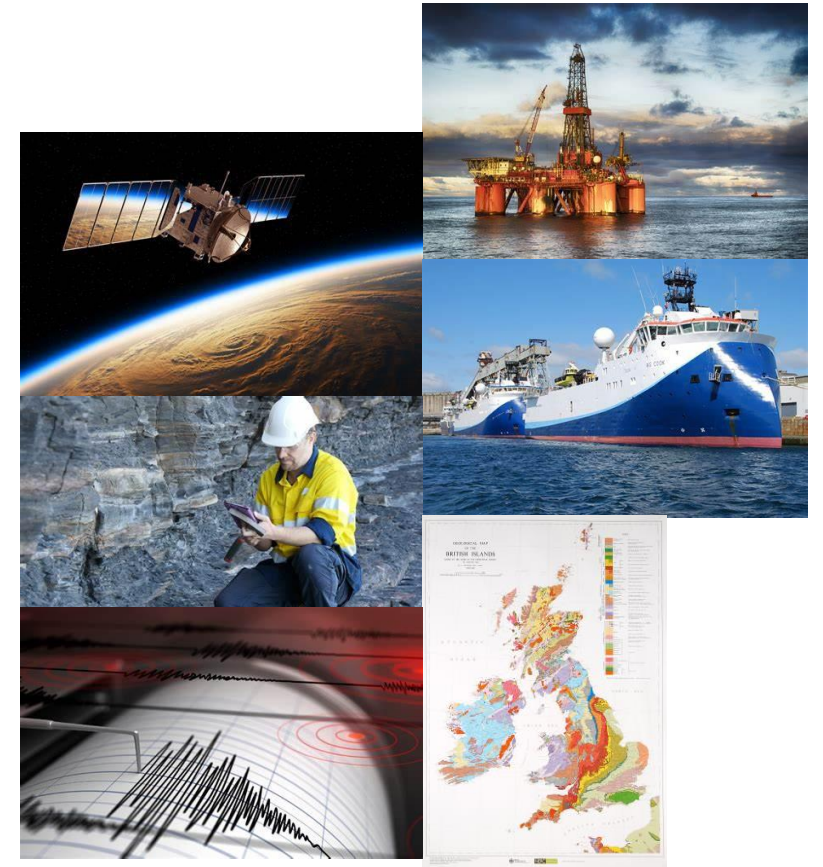
- GDF siting and characterisation datasets are globally unique due to strict quality control and spatial precision, making them ideal for training robust AI models with high confidence in outputs.

- **Enhanced Subsurface Understanding:**

- Successfully applying AI/ML to integrate subsurface data may allow for enhanced predictive models of the subsurface.

DATA INTEGRATION

- Site characterisation programmes aggregate vast quantities of subsurface data.
 - Dense (e.g. Wellbore Data)
 - Sparse (e.g. Seismic Data)
 - Qualitative (e.g. Core Descriptions/ Photographs)
 - Quantitative (Wireline Log Measurement)
 - Temporal (Flow Tests, Pressure Tests)
- Integrating these data often relies on established workflows (e.g. Seismic interpretation, Inversion, Petrophysics, modelling) and reporting may involve synthesis into long form bodies of information (e.g. SDM's)
- The convolution of desperate and esoteric data remains a complex and difficult task.
- The results of successfully integrating all subsurface data into a complex convolutional model is an enhanced understanding of the behaviour of, and ultimately the characterisation of GDF host rock units.



EXAMPLE

- Machine learning allows for the convolution of disparate data types and is fundamentally probabilistic.
- Figures (Right Top, Right Bottom) show an example of bulk lithology and mineral content (quantitative) from drill core images (qualitative).
- The result was a 96.7% accuracy in classification of drill core images into formation classes.
- This is a demonstration of the usage of ML techniques to convert images in data space via convolutional Neural Networks.

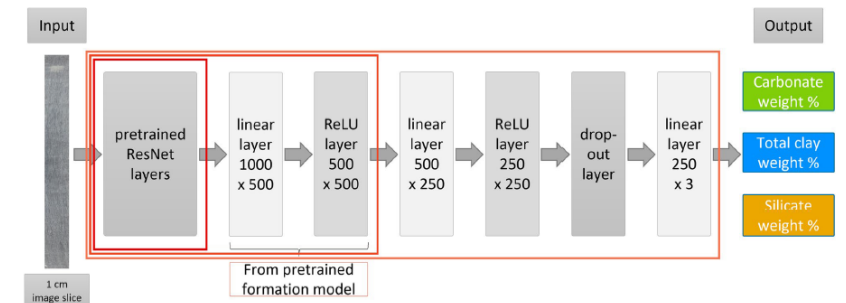


Fig. 10 Architecture of the neural network for the mineral content regression with one formation model as a backbone architecture

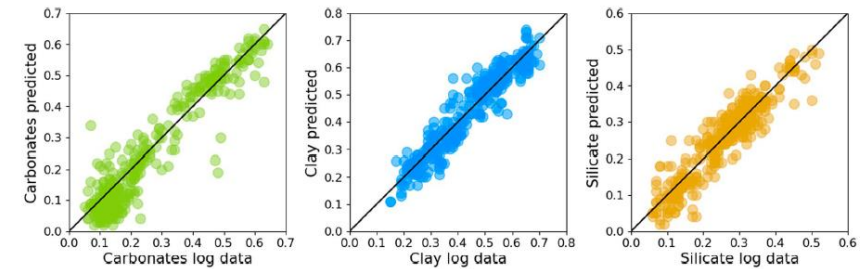


Fig. 12 MultiMin log data vs CNN model predicted data for each mineral separately, the x and y axis show the according weight %

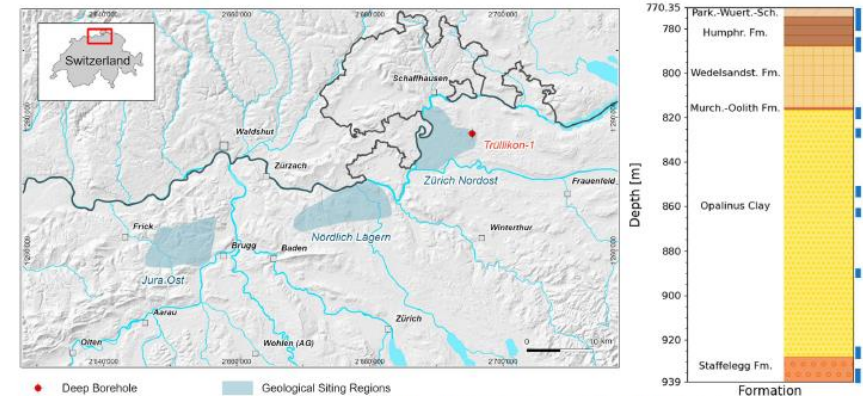
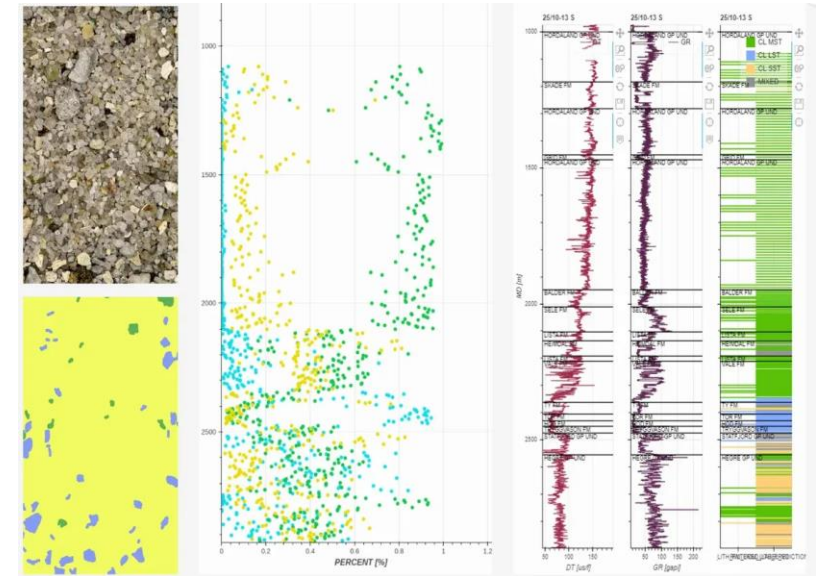


Fig. 1 Left: Cartographic representation illustrating the geographical region of northern Switzerland. The map specifically features the borehole site of Trüllikon 1-1 which is selected for the data analysis of this study. Background: ©Datawisstopo and hillshading from NASA SRTM. Right: Abstracted lithological profile of the section Trüllikon 1-1 showing the interval between 770.35m and 939m depth. The blue bars denote the available data segments

From: Boiger, R et al. Swiss Journal of Geosciences (2024) 117:9

EXAMPLE OF AI APPLICATION: ESA CUTTINGS ANALYSIS

- Digital images of 700,000 cuttings samples generated
- ML supervised training model generated to label a subsample and train algorithm
- Data convolved with additional non-physical parameters
- Produced trained algorithm to evaluate remaining samples.
- Data may now be convolved with other geophysical log data/ seismic data



From: [Interpreted cuttings samples from all released wells on the NCS | Data packages](#)



OBJECTIVES

- The convolution of geophysical/ geological data is an emerging area of research. The application of these processes to a GDF siting process, utilising the scale of site characterisation data has not been explored.
- Research is needed to identify technologies, best practices, data structures and methodologies to compile a toolkit of for future application.
- This project will look at workflows to enable the convolution of subsurface data, incorporating spatial and temporal attributes.
- This will underpin future workflows to allow for the predictive modelling (spatially and temporally) of data based on convolutional models to create predictive prior models.

PROPOSED WORK AREAS

1. **Establish Best Practice for Database Structure**, including optimised database structure
2. **Identify Approaches to Creation of Data Integration Framework** including research and established processes contributing toward development of a convolutional AI model concept.
3. **Identify Approaches to Spatial Modelling** including Improved interpolation and extrapolation between borehole data points.
4. **Identify Approaches to Understanding Variable Dependency Analysis** including Identification of key dependent and independent variables.
5. **Identify Approaches Toward Synthetic Data Generation** including Demonstration of forward and reverse modelling techniques.
6. **Identify Approaches Toward Predictive Behaviour Models** including Creation of predictive models for subsurface behaviour.
7. **Identify Approaches Toward Validation and Benchmarking of AI-generated insights** against traditional geological interpretations.
8. **Identify Approaches Toward Automation and Optimisation of Digital Workflows** including Facilitation of AI algorithms for the automation and optimisation of digital workflows.
9. **Identify Methodologies for Integrating Data Uncertainties Into Modelling Processes.** Including evaluation and analysis of natural geological variability.

THANK YOU
FOR YOUR ATTENTION



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