

Template #2

Short Acronym and full Title	EBS Materials / Sustainable materials and processes for enhancing passive safety and robustness of Engineered Barrier Systems		
Type of activity	<input checked="" type="checkbox"/> R&D		<input type="checkbox"/> Strategic Study
Budget estimation (total budget in M€, i.e ~ 1.5 M€)	2.8 M€	Duration of the WP (in months)	36
Links with EURAD SRA / Roadmap Themes (if multiple choices, indicate the primary link in bold – maximum 3)	<input checked="" type="checkbox"/> Programme Management (Theme 1) <input type="checkbox"/> Pre-disposal (Theme 2) <input checked="" type="checkbox"/> Engineered Barrier Systems (Theme 3) <input type="checkbox"/> Geoscience (Theme 4) <input checked="" type="checkbox"/> Disposal facility design and optimisation (Theme 5) <input type="checkbox"/> Siting and Licensing (Theme 6) <input checked="" type="checkbox"/> Safety Case (Theme 7)		
Links with EURAD SRA topics (if multiple choices, indicate the primary link in bold – maximum 3)	Please indicate the corresponding Domains (number) and Description of R&D, StSt or KM needs (second column of SRA) <ul style="list-style-type: none"> • 3.2.3 Novel Containers • 3.3.1 Buffers • 3.3.2 Backfills 		
SRA drivers (maximum 3)	<input type="checkbox"/> Implementation Safety <input checked="" type="checkbox"/> Tailored Solutions <input type="checkbox"/> Scientific Insight <input checked="" type="checkbox"/> Innovation for Optimisation <input checked="" type="checkbox"/> Societal Engagement <input type="checkbox"/> Knowledge Management		
Objective (What) – 1 sentence	To develop innovative sustainable materials and manufacturing techniques that enhance the robustness and passive safety of radioactive waste disposal systems through the use of alternative waste package materials, innovative backfill materials and the sustainable use of closure materials.		
Justification: impact / innovation / added-value (Why) – bullet points or short paragraph (maximum quarter of a page)	<p>Impact</p> <ul style="list-style-type: none"> • National programme benefits: Solutions for expanding conditioned waste matrices, more sustainable EBS materials, efficient and cost-effective use of space in repositories through material reuse (application of waste hierarchy), options for alternative materials that can be used in the future. • Enhanced robustness and long-term passive safety: By developing of radiation-resistant concretes, the disposal system achieves better durability under in-situ conditions (ionizing radiation, elevated temperatures). Improved backfill material prevent mechanical damage from expansive reactions and gas formation, ensuring the integrity of engineered barrier systems (EBS). • Environmental sustainability: Eco-friendly backfill materials and reuse/repurposing strategies to minimise waste and reduce environmental footprint and can contribute to long-term safety by promoting solubility-limited transport of key radionuclides. <p>Innovation</p> <ul style="list-style-type: none"> • Novel materials: Development of sustainable cementitious composites, repurposing of clay materials and radiation-resistant concretes offer a more sustainable replacements of conventional EBS materials. • Backfill material design: Innovative approaches allow controlled expansion, gas accommodation, and water ingress minimization—addressing challenges not solved by current solutions. • Circular use of materials: Reuse and repurposing of closure/backfill and excavated materials introduce a new paradigm of resource efficiency in disposal system design. <p>Added-Value</p>		

	<ul style="list-style-type: none"> • For EURAD-2 partners: Focused development of advanced EBS materials promotes the evolution of cost-effective and sustainable solutions across national programmes and knowledge transfer. • For disposal system safety: Increased passive safety and robustness, lowering costs. • For sustainability goals: Our approach to sustainability will incorporate specific attributes for radioactive waste disposal, namely long-time scales. Identification, implementation and follow up of sustainability indicators in all sustainability dimensions (social, environmental and economic) will be implemented during the project execution.
<p>List of planned tasks / subtasks with % of effort per task (5% increments) (Maximum 10 bullets)</p>	<p>The purpose of this Work Package (WP) is to support national programmes in making informed decisions regarding EBS solutions that address both current and future challenges. Although the objectives are broad, they form a coherent framework of EBS solutions aligned with national interests. While the execution of individual subtasks may involve fewer partners, the integration of their results will provide a diverse set of potential solutions for many users in the future. To ensure comparability across different approaches, the sustainability task (Task 3) will define the indicators for evaluation.</p> <p>After a three-year period, the stakeholders (end-users, partners) will be able to decide which solutions from the spectrum of EBS components should be further developed or discontinued. To enable such decisions within this timeframe, each subtask will be structured around logical milestones, each delivering meaningful results. For instance, although the testing of endogenous materials may require timeframes extending beyond three years, the scientific foundation, initial samples, and storage strategies should be established now to ensure continuity and facilitate future progress.</p> <ol style="list-style-type: none"> 1. Coordination, project management (5%) 2. Knowledge management, state-of-art, training material, dissemination (10%) 3. Indicators and assessment of sustainable EBS (15%) <ol style="list-style-type: none"> a. <i>Defining a tailored assessment framework for EBS sustainability:</i> Sustainability in the framework of engineered barriers for a nuclear waste disposal has specific attributes. The goal of this subtask is to extend and adapt existing assessment frameworks (criteria and indicators) to the context of EBS, encompassing the different sustainability dimensions (economic, environmental, social) in order to assess what makes a material sustainable in the context of engineering barrier systems. This adaptation notably takes into account also the various timeframes involved – i.e. short-term production/construction vs long-term containment/disposal. b. <i>Validation and application of the framework through case-studies:</i> Materials studied in Tasks 4 and 5 will be selected, and the tailored framework will be applied to them. This serves a dual purpose: 1) further validation and refinement of the criteria and indicators and 2) providing usable inputs for WP partners to guide their work on sustainable EBS components. Application to specific materials also allows for identification of potential tensions between various sustainability dimensions and temporal scales. c. <i>Transversal involvement in other tasks to integrate outcomes of the sustainability perspective:</i> Reflection exercises across the tasks to better integrate sustainability perspective in all aspects of this WP. 4. Development of novel cementitious backfill materials (35%) <ol style="list-style-type: none"> a. <i>Development of improved and sustainable innovative backfill material</i> to offer practical solutions for managing expansive waste by allowing controlled expansion and minimizing water ingress into the waste, thereby reducing expansive reactions. The steps will include (1) numerical modelling to determine the required properties of material in terms of physical properties (e.g. required water retention properties), mechanical properties (strength, deformability), and (2) experiments to find a material with required properties and sustainability components (incl. self-healing mechanisms)

	<p>b. <i>Use of different fillers or raw material in concrete</i> to improve properties or allow for waste volume reduction by recycling. These materials can be used as a backfill or package materials. The following types of materials are proposed as examples</p> <ol style="list-style-type: none"> i. Use of depleted uranium ii. Use of modified basalt fiber iii. Use of barium <p>(i): the aim of the study on depleted uranium is to assess the possibility to use depleted uranium either as high density aggregates within backfill/other cementitious components of a disposal system or as direct emplacement as a backfill material (i.e. without cementation), which would improve shielding properties and lead to the reduction of national waste liabilities (of depleted uranium) and thus minimise GDF footprint.</p> <p>(ii) partial or complete replacement of calcium oxide with barium oxide in the composition of cement would result in innovative barium compounds formed during the hydration process that has higher density compared to ordinary cements and may improve robustness and the stability of concrete under irradiation.</p> <p>(iii): the aim is to enhance the radiation resistance and shielding properties of concrete through reinforcement of concrete matrix with micro- or macro modified basalt fiber materials. Such modification will reduce activation of concrete material and enhance durability of respective EBS (reduce microcracking, improve toughness and enhance resistance to fatigue and thermal stresses), and improve the shielding properties as an alternative to traditional heavy-weight concretes.</p> <p>5. Host rock backfill/filling materials (35%)</p> <ol style="list-style-type: none"> a. <i>Claystone excavated during the construction of the geological repository</i> will be stored at the surface. It is currently planned that this material could later be reused as backfill after the repository's operational period or employed to create seals for galleries and disposal cells. Two key aspects are considered in this study: environmental aspect where continuous chemical monitoring will track their aging processes—primarily acidification—and the leaching of trace elements that may cause pollution. Another aspect covers the ageing of excavated materials and its compatibility with the original material after being exposed to environmental conditions for a long time. The study will involve large-scale outdoor experiments where both freshly excavated and previously stored rock deposits are exposed to natural conditions. In addition, modeling will be carried out to evaluate the significance of chemical and physical processes and to identify key monitoring variables. Complementary experimental work will focus on long-term analysis of thermal, hydraulic, mechanical, and chemical (THMC) changes, considering both time and scale dependencies. b. <i>Repurposing of excavated materials for its use as EBS material</i> (liners, components,..). This task will explore the possibility of using the excavated clays for an EBS material, potentially as a supplementary cementitious material. This would lead to reduction of waste excavated material, saving on the resources, reduce the transport and significant reduction of CO₂ footprint. The goal is to look at the new approaches of calcinated clays. The first step is to look at the feasibility related to the clay type. In the second step first experiments will be carried out. Further options is to look at the possibility to use excavated rocks as filler/aggregates in EBS concrete.
<p>List of expected outcomes linked to the identified SRA drivers (Maximum 6 bullets)</p>	<ul style="list-style-type: none"> • Adapt and define criteria for sustainability assessment in the framework of radioactive waste disposal • Optimisation of backfilling and other major implementation processes, including waste emplacement, retrieval and sealing technologies. • Approaches and concepts regarding sustainability in the context of nuclear waste disposal. • Development of solutions to support the application of circular economy principles to waste management

<p>Deliverables (Maximum 6 – including the prescribed deliverables)</p>	<ul style="list-style-type: none"> • D1: State of the art report (initial and final) • D2: Identification and implementation of criteria and indicators for assessing the sustainability of EBS materials and approaches • D3: Materials and processes for alternative disposal container materials • D4: Improved cementitious backfill materials • D5: Reuse and repurposing of excavated backfill materials
<p>Critical input requirements & identified risks (Optional - Explain what is out of the scope?)</p>	<p>The main driver for this work package is the identification of needs for EBS materials and issues with current approach/EBS materials. This can be based on the current or future needs. The crucial input is on the current state of art to reduce redundancies.</p> <p>Out of the scope are pure safety assessments. The reason is that safety assessment relies on many assumptions and conceptualisations that are already of interpretative nature and a subject of the national design/approach. The safety function concept is taken into account from the quantitative point of view that the proposed alternatives do not reduce or impair the safety of the existing solutions.</p>
<p>List of preliminary interested organisations as partners in the WP contributing effort; % of effort (person months, by College)</p>	<p>REs (50%): BGR(DE), CEA (FR), CVREZ (CZ), HUN-REN EK (HU), KIPT (UKR), KhPI(UKR) NNL (UK), POLIMI (IT), PSI (CH), SCK CEN (BE), GTK (FI), UJV (CZ), EGIS (FR), BRGM (FR), GSL (UK), SIIEG (UKR), Univ-Lorraine(FR), Univ-Hannover(DE), TUDelft (NL), CVUT(CZ)</p> <p>TSO (40%): Merience/CIEMAT (ES), NTW (FR), ASNR (FR), Energorisk(UKR), GRS(DE), EIMV(SI), CEPN(FR), NRG Pallas (NL)</p> <p>WMO (10%): ANDRA (FR), SÚRAO (CZ), ENRESA (SP), POSIVA(FI), NAGRA (CH)</p>
<p>If applicable - links with previous projects / work packages</p>	<p>WP3 ASTRA – alternative waste management strategies for NORM/DU WP6 STREAM – sustainable treatment of challenging waste WP9 InCoManD – Innovative container materials WP10 ANCHORS – Evolution of bentonite barriers WP13 OPTI – HLW repository optimization</p>
<p>WP Preparation Team (1 member per College) contact (organisation + person, email)</p>	<p>RE: Janez Perko (SCK CEN), janez.perko@sckcen.be TSO: Oliver Czaikowski (GRS), Oliver.Czaikowski@grs.de WMO: Jean Talandier (ANDRA), jean.talandier@andra.fr</p>