SSbD for High-T Thermal Storage in CSP Systems

Mendoza Gemma (1), Fuentes Elena (1), Ormazabal Guillermo (1), Chaves Jaime (2), Fco Javier Pérez (2), Pascual Jon (3) Grahn Leidigkeit Carolin (4)

(1) Tekniker, (2) UCM, (3) INTA, (4) VDM

Type of abstract: Oral

Subject area: T3. Industrial challenges and solutions to implement the safe and sustainable by design (SSbD) framework

Subject sub-area: T3.5. Industrially oriented research projects

Keywords: SSbD, CSP, Concentrated Solar Power, molten salts, coatings,

Brief description of the submission

This presentation highlights the implementation of Safe and Sustainable by Design (SSbD) framework in the development of high- temperature thermal energy storage materials for next-generation concentrated solar power (CSP) systems. The work was carried out within the HELIOTROPE project, funded under the EU's Horizon Europe programme. It focuses on the development of novel molten salts, stainless steel and nickel-based alloys, and various protective coatings designed for operation in CPS plants above 600 °C, thereby improving efficiency. Safety, environmental, and socio-economic factors were assessed early in the development process, with particular attention to hazardous substances and critical raw materials (CRMs). Key findings include the identification of nickel, cobalt, and lithium compounds as high-risk substances, prompting strategies for their substitution or reduction. The project demonstrates how integrating SSbD approach can guide material selection and process design in industrial energy technologies.

Abstract - Contribution details

Transition to climate-neutral energy systems requires advanced, high-performance thermal energy storage (TES) solutions that must be not only efficient but also safe and sustainable. In this context, the HELIOTROPE project, funded under the EU's Horizon Europe programme, is developing novel TES technologies for concentrated solar power (CSP) plants operating at temperatures above the current 600 °C threshold, increasing plant dispatchability. These innovations are grounded in the Safe and Sustainable by Design (SSbD) framework, aiming to integrate safety, environmental performance, and socio-economic viability from the earliest stages of materials development.

The project focuses on new high-temperature molten salt formulations, advanced metallic alloys, and protective coatings. Selection and development processes are guided by SSbD principles: reducing hazardous substances, minimizing critical raw material (CRM) dependency, improving recyclability, and lowering lifecycle environmental impact.

Preliminary safety and sustainability assessments revealed critical findings regarding material selection. Among the analyzed high-temperature molten salts (chloride and carbonate-based systems), stainless steel and Ni-based alloys, and protective coatings candidates (Fe50Cr and Ni20Cr High Velocity Oxygen fuel coatings, Ni electrodeposition and AlSi slurries), several hazardous substances were identified according to H1 criterion classification, criteria which is proposed by the framework itself, including nickel and cobalt compounds. CRMs (Critical Raw Materials) analysis identified lithium, cobalt, tungsten, manganese, and titanium as supply chain risk factors, with specific recommendations for material substitution or minimization strategies. The ex-ante LCA and techno-economic analysis conducted revealed potential environmental impact reductions through strategic material selection and process optimization.

Key strategies include replacing high-impact materials like lithium and cobalt, optimizing synthesis pathways for energy efficiency, and designing components with end-of-life treatments and circularity actions in mind.

This approach demonstrates how industrially relevant research can embed SSbD into the development of clean energy technologies.

Acknowledge: This project has received funding from the European Union's Horizon Europe research and innovation programme under the grant agreement No 101147455 (HELIOTROPE)