

EURAD-2 SECOND WAVE

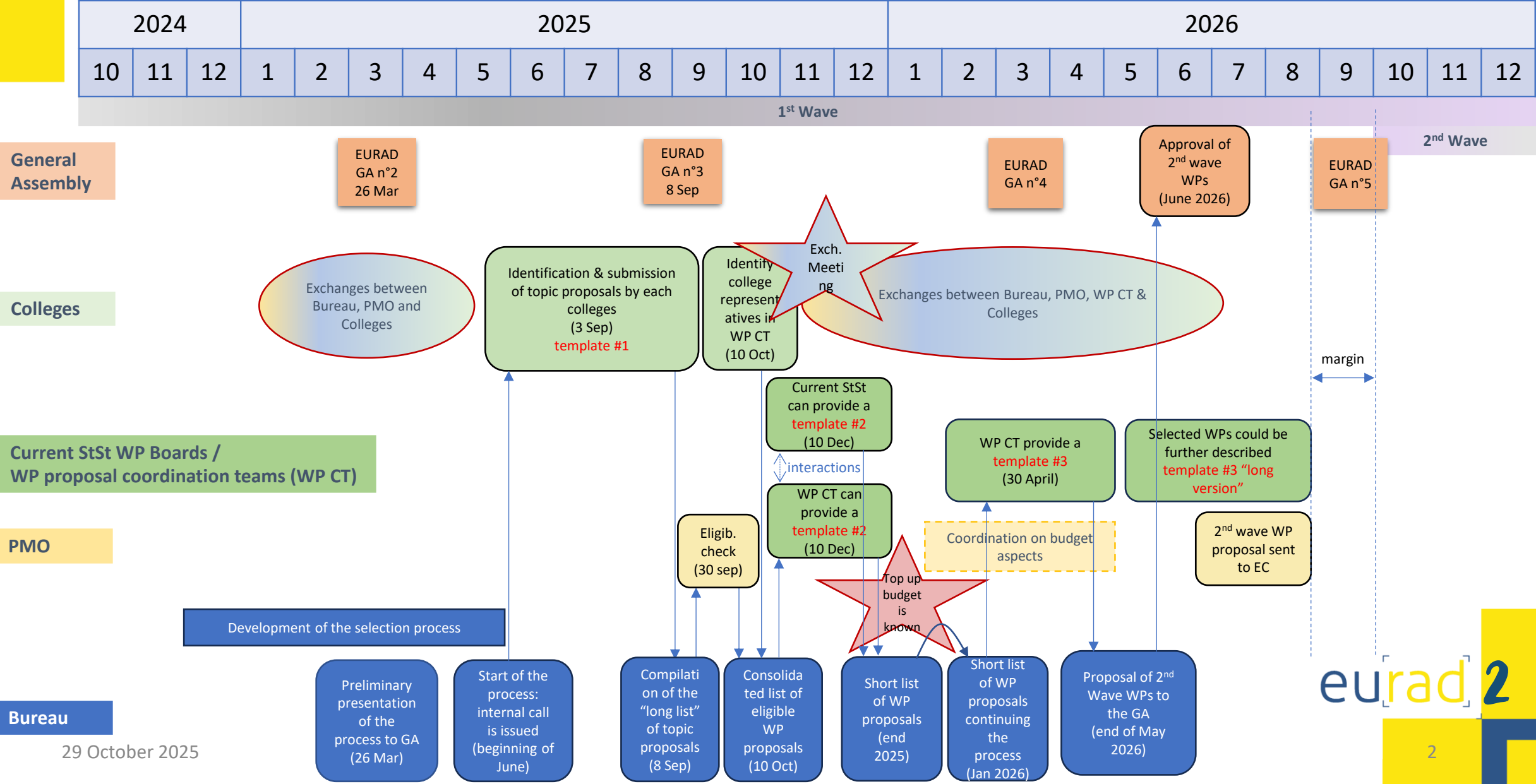
RD&D and StSt WP selection process

Webinars to assist templates #2 preparation

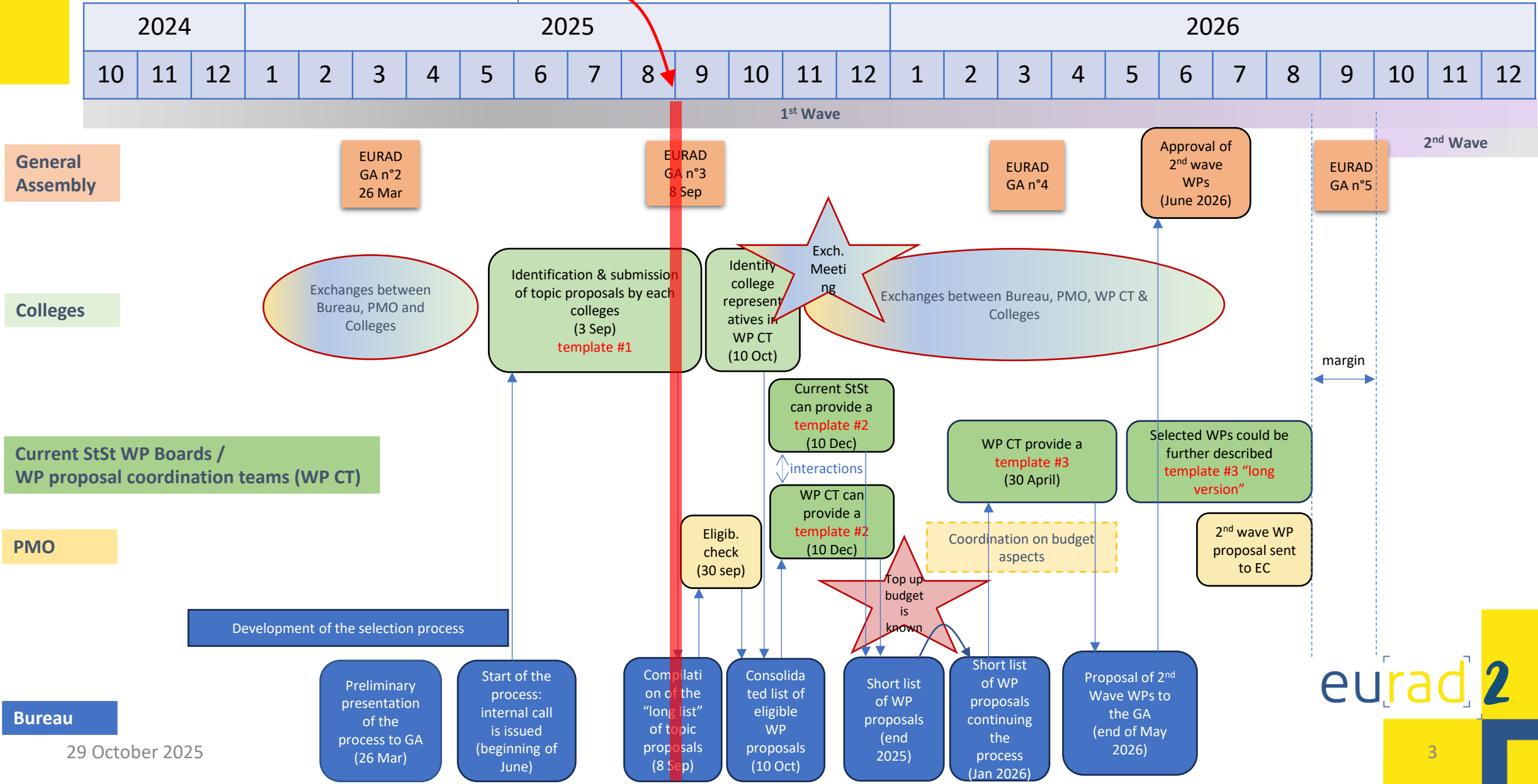


Co-funded by the European Union under Grant Agreement n° 101166718

SELECTION PROCESS: OVERVIEW



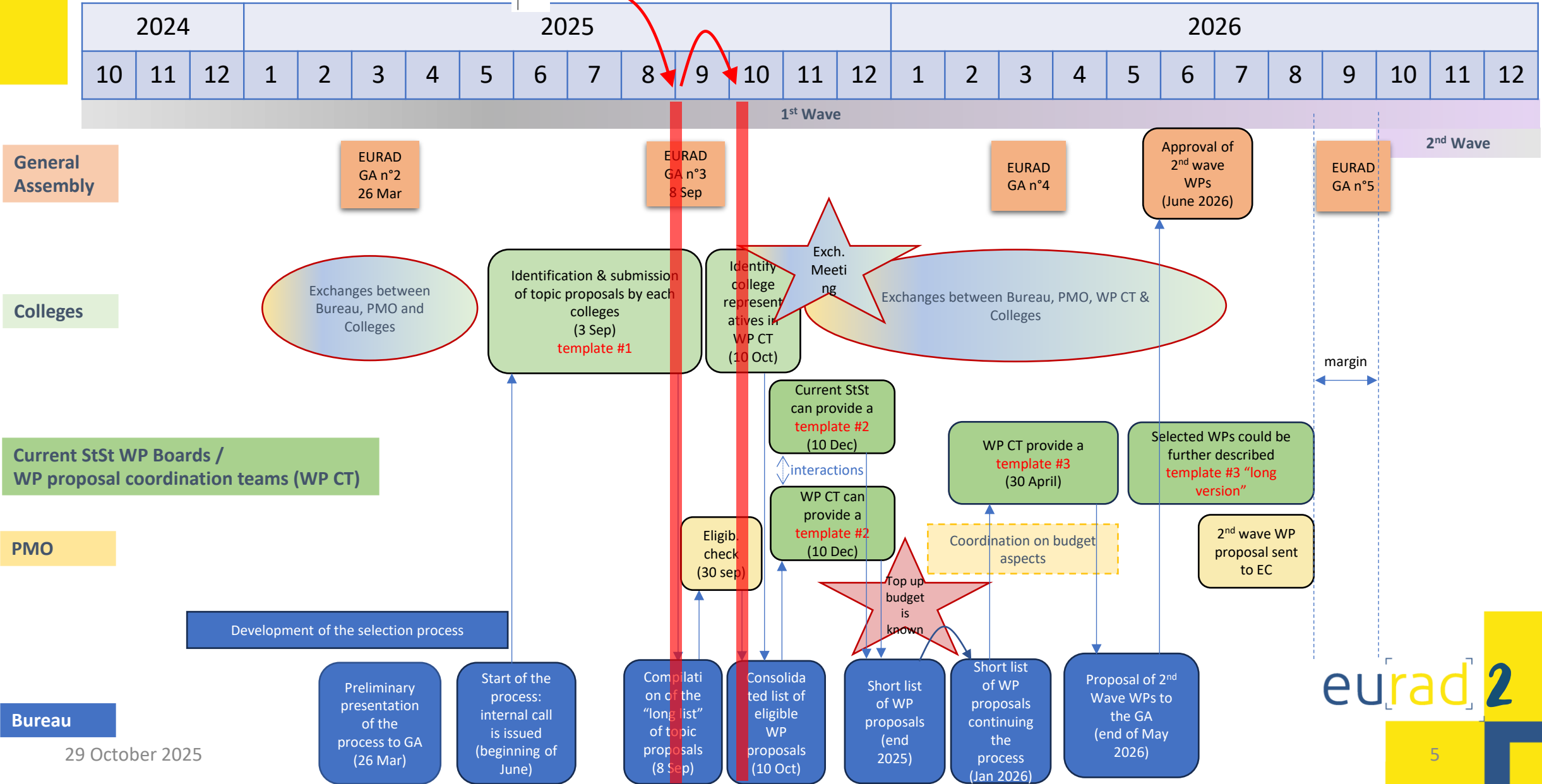
SELECTION PROCESS: OVERVIEW



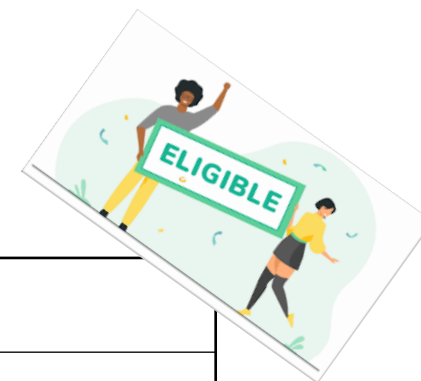
3/09/2025: LONG LIST OF TOPIC PROPOSALS

	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



	From College			Title of the received template #1
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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
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	X			Toxic substances/ chemicals
		X		Guidance for European (TE)NORM & DU enabled strategies for integrated stewardship
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			X	Natural Analogues: Strategic review of holistic utilisation of NAs in radioactive waste disposal (NATSTRAT)
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SELECTION PROCESS: OVERVIEW

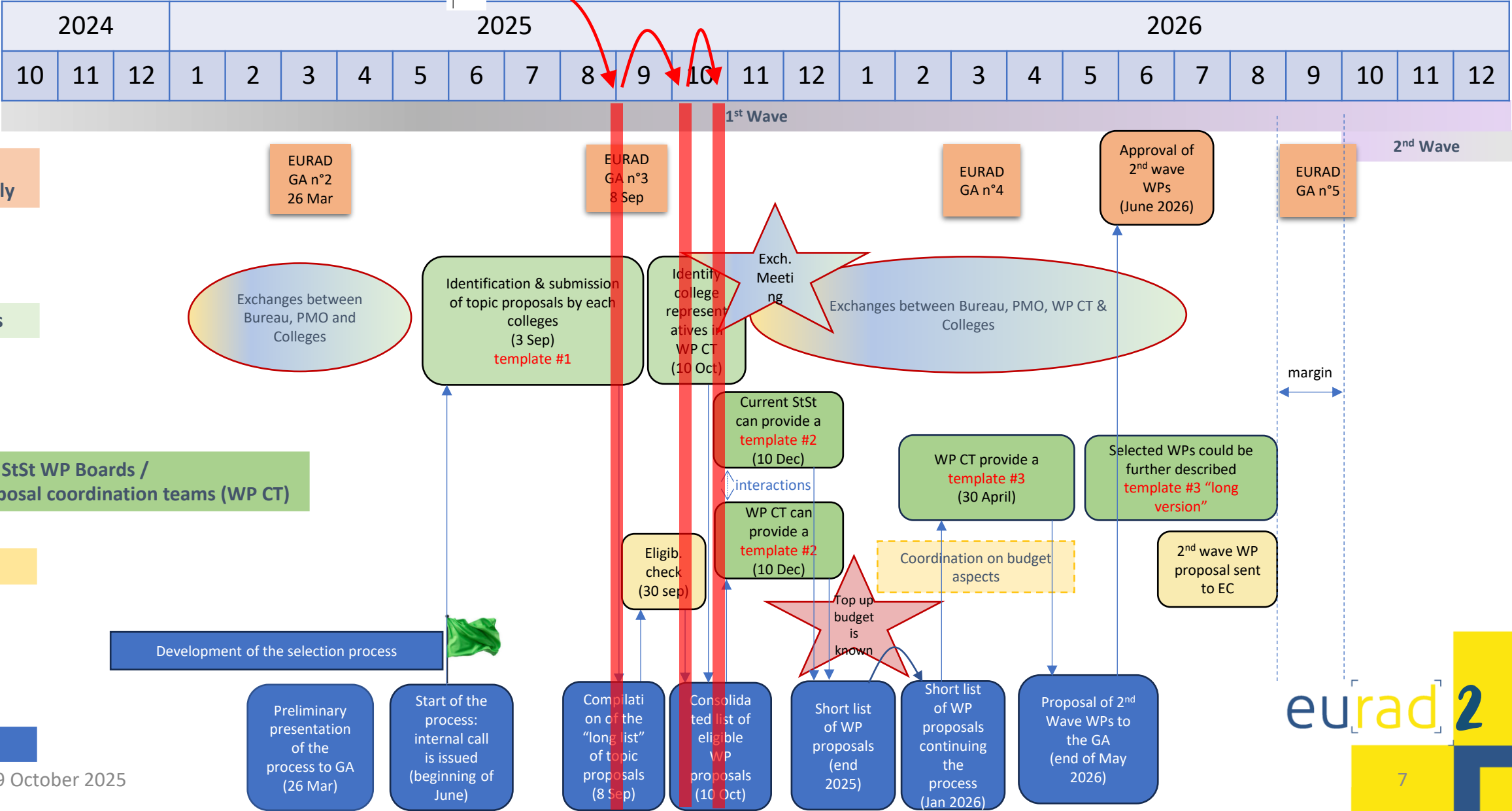
General Assembly

Colleges

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

PMO

Bureau



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		jan.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
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	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
		Towards robust decision-making processes in RWM through participatory data analysis and co-creative development of scenarios		X				
	StStWP2	Toxic substances/ chemicals	X			benjamin.frasca@andra.fr	frederic.coppin@asn.fr	anke.neumann-jenal@psi.ch
	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
	StStWP4	Investigating analogues for trusted understanding of repository assessment		X		erika.neeft@covra.nl	anamaria.fernandez@ciemat.es	heini.reijonen@gtk.fi
		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

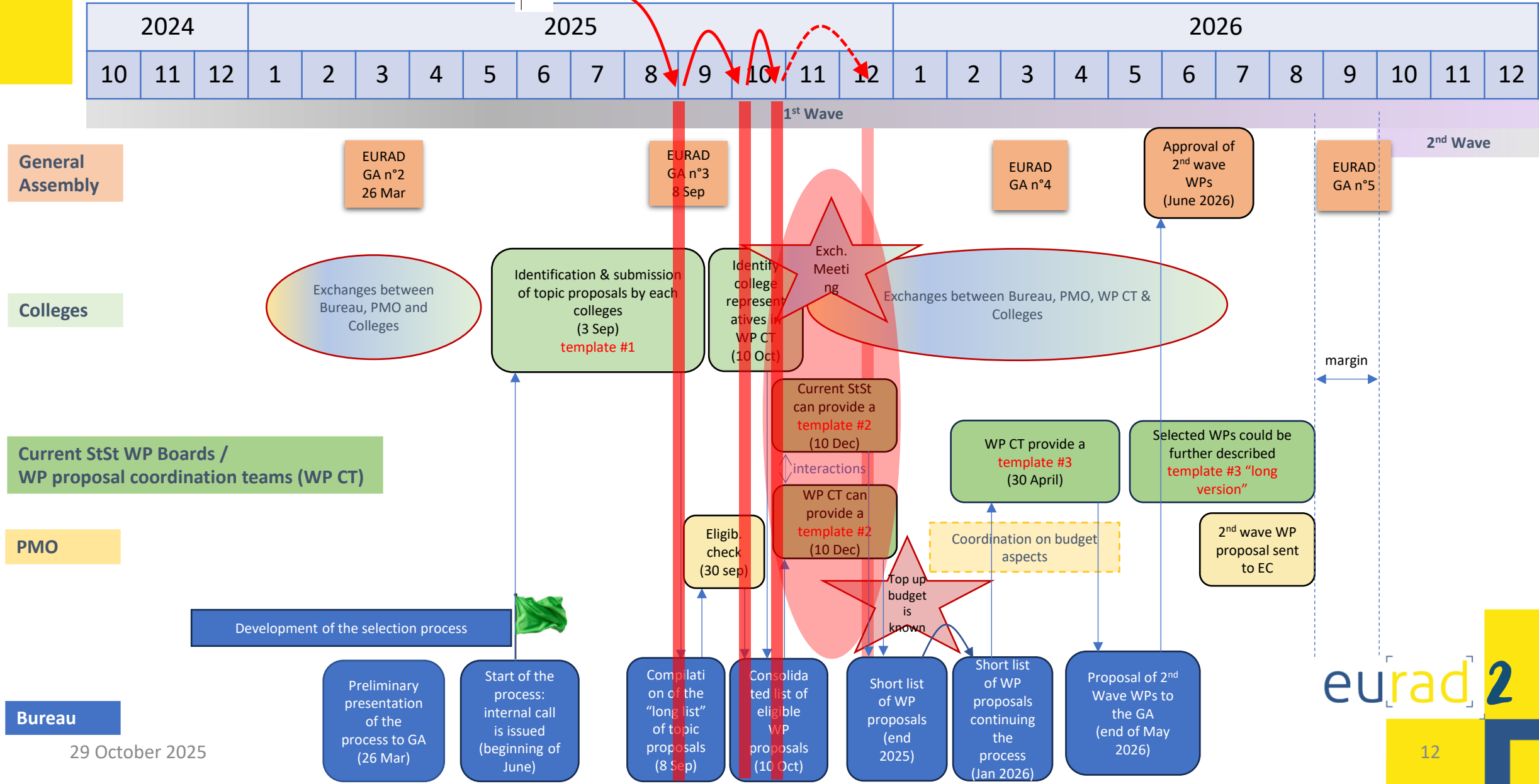
- You can start working on preparing templates #2.
- 2 WMO WP CT members still to be identified (discussion on going within the Bureau)



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	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

SELECTION PROCESS: OVERVIEW

WE ARE HERE



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 their 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.**

NATURAL ANALOGUES – STRATEGIC REVIEW OF HOLISTIC USE OF NAS IN RADIOACTIVE WASTE DISPOSAL (NATSTRAT)

H.M. Reijonen (GTK) &
A.M. Fernández (CIEMAT)



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

LINKS TO EURAD SRA AND ROADMAP

EURAD SRA Themes

EBS (Theme 3)

Geoscience (Theme 4)

Safety Case (Theme 7)

SRA Drivers

Implementation Safety

Scientific Insight

Social Engagement

Knowledge Management

(Innovation for
Optimisation)

Roadmap domain insights

1.1.3 Public information and
participation

3.4.1 EBS system

7.1 Safety Strategy

**7.1.2 Performance indicators (Shared
experience in the use of NA)**

7.3.1 Performance assessment and
system models

The topic will also provide input to several
4.X.Y domains and subdomains.

JUSTIFICATION & ADDED VALUE

Analogues (natural, archaeologic, anthropogenic) play a crucial role in understanding many long-term processes, and in validating experimental rates and models against long-term records.

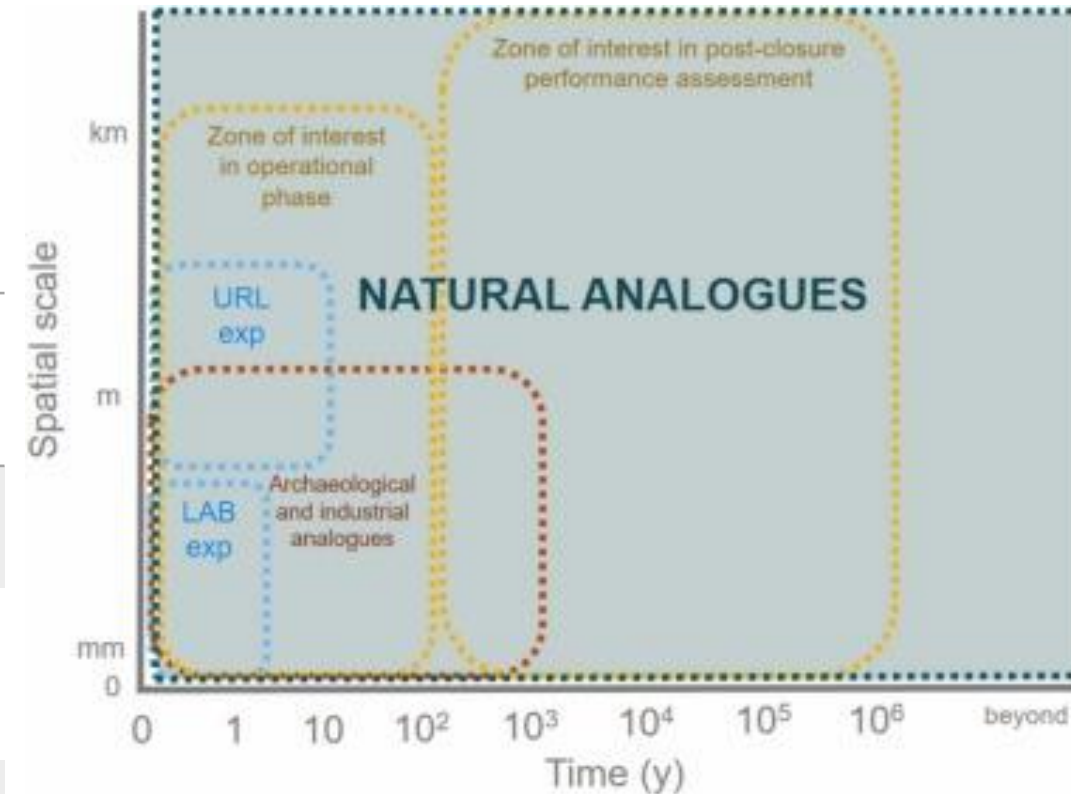
NAs are the only way to directly study geological timeframes and natural systems (which the repository is/will become)

Recent reviews on the application of natural analogues (NAs) in safety cases, including archaeological and anthropogenic analogues, in safety cases have identified several knowledge gaps.

There are several topical areas where the use of NAs remains largely unexplored: barrier systems (e.g. earth covers), external processes (e.g. climate), biosphere and industrial analogues.

NAs are seen as an underused asset for communicating the robustness of safety cases to civil society groups.

Well-established research plans for future work are needed to provide data on processes on repository relevant timescales → Need based WP for EURAD-3 R&D.

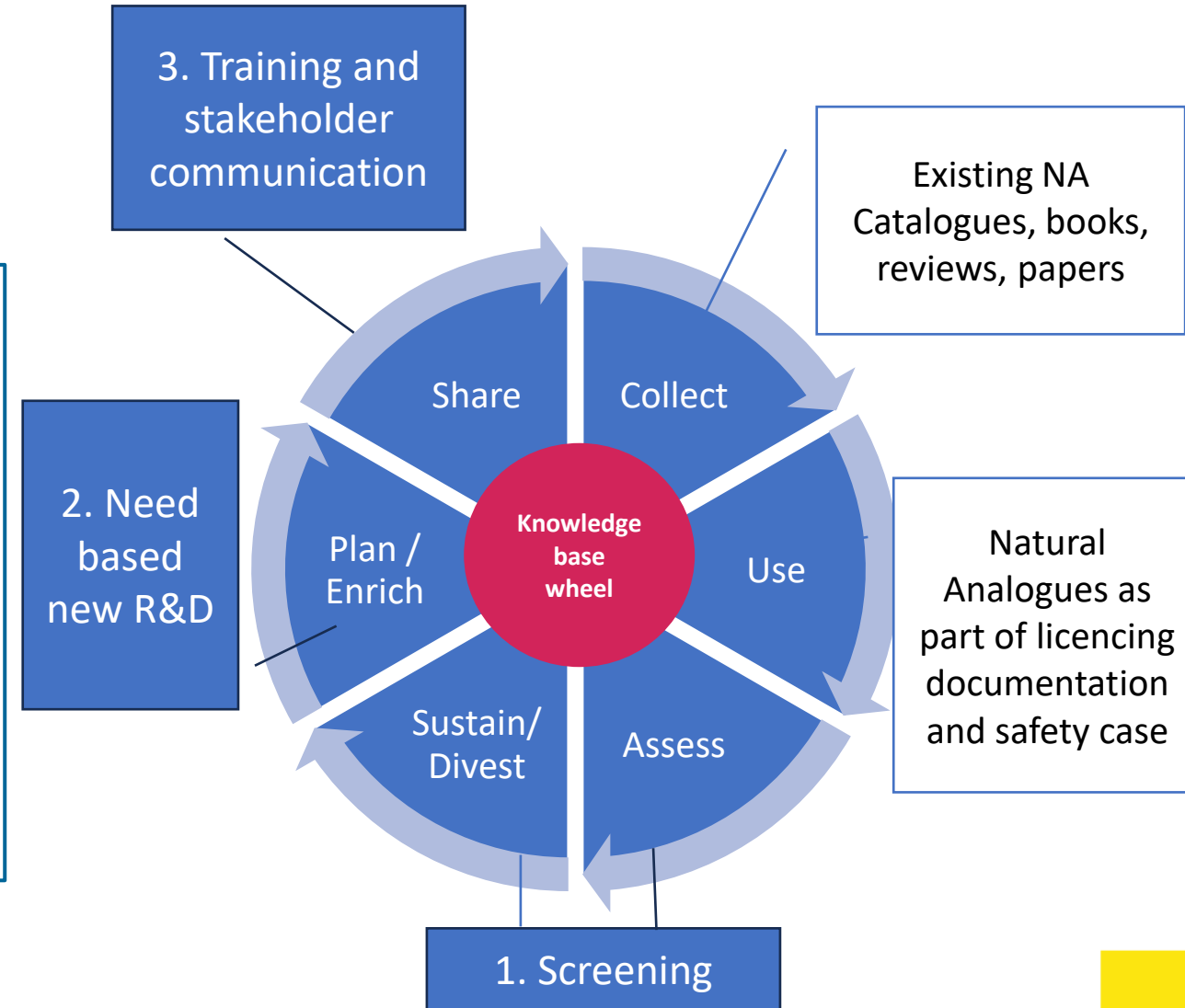


Reijonen, H., Alexander, W.R., Marcos, N. & Pastina, B. 2022. Implementing natural analogue information in Posiva's safety case – methodology and case-specific review. Abstract for Clay Conference 2022, Nancy, France.

OBJECTIVE

This strategic study would:

1. Focus on defining state-of-the-art and critical gap analysis on NAs (including archaeological and anthropogenic analogues) for HLW and L/ILW concepts.
2. Provide a systematic approach for developing R&D WP for EURAD-2, focusing on the most important themes for the EURAD community – NEED BASED.
3. Providing guidance and training for holistic use of NAs in disposal programmes (including safety cases and stakeholder communication).



OVERVIEW ON THE POTENTIAL

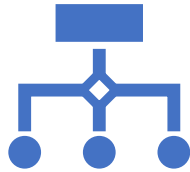
- Multiple projects are ongoing, funded by various waste management organisations, research institutes, and other entities.
- Analogue projects are expensive, field work is required, and analysis is usually multidisciplinary
 - Boundary conditions can be better constrained if enough effort is made.
- Analogue studies are perfect for joint programming
 - Relevant R&D WMOs → results that are useful for SC
 - Needed experience for SIMS and developing programs
 - Multidisciplinary training for experts
- EURAD-2 would allow planning for targeted studies for EURAD-3, where research plans with high ambitions could be executed → more could be achieved with less effort by a joint programme!



Reminder:

*Analogue studies are **not** inherently negative or positive. Over the years, many negative aspects have been learned from nature, e.g. copper corrosion.*

HOW



Task 1: FEP based gap analysis and state-of-the-art review on the analogues used in safety cases (utilizing existing literature)

- Revisit/redefine the use of analogues to support various stages of geological disposal programmes and components of the safety case;
- Provide holistic understanding of the current status of NA research and a way forward for different repository concepts (guidance);
- Identify NAs that are crucial to fill the knowledge gaps, provide evidence thus reducing key uncertainties in the safety cases, and/or aid optimization / robustness of the repository systems.



Task 2: Knowledge management and training

- Implementation of the results to EURAD-2 KM
- Training:
 1. Expert level training / workshop on NAs: Focused on how to effectively integrate NA data and insights into the development and justification of the safety case.
 2. Expert level training / workshop on stakeholder communication: Exploring how to translate findings from NA studies into accessible, transparent and meaningful narratives to support stakeholder and public engagement and communication.



Task 3: Feasibility assessment for future NA studies

- Based on Task 1 Gap Analysis, topics for future work will be provided including preliminary assessment of the sites / samples (Potential R&D for EURAD-3).
- Structured and versatile assessment template for selecting future study topics accounting for feasibility, national needs, scientific gaps (especially NAs for upscaling over long time scales).

SUPPORTING ORGANIZATIONS

- **REs:** GTK (FI), CEA (FR), UniBern (CH), TUDelft (NL), SCK CEN (BE), BGS (GB), TNO (NL), Amphos21 (ES), KIT (DE), SIIEG NAS of Ukraine (UA), UKNNL (GB), UFZ (DE), EPFL (CH), ÚJV Řež (CZ), BRGM(FR), ENEA (IT), RATEN INC (RO), CEPN (FR)
- **TSOs:** SURO (CZ), CIEMAT (ES), VTT (FI), EIMV (SI), NTW (FR), GRS (DE), Merience (ES), UGR (ES), SSTC NRS (UA), JUELICH (DE), UDC (Spain).
- **WMOs:**
 - ENRESA (Spain), COVRA (NL)
- Non-EU support:
 - NUMO (Japan), KAERI (South Korea), LBNL (USA)



CONTACT DETAILS

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(anamaria.fernandez@ciemat.es, +34627245016)

IMPACTS OF CLIMATE CHANGE ON MULTI-LAYER COVER PERFORMANCE AT NEAR- SURFACE DISPOSAL SYSTEMS

WP11 CLIMATE - 2nd Wave Proposal



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

PROPOSAL IN SHORT

Safety-relevant impacts of climate change on multi-layer cover performance at near-surface disposal systems

- **Aims**

- To develop a validated, interoperable EU framework that quantifies climate-driven change (including extremes) in multi-layer cover performance at near-surface disposal sites
- To provide regulator-ready decision tools to incorporate climate change and extreme (rare but credible) events into safety cases

- **Why**

- No harmonized or validated framework currently exists across Europe to evaluate these processes and impacts

- **Who**

- WP CLIMATE second wave meeting: Amphos21, VTT, SCK CEN, EIMV, GRS, ANDRA, ENEA, NTW, POSIVA, MINES PARIS, SKB, BRGM, TUS, TUL, FMTC, BGE

PROPOSED ACTIVITIES

- **Intensity-frequency mapping of climate hazards at centennial-millennial timescales for various climate zones**
 - Probabilistic and geostatistical approaches
 - Rainfall intensity, freeze-thaw cycles, wet-dry cycles, storms, flooding (marine, fluvial and pluvial)
 - Input from this WP: future climate scenarios, climate hazards and risks for different climate zones
- **Modelling of climate-related processes**
 - Develop integrated **models coupling** erosion, infiltration, and hydrochemical processes
 - Create open benchmarks, run code-to-code and code-to-data validations
 - Generate **validated predictive tools for safety-relevant parameters**
 - Infiltration rates
 - Soil structure degradation, hydraulic conductivity changes
 - Boundary conditions for concrete degradation

PROPOSED ACTIVITIES

- **Development of a calibration/validation/verification database**
 - Experiments
 - Design field and lab tests to measure infiltration and erosion rates under evolving climate conditions
 - Harmonize experimental protocols and data formats across programs
 - Validate models using multi-site and multi-climate datasets (e.g., Dessel, El Cabril, Aube, ...).
 - Natural and engineered analogues
 - Observe representative slopes and multi-layer soil sequences in analogue climates that have been exposed for a time period beyond experiments
 - Quantify impact (erosion, infiltration) and include in validation database

PROPOSED ACTIVITIES

- **Decision and prioritization framework**

- Develop a **structured pluralistic decision framework** to guide how **climate-related impacts** are identified, prioritized, and incorporated into safety assessments
- Create a **transparent methodology for linking climate impacts to safety functions**
- Provide **practical tools** (decision trees, flowcharts, weighting schemes) to ensure consistent, traceable treatment of climate uncertainties **across national programs**

- **Complementarities**

Community-supported climate scenarios and risks/hazards, coupled modelling, natural analogues (SUDOKU)

R&D versus StSt proposal (STRATNAT)

EXPECTED OUTCOMES AND ADDED VALUE

- **Scientific & Technical Outputs:**

- **Decision-making framework** for identifying and prioritizing climate impacts on safety functions
- Validated **coupled models** linking erosion, infiltration, hydrochemistry, and climatic extremes for near-surface facilities
- **Integration of natural and engineered analogues** to evaluate long-term barrier integrity under evolving climates
- **Guidance for incorporating “rare but credible”** events and climate variability into performance assessment in the safety case

- **Strategic Impact:**

- Provides a **holistic and safety-relevant approach** to assess climate change effects on disposal systems
- **Bridges scientific understanding and regulatory practice** by linking physical processes to safety case argumentation and uncertainty management
- **Enhances coherence among WMOs, TSOs and REs** through common methodologies, interoperable models, and data-sharing protocols
- **Feeds into the EURAD Knowledge Management System**, contributing verified datasets and harmonized tools for EU-wide use in design, regulation, and performance assessment
- Engagement with actors from **civil society** enabling enriched framing and enhanced understanding

OPTI SECOND WAVE PROPOSAL



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

INTEGRAL MULTI CRITERIA OPTIMISATION (MCO) FRAMEWORK

Objective: Develop and demonstrate a multi criteria optimisation (MCO) framework and digital tool that integrates safety case evidence, cost functions and environmental/social indicators, with uncertainty and robustness analysis.

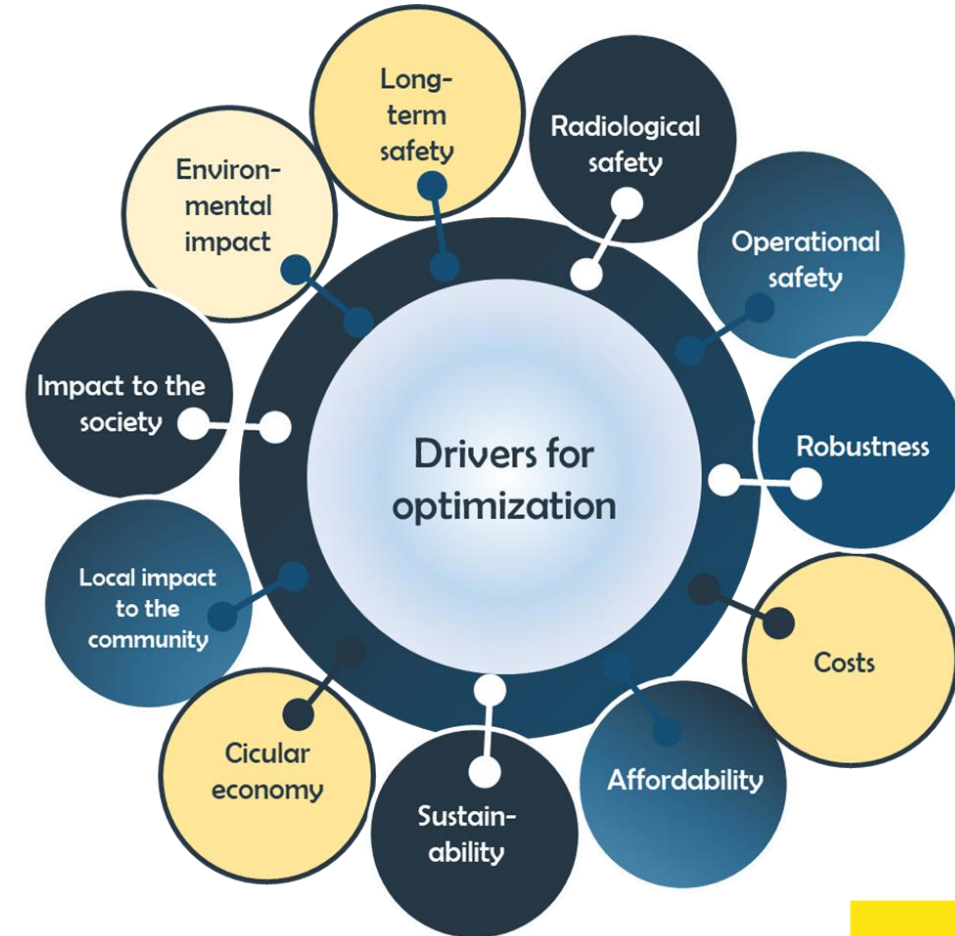
- **Research would contribute to answer the following question: How can MCO be structured so that safety case lines of argument, cost and environmental/societal factors are commensurable yet traceable under prevailing circumstances?**
- **Research addresses the SRA themes Disposal facility design and optimisation (Theme 5) and Safety Case (Theme 7)**
- **Linked to Civil Society topics:**
 - Optimised decision-making processes, including legal framework and transparency and public participation Achieving optimal safety and security (optimal long-term storage, the use of best available site and technology, and processes for siting and technology development)

„INTEGRAL MCO FRAMEWORK“ POSSIBLE TASKS I/IV

T1 and T2 as usual (PM and KM)

T3 Conceptual framework & indicators:

- Develop suitable indicators from the drivers for optimization:
 - Technical feasibility and technical challenges
 - E.g. harmonise safety, cost, environmental & societal indicators
- Define normalisation/weighting schemes
- Establish traceability & change management links across lifecycle stages



„INTEGRAL MCO FRAMEWORK“ POSSIBLE TASKS II/IV

T4 Development of the MCO digital tool

- Develop of the MCO digital tool
 - Requirements assessment
 - Use cases
 - Develop Application Programming Interfaces and digital tool?
- Uncertainty & robustness
 - Embed global sensitivity analysis
 - Probabilistic uncertainty quantification
 - Value of information
 - Robustness metrics (e.g., regret, satisficing, Pareto front stability under scenario ensembles)

„INTEGRAL MCO FRAMEWORK“ POSSIBLE TASKS III/IV

T5 Demonstration by pilot applications/case studies

- Demonstration of MCO digital tool using a case study
- Document model interfaces to safety case tools
- **Potential case studies:**
 - Rock-liner system in Clay
 - Optimisation of sealing structures
 - Backfill or Backfill-DWP system (complementary to proposal *Materials for enhancing passive safety and robustness of Engineered Barrier Systems*)

Optimisation of rock-liner system in clay

The design of (concrete) liners is characterized by different constraints such as the chemical degradation, thermal-hydro-mechanical interactions, material compatibility and predictive modeling

Optimisation of sealing structures

The design of such structures brings technical challenges from a feasibility perspective (e.g. removal of concrete liner), and raises a number of non-technical questions (e.g. retrievability)

„INTEGRAL MCO FRAMEWORK“ POSSIBLE TASKS IV/IV

T6 Methodology refinement and stakeholder engagement

- Review and iteration with WMOs/TSOs/REs/CSOs and relevant stakeholders
- Integrating reflections, lessons and experiences into holistic guidance
- Draft EURAD 2 guidelines for MCO in repository programmes
- and/or Multi-Criteria Decision Analysis [MCDA] in repository programmes

MCO (Multi-Criteria Optimisation): an *optimisation* framework to **generate** the best feasible designs/solutions by trading off criteria (objectives). Output: the **Pareto set/front** (no single “best” unless preferences are imposed).

MCDA (Multi-Criteria Decision Analysis): a *decision* framework to compare **given alternatives** across several criteria (e.g., AHP, MAVT, ELECTRE, PROMETHEE). Output: a ranking, choice, or sorting—with explicit preferences (weights, value functions, veto, etc.).



Coffee Break

We'll be back at 15:00

SELF-POWERED MONITORING SYSTEMS FOR RWR

García-Siñeriz J.L., Tuñón S. (Amphos21), Cancemi S. (University of Pisa), Gedeon M. (SCK CEN), Heerens G-J. (TNO), RE College



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

MOTIVATION

Monitoring: Continuous or periodic observations and measurements of engineering, environmental, radiological or other parameters and indicators/characteristics, to help evaluate the behaviour of components of the repository system, or the impacts of the repository and its operation on the environment - and thus to support decision making during the disposal process and to enhance confidence in the disposal process.

This WP is focused on the development and demonstration of innovative monitoring technologies that enhance the ability to monitor Radioactive Waste Repositories.

This topic was developed in detail along MoDeRn, Modern2020 and MODATS. Why we need to do more?

As concluded in Modern2020 further development is required:

- (i) to improve the possibility of providing **long-term self-sufficient power**
- (ii) to improve the **reliability of monitoring** technologies and the implementation of failure identification procedures,
- (iii) to **monitor specific parameters**

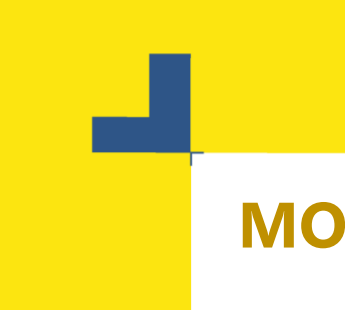
OBJECTIVE & ADDED-VALUE

Develop sustainable, cyber resilient, self-powered monitoring systems providing long-term RWs predisposal and repositories surveillance.

- **High Impact Risk Reduction & Safety Assurance**
 - Continuous, autonomous, wireless, and self-powered monitoring of radioactive waste facilities,
 - Benefits: lower energy use, reduced battery waste, improved safety, and enhanced cybersecurity.
- **Breakthrough**
 - Minimizes hazardous battery waste over repository lifecycle,
 - Cuts operational costs and boosts cyber resilience.
- **Added Value**
 - Wireless tech connects with existing instruments, replacing chemical batteries with nuclear alternatives,
 - Enhances monitoring efficiency, lowers costs, and improves safety.
- **Innovation**
 - Edge AI enables onboard data cleaning, labeling, filtering, and anomaly detection,
 - Ensures high-quality, decision-ready data for knowledge platforms.

SCOPE & LINKS WITH EURAD/SRA THEMES

- **Addition of new sensors (iii), to wireless *monitoring* system & nuclear batteries as alternative to conventional chemical ones (i) (Amphos21 & BAM):**
 - Disposal facility design and optimization (Theme 5)
- **Energy harvesting for self-powered *monitoring* (i) (ENEA/UPisa) & Energy efficiency (BAM):**
 - Pre-disposal (Theme 2), Engineered Barrier Systems (Theme 3), Disposal facility design and optimization (Theme 5)
- **Data management strategies (cleaning, labelling, and filtering) to extract high quality data from the *monitoring* systems (ii) (SCK CEN):**
 - Transversal, especially Geoscience (Theme 4), Disposal facility design and Optimisation (Theme 5), Siting and Licensing (Theme 6) and Safety Case (Theme 7)
- **System design (self-powered) of a *monitoring* system for ultra deep borehole disposal facilities (TNO):**
 - Geoscience (Theme 4), Disposal facility design and Optimisation (Theme 5) and Siting and Licensing (Theme 6)



MONITORING TOPIC – DESCRIPTION&TASKS

- **Project Structure**

- WP0 - Coordination
- WP1 – AI, Data and Knowledge Management,
- WP2 – Sensor and Energy-Harvesting Hardware,
- WP3 – Wireless Communication, monitoring system for ultra deep boreholes and Power Delivery,
- WP4 – System Integration and Demonstration,
- WP5 – Dissemination & ICS



PARTNERS & COUNTRIES

- **Preliminary interested organisations in the RE College**

- Amphos 21 (Spain),
- BAM (Germany),
- GRS (Germany),
- SCK CEN (Belgium),
- SI IEG NAS (Ukraine),
- TNO (Netherlands),
- University of Pisa (Italy).

- **WMOs potentially interested:**

- ENRESA (Spain)
- NAGRA (Switzerland)
- ANDRA (France)
- ENEA (Italy)
- ONDRAF (Belgium)
- COVRA (Netherlands)
- BGE (Germany)

DETECTION AND EVALUATION OF ELECTROCHEMICAL AND pH CONDITIONS FOR CORROSION AND HETEROGENEOUS MONITORING



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

OBJECTIVE & ADDED-VALUE (TEMPLATE #1)

Topic	DEEP-CHEM : Detection and Evaluation of Electrochemical and pH Conditions for Corrosion and HETerogeneous Monitoring
Justification: impact / innovation / added-value (Why)	Geological disposal is the safest, most sustainable solution for high-level waste, with research now focused on refining models and processes to ensure long-term safety. A key challenge lies in addressing coupled thermal, chemical, mechanical, and hydrological phenomena, which can significantly influence the durability of backfill and other barrier materials. Despite advances in thermal, mechanical, and hydrological understanding, chemical processes remain Unquantified, requiring high-quality measurements and validated models to improve safety and performance assessments.
Objective (What)	The project aims to develop and validate robust in situ chemical sensors, designed to support model consolidation, disposal performance assessment, and reliable monitoring of key parameters under harsh conditions, with thorough testing for sensitivity and long-term stability. The project will establish a structured framework to prioritize pilot scenarios integrating chemical sensor data into reactive transport and corrosion models, ensuring development aligns with practical applications.

SHORT DESCRIPTION: OUTCOMES / TASKS (HOW) (TEMPLATE #1)

Task 1: Review and gap analysis of chemical sensing technologies for geological disposal: Addressing requirements of advanced and less-developed programs

Goal: The project will identify and compare chemical sensing needs across waste management programs to assess current technologies, reveal gaps and constraints, and highlight opportunities for innovation.

Activities: Gather input from all programs via a questionnaire / State-of-the-art report about chemical sensors

Task 2: Development of chemical sensor technologies

Goal: Development of robust sensors for in situ measurement of chemical parameters in challenging environments (e.g., reducing, high-salinity, low-permeability, alkaline). Priority is first given to corrosion and pH/redox.

Activities: 2.1 Corrosion rate sensors – Develop and test techniques such as resistance measurement, LPR, EIS, and HDA. 2.2 pH and redox sensors – Adapt and optimize electrochemical and optical technologies. 2.3 Chemical species sensors – Develop/adapt sensors for key ions, metals, metalloids, radionuclides, and other relevant species. 2.4 Organic contaminant sensors – Explore solutions for complexants and degradation products.

Task 3: Integrated laboratory-scale sensor testing

Goal: Evaluate the performance, reliability, and compatibility of multiple sensor types under controlled, relevant conditions, testing them together rather than individually to simulate real-world interactions and interferences.

Activities: Laboratory-scale tests will integrate multiple sensor types under controlled repository-like conditions to assess cross-interference, validate performance against reference methods, and evaluate durability, sensitivity, stability, and overall reliability for integrated data collection

Task 4: Definition and planning of pilot application cases

Goal: Identify, elaborate, and prioritize pilot scenarios for integrating chemical sensor data into reactive transport and corrosion models to ensure practical, demonstrable outcomes.

Activities: The activity will involve workshops and modellers consultations to define pilot scenarios across repository components and host rocks, establish integration strategies with relevant sensors and models.

COMPLEMENTARY INFORMATION (TEMPLATE #1)

What is out of the scope?	Gas measurements / Field deployment and demonstration activities are not planned within this project, given its limited duration
List of preliminary interested organisation in the WMO College	Active participation : Andra, (BGE,) SKB, ONDRAF/NIRAS Outcome interest: Nagra, ARAO, PURAM, SOGIN, NES Response pending: Posiva, RWS, ENRESA,
Links with previous or ongoing projects / work packages	Modern2020, Concord, RAMPEC? InCoMand, DITUSC
Main contact	Johan BERTRAND / Andra /Johan.bertrand@andra.fr

MERGING PROCESSING

TSO / R&D

Towards robust decision-making processes in RWM through participatory data analysis and co-creative development of scenarios

WMO / StSt

Operational scientific data management

StSt

ECOFFRAME - European
COmmon FRAMEwork for
Operational Scientific Data in
RWM

Turning fragmented and project-specific data practices into **a coherent, FAIR-compliant, societally anchored framework**

Long-term preservation and transfer of knowledge across the extended timescales of RWM

SRA, DI AND DRIVERS

Roadmap DI:

1.1.1 National RWM Policy

1.1.3 Public information and participation

2.3.1 Waste and package characteristics

4.1.1 Site descriptive model

4.4 Geosynthesis

5.5.2 Monitoring programs to be performed during site investigation, construction and operational phases of the repository

6.2.1 Site investigation

6.2.2 Detailed site characterisation and site confirmation

7.2.2 Information, Data and Knowledge Management

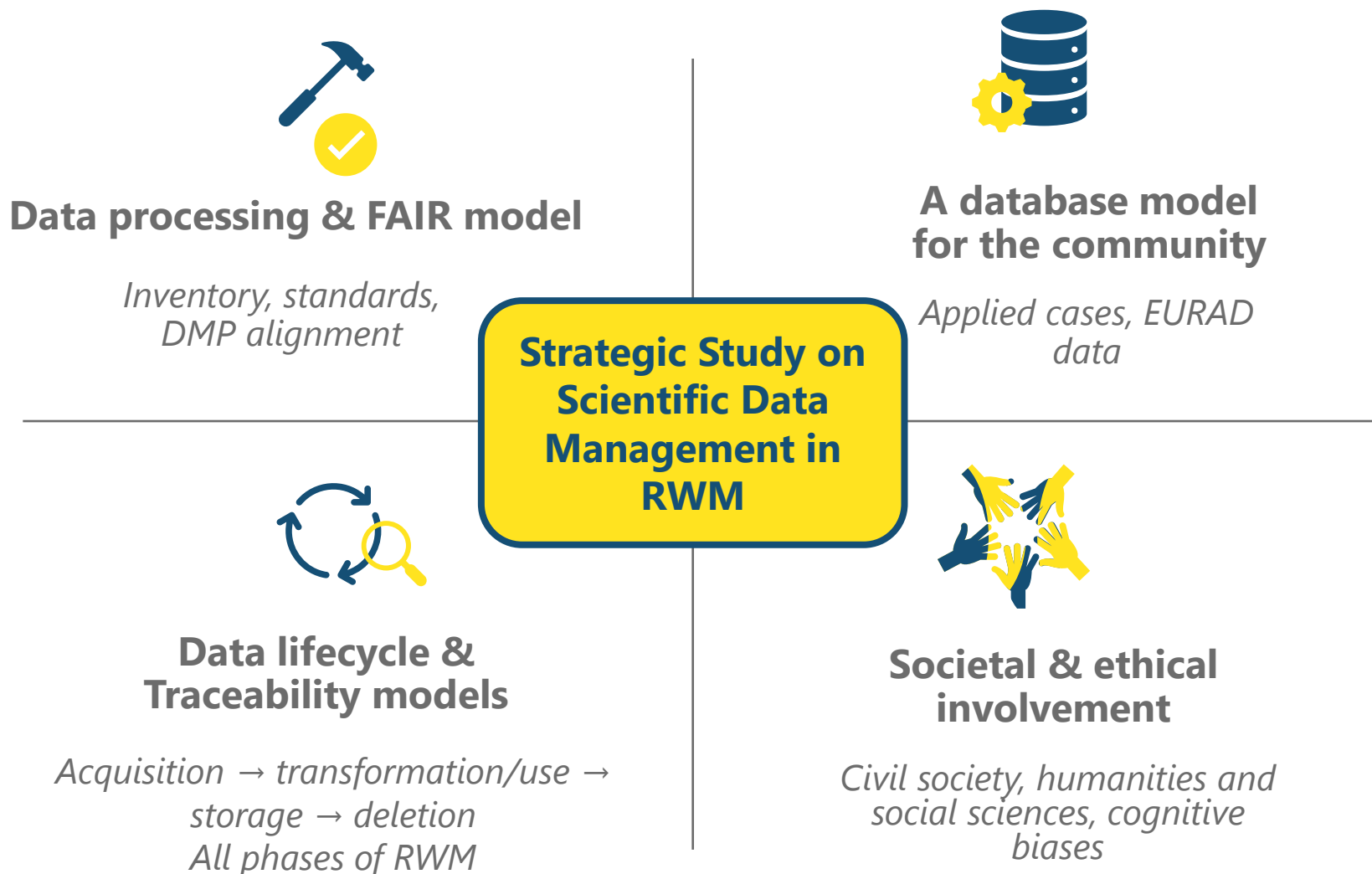
SRA drivers:

- Implementation Safety
- Innovation for Optimisation
- Societal Engagement
- Knowledge Management

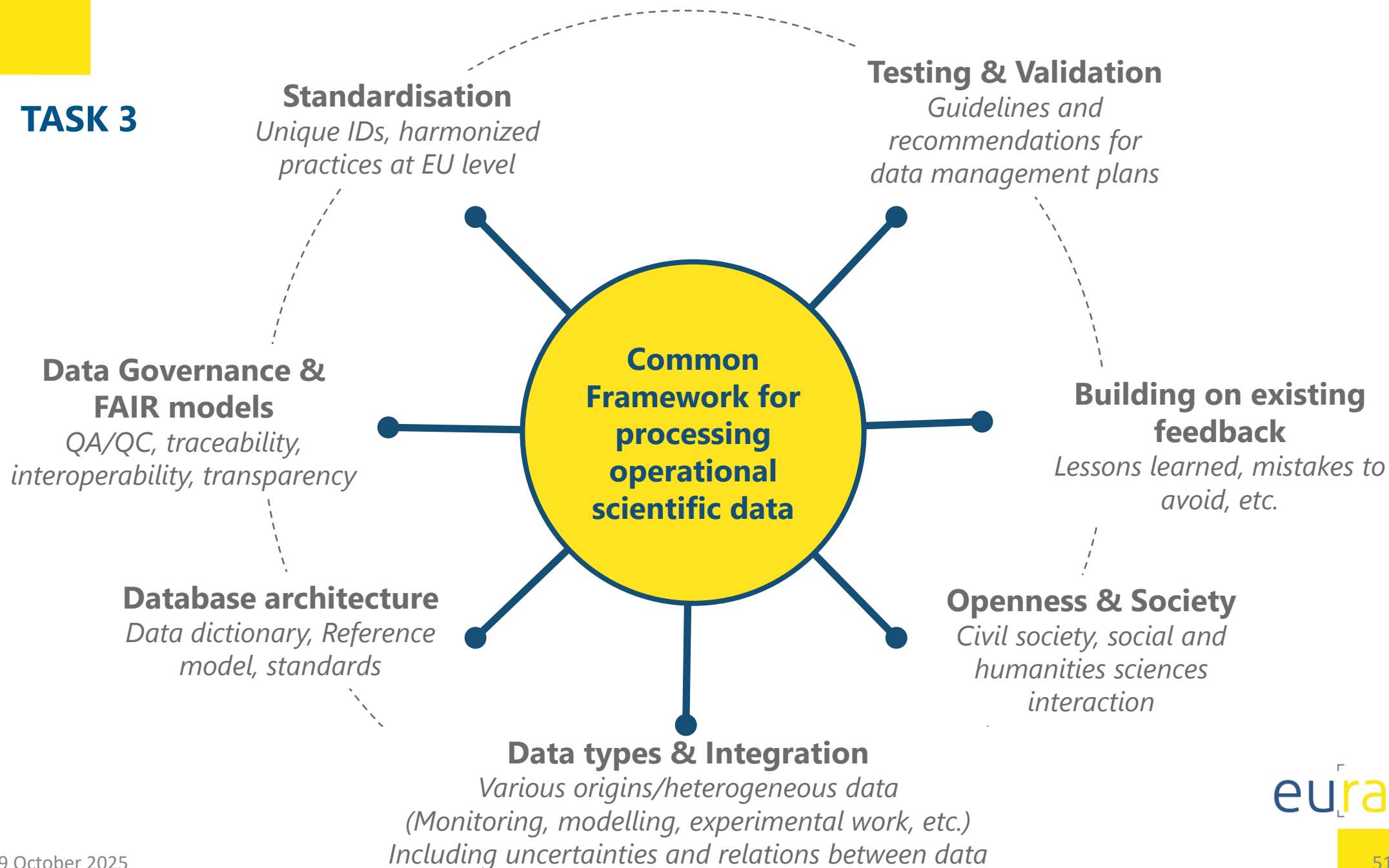
- ☒ Programme Management (Theme 1)
- ☒ Pre-disposal (Theme 2)
- ☒ Engineered Barrier Systems (Theme 3)
- ☒ Geoscience (Theme 4)
- ☒ Disposal facility design and optimisation (Theme 5)
- ☒ Siting and Licensing (Theme 6)
- ☒ Safety Case (Theme 7)

OBJECTIVES OF THE WP

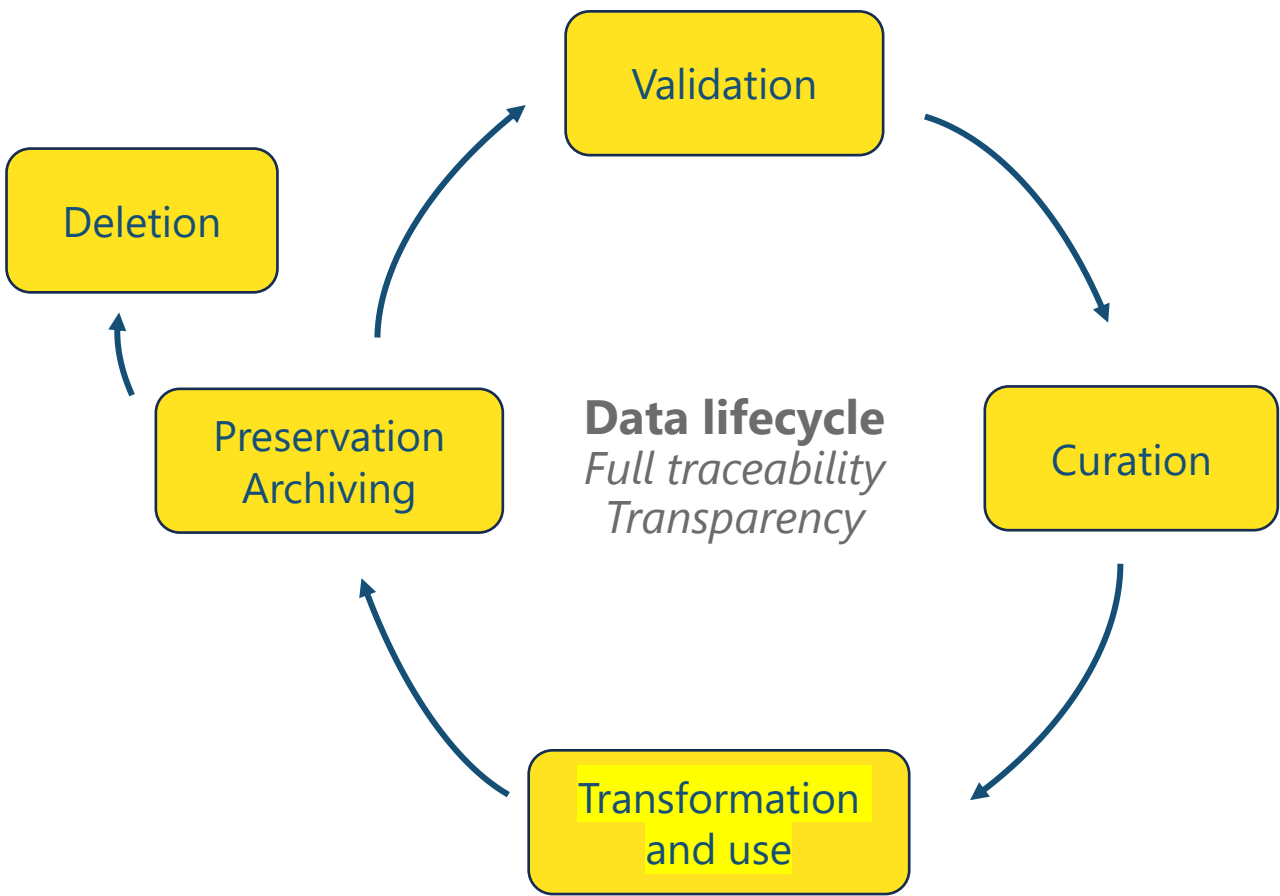
Operational scientific data refer to all scientific data, along with associated metadata on context (origin, acquisition conditions and methods, models, software, uncertainties, etc.) and evolution of the corresponding datasets (consolidation, discarding, merging), from its acquisition to its use in design and safety assessments



TASK 3



TASK 4



Framework for data catalogue



Guidance for lineage document, assembly of data of various origin (choices, etc.)



Recommendations for dataset curation and validation



Reference workflow and comparative assessment of data lifecycle tools



Domain-specific recommendations

TASK 5

FROM INTERPRETATION PROCESS TO DECISION PROCESS: Bridging the gap between research monitoring and operational monitoring

Selected datasets from previous projects and/or from possible R&D WP on sensors or related modelling activities



Scenarios and simulations
Stakeholders & societal concerns
Decision-support
Ongoing gouvernance

NEXT GENERATION DIGITAL TWINS TO SUPPORT OPTIMISATION OF SURFACE AND SUBSURFACE RADIOACTIVE WASTE MANAGEMENT FACILITIES

DITOCO StSt WP



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

WHY NOW?



RISING DEMAND FOR SAFE
NUCLEAR STORAGE



TECHNOLOGICAL DEVELOPMENT
PACE

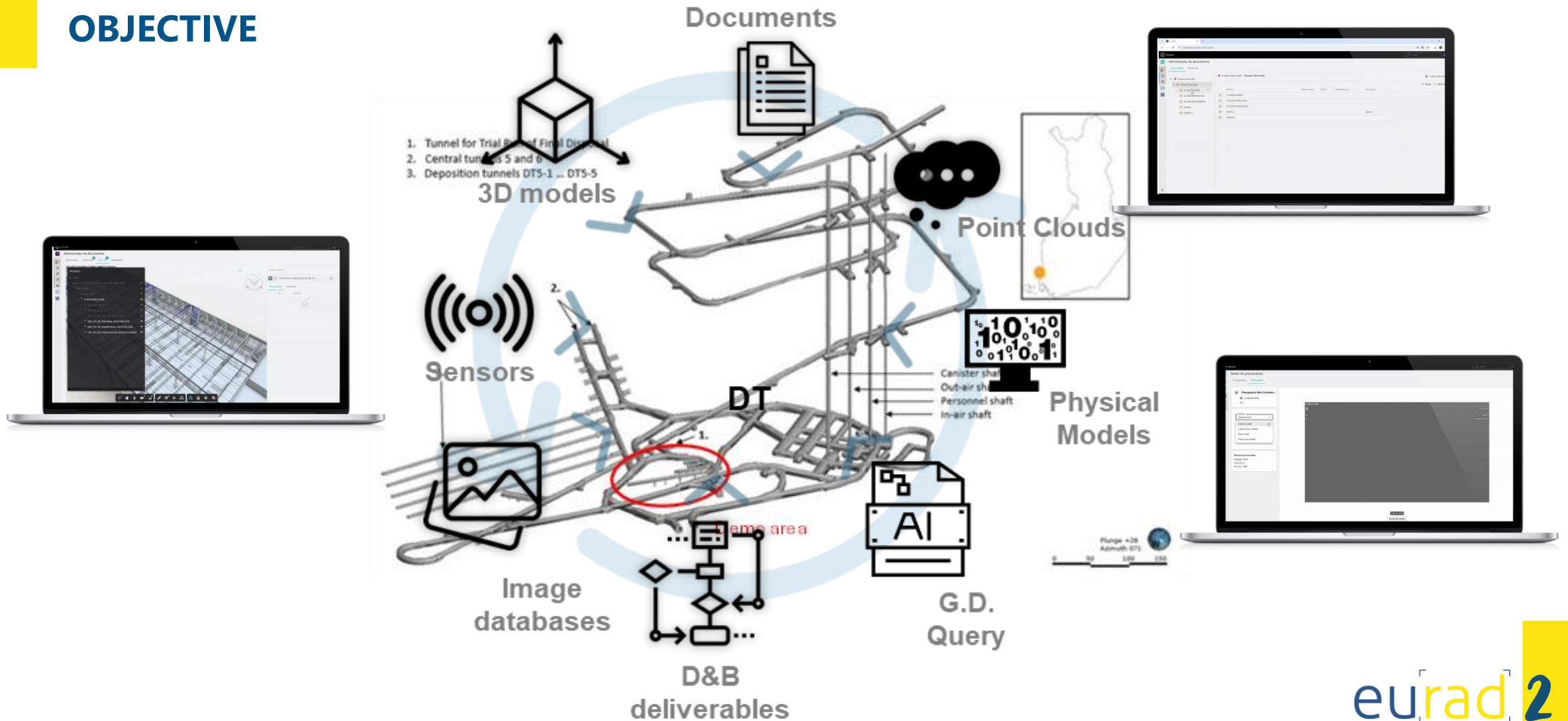


ADDOPTION INTO THE CIVIL,
INDUSTIAL AND OTHER AREAS OF
THE NUCLEAR SECTOR
APPLICATIONS.

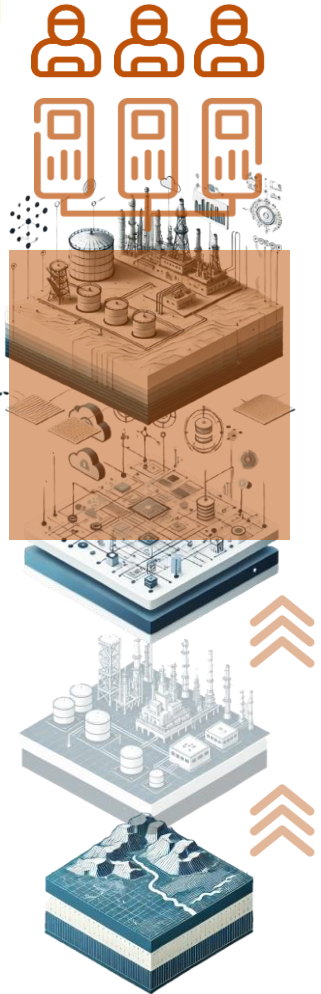


LEVERAGE WMO EXPETISE AND
SYNERGIES WITH DITOCO WPS -
HERMES

OBJECTIVE



ADDED VALUE



SAFETY

Sensing, Remote AI
Assisted operation

Track, monitor and
register activities

AI boosted -Process
simulation -
IT workflows, decisión
making track record.

Single Source of Truth

AFFORDABILITY

Open, flexible, scalable
and interoperable

Pre-FAB – Optimized
cons. Sequences. First
time right

AI Optimised design
processes – G. D.

Full connectivity of the
ecosystem

ACCEPTANCE

Augmented Reality
Simulations

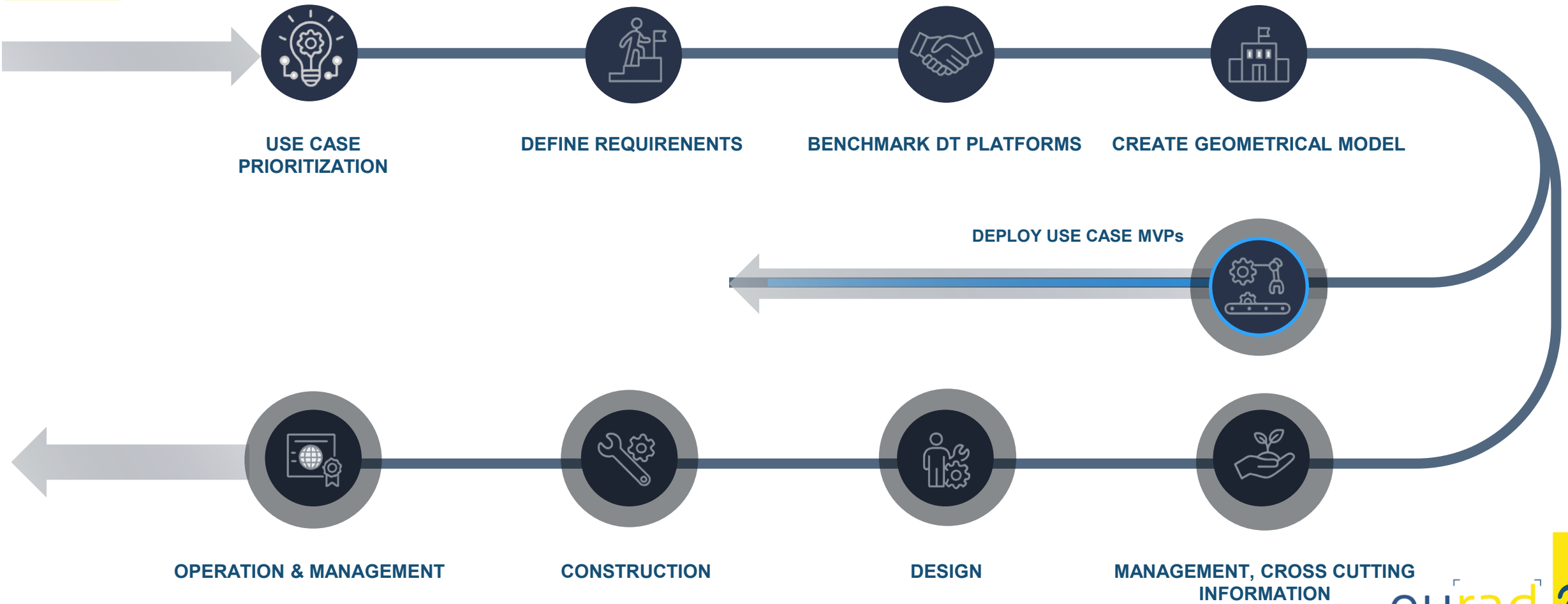
Augmented Reality
Simulations

Compliance with the
Regulator / Stakeholder
engagement

Single Source of Truth

eu[r]ad²

SCOPE AND METHODOLOGY



SCOPE AND METHODOLOGY



USE CASE
PRIORITIZATION

IDENTIFY

PRIORITIZE

SELECT



DEFINE REQUIREMENTS

GEOMETRIC

CODING

DATAMODEL



BENCHMARK DT PLATFORMS

IDENTIFY

REQ. COMPLIANCE

SELECT



CREATE FOUNDATIONAL DATA
MODEL

MODEL

DEPLOY USE CASE MVPs

COORDINATE

INTEGRATE



ADDITIONAL LAYERS

PHYSICAL
NUMERICAL

DOCUMENTATION

AR / VR



DESIGN

USE CASES MVPs



CONSTRUCTION

GENERATIVE DESIGN
(Geotechnical, civil, structural,
radiological, logistics)

**AI SUPPORTED
CONSTRUCTION**
(Image recognition, sensor
and data capture)

**AI SUPPORTED
MANAGEMENT**
(Optimized facility
management based on AI
processed data integration)



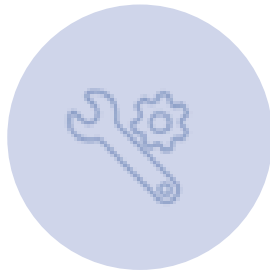
OPERATION & MANAGEMENT

eurad 2

TOWARDS A DIGITAL LIVING ECOSYSTEM



ADDAPT AND EVOLVE



**STRUCTURED SMOOTH
DATA FLOW**



**SINGLE SOURCE OF
TRUTH**

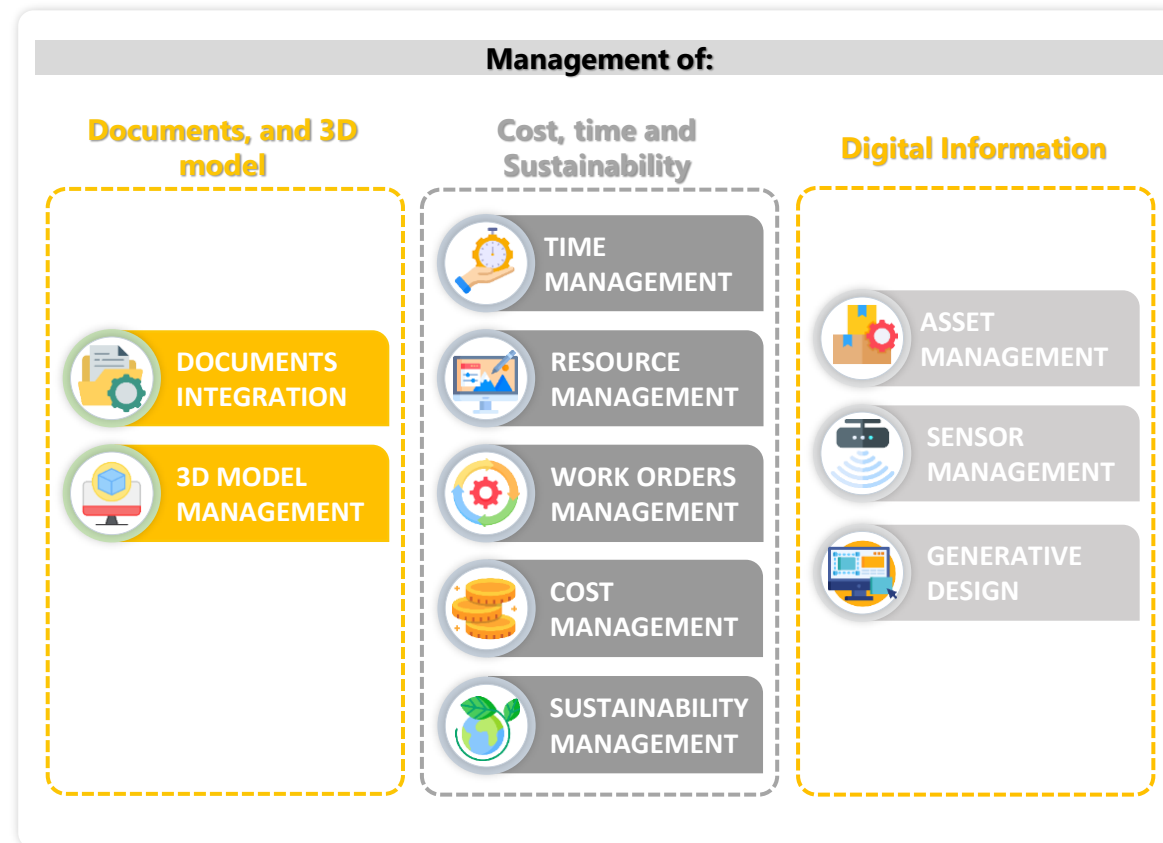


**IT ROBUSTNESS AI
POWERED ALTERNATIVES**

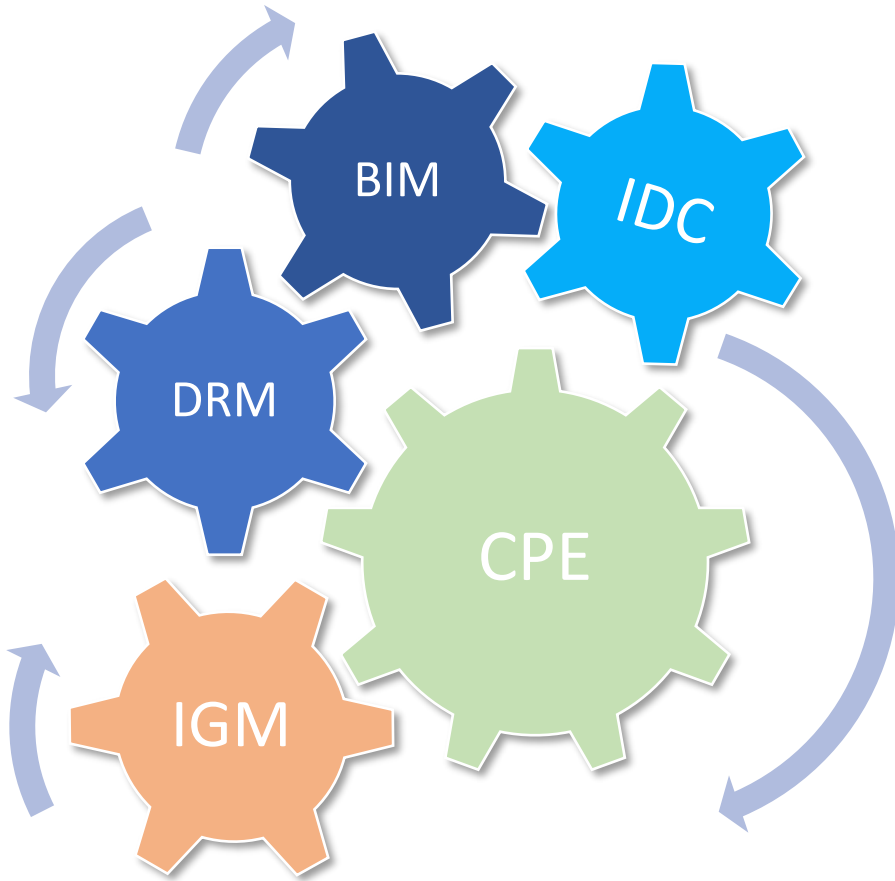
Q&A

01 – INDUSTRIAL INNOVATION MEETS NW CHALLENGES

DIGITAL TWIN framework is structured to interconnect involved stakeholders of a project, enabling seamless data flow and connectivity while facilitating integrated management, consumption, and use of information instead of isolated processes. Thanks to its flexibility and adaptability, digital twins can integrate effortlessly with any industry need due to its principle of digital information.



NAGRA'S INTEGRATED DIGITAL ENVIRONMENT



- **Integrated Geo-Model (IGM)**
→ *Subsurface representation and evolution*
- **Building Information Modelling (BIM)**
→ *Engineering design and construction information*
- **Dynamic Repository Modelling (DRM)**
→ *Safety and Performance Assessment*
- **Common Project Environment (CPE)**
→ *Reference configuration, requirements and change*
- **Information & Data Centre (IDC)**
→ *Storage, archiving, provenance*

3D/4D/5D/6D
models

**THANK YOU
FOR YOUR ATTENTION**



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