Short Acronym and full Title	**S**ustainable **Trea**tment and I**m**mobilization of challenging waste (STREAM)		
Type of activity	☒R&D	☐Strategic Study	Knowledge Management – covered by a separate committee and template
Budget estimation (total budget in k€)	5 M€	Duration of the WP (in months)	60 months
Links with EURAD SRA / Roadmap Themes (if multiple choices, indicate the primary link **in bold – maximum 3**)	☐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)		
Links with EURAD SRA / Roadmap Domains (if multiple choices, indicate the primary link **in bold – maximum 3)**	- 2.2.2 Treatment and Processing - **2.2.3 Conditioning** - 3.3.2 Backfills		
SRA drivers[1] **(maximum 3)**	☐Implementation Safety	☒Tailored Solutions	☒Scientific Insight
	☒Innovation for Optimisation	☐Societal Engagement	☐Knowledge Management
Objective (What) – **1 sentence**	Innovative and sustainable design, optimization and upscaling of treatments and conditioning materials for the predisposal of problematic waste.		
Justification: impact /	Large amounts of waste in Europe need the implementation of management routes prior to disposal. Specifically, management routes for wastes such as		

[1] **Implementation Safety:** Contributing to the safe construction, operation and closure of DGRs (and other disposal facilities), ensuring long-term safety.
Tailored Solutions: Supporting the development of tailored solutions for the management of various radioactive waste types in Europe: Working together on scientific, technical, managerial, societal and regulatory issues of common interest and considering the full range of potential disposal solutions and waste groups accounting for IAEA's graded approach and taking economic aspects into consideration. Increasing robustness of approaches by addressing cross-correlations, path dependencies and potential pitfalls in the RWM strategy.
Scientific Insight: Advancing state of the art science in waste management and disposal throughout the waste management chain: Exploratory research in areas with significant uncertainty or in areas with high potential to improve knowledge.
Innovation for Optimisation: Supporting RWM innovation for optimization: Continuously managing uncertainty, improving robustness, reducing complexity and costs and optimizing RWM routes and advancing technology and solutions to meet the needs of Member States.
Societal Engagement: Helping to engage with and maintain mutual trust with stakeholders, and awareness in RWM: Addressing issues emerging from regulatory and societal concerns, fostering transparency and fruitful interactions with Civil Society along all stages of a RWM programme.
Knowledge Management: Enhancing knowledge management and transfer between organisations, Member States and generations: Capturing, maintaining, and efficiently developing skills, knowledge and infrastructure, in view of the long lead-times and the intergenerational dimension associated to RWM.

innovation / added-value (Why) – bullet points or short paragraph **(maximum quarter of a page)**	solids (SIERs), organic (liquid and solid), metallic and legacy or failed wastes still need to be further investigated. Processing routes (e.g. thermal treatments) and alternative conditioning methods compared to the traditional cement-based immobilisation (e.g. geopolymers, phosphate binders) have been investigated in previous projects (EURAD, THERAMIN, PREDIS). However, these processes are not yet fully mature and need future studies on e.g. : - The influence of the waste composition on the consolidation process of the conditioning matrix, - The durability of the hardened waste forms, - The minimization and management of secondary waste. The impact of these novel treatment and/or conditioning routes to the safety case has to be demonstrated to allow their implementation by end users in the future. Ensuring the technical and economic performance is critical to the nuclear sector. Reducing the environmental impact and ensuring the availability of raw materials in the context of the strongly evolving cement industry is becoming an increasing priority. LCA and LCC analyses enable and help the end users making choices on the materials. New conditioning matrices and backfills incorporating low-carbon cements (with less clinker) or recycled aggregates need to start RD&D activities to demonstrate their performance and to anticipate from now their implementation at an industrial level considering circular economy principles.
List of planned tasks / subtasks with % of effort per task (5% increments) **(Maximum 10 bullets)**	**1. <u>Coordination of the WP (10%)</u>** **2. <u>Knowledge Management (10%)</u>** 2.1. **Waste inventory**: gather data from other previous EU projects (PREDIS, THERAMIN) and select wastes of interest (solid and liquid organic waste such as organic sludges/solvents/oils/scintillation cocktails, co-precipitation sludges, evaporator concentrates, ion exchange resins, decontamination effluents…) 2.2. **Technology assessment and selection** of the optimal treatment technologies (thermal/plasma treatments, wet oxidation, molten salt oxidation) prior to conditioning, depending of the type of waste 3. **<u>Study of treatment and conditioning methods (30%)</u>** 3.1. **Optimization of available treatment technologies and conditioning matrices based on alternative binders** investigated in previous projects. The treatments include thermal treatments (incineration, plasma, gasification/liquefaction, thermal treatment + C14 capture) and wet methods (wet oxidation, molten salts…). The conditioning matrices are for instance alkali-activated materials-based matrices developed in PREDIS WP5, magnesium-phosphate binders developed in PREDIS WP4…. The minimization and management of secondary waste will also be taken into account in this task. 3.2. **Investigation of physico-chemical interactions between low-carbon binders and challenging waste**. The strong mutation of the cement industry under way to reduce its carbon footprint has led to the development and standardization of new cements (CEM II/C-M, CEM VI…) which may offer new prospects for nuclear waste management. Prior to the development of low-carbon conditioning matrices (T3.3), the chemical compatibility of these cements with selected waste streams (T2.1) currently stabilized with binders having a high carbon

	footprint (e.g. CEM I 52.5) must first be evaluated. The focus in this task will be placed on the influence of the waste components on the cement hydration rate and on the products formed. 3.3. **Design and characterization of low-carbon binders-based mortars** for conditioning matrices and backfills materials, incorporating recycled or secondary aggregates, and taking into account the possible cement-waste interactions evidenced in task 3.2. ➔ *Need to have input from WP2 Sustainability before starting this task about the selection of relevant mortar components.* 4. **<u>Scaling-up of treatment and conditioning processes (40%)</u>** 4.1. Demonstrate the **upscaling feasibility of processing and conditioning methods** as well as waste packages by a combination of large scale testing (e.g. used installed sensors). The objective is to select the most appropriate large scale technologies (treatment, mixing…), minimize the volume of secondary waste and design instrumented mock-up waste containers (e.g. AE sensors, vibrating strain gauges, fibre optic cables, pressure sensors) to monitor thermal excursion during hydration, stress development, expansion.. This task will also provide input data for the development of numerical models. 4.2. **Development of numerical models** to simulate the large-scale experiments. 5. **<u>Deploying safe solutions achieving cost and environmental performances following the principles of circular economy (10%)</u>** 5.1. **Fulfilling technical and economic requirements** related to the treatment and conditioning methods: providing case studies for LCA/LCC analysis 5.2. **Evaluation of fulfilment of WACs and disposability assessment** according to disposal facilities features (near-surface and/or intermediate-depth and/or geological) 5.3. Deploy results for **safe utilisation by end users** in close collaboration with WP7 to ensure the long term performance in order to safely utilise and implement the results by end users of repositories and regulators.
List of expected outcomes linked to the identified SRA drivers **(Maximum 6 bullets)**	• Development of new management routes including treatment and conditioning methods as well as new backfills materials, in a safe and sustainable way for waste streams without any previously identified or industrially implemented management routes (to increase TRLs). • Moving technologies from the lab-scale to industrial-scale. Facilitate improved treatment and processing of new and different types of waste streams, including thermal treatment solutions, and the optimisation of thermally treated product composition to increase waste loadings and/or improve waste form performance and reduce volumes of secondary waste. Development of more flexible, modular treatment facilities and solutions. Optimised chemical and physical methods of treatment, especially including solutions for decontamination. • Increased confidence in simulations by reducing uncertainties in input data and understanding of key processes. • Identification and sharing of good practice in waste conditioning and packaging approaches for problematic wastes and new / future wastes.

Deliverables **(Maximum 6 – including the prescribed deliverables)**	• D1: State of the art report (initial and final) • D2 (T2): waste/routes diagram showing the waste inventory and corresponding state-of-the art treatment/conditioning routes to be developed further in this WP • D3 (T3): Experimentations report of treatment and conditioning methods investigated in the WP • D4 (T4): Experimentations report of the treatment and conditioning scaling-up of processes and modelling approach • D5 (T5): LCA/LCC case studies • D6: Outcome/impacts report to Member States and End Users
Critical input requirements & identified risks	• Inputs regarding the waste inventory and technology assessment and are critical as foundation of the experimentations that will be performed in this WP. The risks are that the data are not available or not precise enough to build a robust database. • This WP needs to have strong interaction with WP "Characterization" and WP "Long term performance" as wastes need to be well characterized before defining sustainable management routes but also the long-term performance needs to be demonstrated to build strong safety case and pave the way to an industrial application in the future. • Inputs from WP2 Sustainability are critical to start the subtask 3.2 (design and optimization of low-carbon cement-based conditioning matrices) and later the Task 4 (upscaling of T3.2 matrices), in particular the availability of "D.5: Summary on concrete components availability, the development of new types of materials and the impact of the expected regulations evolutions in the field of nuclear waste management (impact on concrete acceptance criteria and qualification process)".
Major achievements expected by end of Year 2 (Go/No Assessment)[2] **(Maximum 5 bullets)**	• Waste inventory and technology assessment (T2) – *by Month 6* • Compatibility chart between "low CO_2" cements and challenging wastes (T3.2) – *by Month 24* • Optimize formulations developed in previous EU project (geopolymers matrices for RLOW direct conditioning and MKP matrices for cementitious materials) as input to WP7 Long Term Performance (T3.1) – *by Month 24* • TRL increase of treatment technologies for metallic and organic waste (T3.1) – *by Month 24*
(Optional - Explain what is out of the scope?)	Long-term performance of the waste forms and characterization, which will be addressed in other WPs at this stage. Bituminized waste are out of scope (the Core Group proposed to drop out this proposal due to a lack of interest expressed by the Colleges – besides, the pending issues concerning the bitumen matrix mainly concern its long-term evolution).

[2] EC budget being only allocated for the first 2 years, each work package progress will be reviewed at the end of Year 2, to assess its continuation based on the total budget that EURAD-2 will be granted.

List of preliminary interested organisations as partners in the WP contributing effort; **% of effort (person months, by College)**	**REs (60%):** CEA (FR), CSIC/UAM (ES), CVREZ (CZ), ECL (FR), INCT (PL), KIPT (UKR), NNL (UK), POLIMI (IT), PSI (CH), RATEN (RO), SCK CEN (BE), UOF (FI), UJV (CZ), EGIS (FR), BRGM (FR), KU Leuven (BE), GSL (UK), SIIEG (UKR), IMT SUBATECH (FR), ENEA (IT), UNIPI (IT), ORANO (FR) **TSOs (20%):** CIEMAT (ES), VTT (FI), NTW (FR), EIMV (SL), IRSN (FR), NCSR (GR), MKG (DK) **WMOs (20%):** ANDRA (FR), ENRESA (ES), NIRAS/BELGOPROCESS (BE), SOGIN (IT)
If applicable - links with previous projects / work packages	THERAMIN, PREDIS (Treatment and conditioning) EURAD-ROUTES (WACs & management routes) CARBOWASTE, CAST, IAEA-GRAPA projects (graphite)
WP Preparation Team (1 member per College) contact (**organisation + person**, email)	RE: Hélène NONNET (CEA), helene.nonnet@cea.fr TSO : Maria OKSA (VTT), maria.oksa@vtt.fi WMO : José Luis LEGANES (CIEMAT), JLEN@enresa.es CG observer : Christophe BRUGGEMAN (SCK CEN), christophe.bruggeman@sckcen.be

Links:

EURAD Roadmap: https://www.ejp-eurad.eu/roadmap