

X-SEED

EXPERIMENTAL SUPERCRITICAL ELECTROLYSER DEVELOPMENT



Project ID	101137701
PRR 2025	Pillar 1 - H ₂ Production
Call Topic	HORIZON-JTI-CLEANH ₂ -2023-01-01
Project Total Costs	2 989 495.00
Clean H ₂ JU Max. Contribution	2 989 495.00
Project Period	01-01-2024 - 30-06-2027
Coordinator Beneficiary	ACONDICIONAMIENTO TARRASENSE ASSOCIACION, ES
Beneficiaries	SNAM S.P.A., PARTICULAR MATERIALS SRL, INDUSTRIE DE NORA SPA-IDN, DANMARKS TEKNISKE UNIVERSITET

<https://www.xseedproject.eu/>

PROJECT AND GENERAL OBJECTIVES

X-SEED aims to develop an innovative electrolyser that does not use an alkaline membrane and that works in supercritical water conditions (SCWC, >374 °C; >220 bar) generating high-quality H₂ at pressures over 200 bar. Novel catalysts and electrodes are designed, synthesised, and characterised to ensure high levels of efficiency. Multiscale modeling and cell design ensure laminar fluid flows, allowing H₂ and O₂ separation without a membrane. X-SEED validates results at the laboratory scale (technology readiness level 4) for a single cell and a five-cell stack achieving high energy efficiency (42 kWh/kg H₂), current density (> 3 A/cm²), and robustness (degradation rate 1%/1 000h). X-SEED also integrates circularity and sustainability assessments in decision-making, limiting the use of critical raw materials (CRM) (use of less than 0.3 mg/W) and using waste water both for catalyst production and as a possible electrolyte for the supercritical electrolyser.

NON-QUANTITATIVE OBJECTIVES

- Maximise the efficiency, sustainability and stability of the innovative nanostructured catalysts and electrodes for anode and cathode based on earth abundant materials.
- Improve the efficiency, cost, and durability of the electrolyser by developing an innovative electrolysis cell and short stack, that do not use an electrolysis membrane, based on use in supercritical water conditions (SPWC).
- Gather evidence of the sustainability and circularity benefits of SPWC electrolyser over current solutions (proton-exchange membrane electrolysis (PEMEL), alkaline water electrolysis (AWEL)) by assessing the economic (life cycle costing), environmental (life cycle assessment) and social (social life-cycle assessment) impacts.
- Demonstrate the improvement of the sustainability and cost competitiveness of the SPWC electrolyser in comparison with PEMEL and AWEL technology.

- Contribution to scientific advances and creation of social awareness and acceptance of green H₂ economy.
- Ensuring exploitation of materials, components, and technologies developed in X-SEED project.

PROGRESS, MAIN ACHIEVEMENTS AND RESULTS

- Definition of SPWC electrolyser framework: state of art of catalyst and electrodes, survey of industrial wastewater to be used as source of catalyst and electrolyte, survey of industrial thermal waste appropriate for operation of SPWC electrolyser (no IR / no Horizons Results Platform).
- SPWC cell and stack design through 2D and multiphysics simulation.
- Synthesis of first batch of nanostructured catalyst stable at SPWC. Catalyst are based on perovskites, metal oxides and transition metal decorated nanoparticles structures.

FUTURE STEPS AND PLANS

- Selection of waste water suitable for catalyst synthesis via hydrothermal supercritical processes.
- Selection of electrolyte to use at SPWC electrolyser.
- Selection of waste thermal energy form industries suitable to operate the SPWC.
- Electrochemical and physic-chemical characterisation of catalyst and synthesis of improved catalysts.
- Electrode design and development based on high stability materials and synthesised catalysts.
- Start the design and preparation of test bench to operate and evaluate SPWC electrolysis cell.

PROJECT TARGETS

Target source	Parameter	Unit	Target	Target achieved?	SoA result achieved to date (by others)	Year for reported SoA result
Project's own objectives	Production capacity (Synthesis of catalysts using up-scalable processes -supercritical hydrothermal and electrospinning)	kg/h	1		tn per day is possible for different manufacturing techniques and types of catalyst (not achieved in the article but indicated as a basis for the technoeconomic analysis done in the study) CHFS process: 130 g/h	2018; 2016; 2017; 2011;
	Metals (Ni, Co, Cu, etc.) for the catalyst used coming from wastewater (e.g. mining, galvanic, etc.) using Continuous Hydrothermal Flow Synthesis process	% of metals from wastewater	50		N/A	N/A
	Catalysts with high surface area	m ² /g	>10		> 100 m ² /g	2020
	Catalyst and electrodes with high electrolytic efficiency. For HER and for OER	mVη ₁₀ @ NTP	< 100 for HER < 150 for OER		90 for HER 150 for OER	2021
	High stability catalyst and electrodes (in the electrochemical, thermal, and chemical aging tests).	%/1 000h	< 0.8		N/A	N/A
	Cell and stack electrolyser works at current density	A/cm ² @ 1.8 V at SPWC	3		35 A/cm ² 3 A/cm ² at 2.5V	2023; 2022
	Validate at laboratory scale a short stack supercritical electrolyser integrated by 5 cells of 25 cm ²	kW	0.5		for SPWC electrolyser only single cell has been tested	N/A
	Validate electricity consumption at nominal capacity	kWh/kg of H ₂	42		47-66 for PEMEL and AWEL 35 -50 for SOEL at stack level	2020
	Produce H ₂ at P	bar	> 200		30 (PEMEL, AWEL) test at 300 bar are realised for SPWC	2020; 2022; 2022
	Separation of products (O ₂ and H ₂) ensuring that outflows are outside the flammability limits of mixtures at operating temperatures and pressures	% of H ₂ @ O ₂ gas stream	< 4		N/A	N/A
	Degradation rate, demonstrated by aging stress tests at SPWC cell and stack level	%/1 000h	< 1	⚙️	N/A	N/A
	High operational flexibility: load range and fast start up and cold down	% sec	5-100 600		load range is 5 to 120 % for PEMEL, 15 to 110% for AWEL or 30 to 125 % for SOEL and the start up and cold down time ranges from <60 seconds for PEMEL to >10 h for SOEL	2020
	Able to operate with direct electrolysis of wastewater	-	yes		N/A	N/A
	Potential cost production of below 3 €/kg H ₂	€/kg	3		Supercritical electrolysis has production cost about 7.5 \$/kg H ₂ . With CAPEX, cost of electricity, etc. optimized, is expected to achieve 3.10 \$/kg H ₂ while AWEL and PEMEL are expected to produce H ₂ at 4.0 - 4.5 \$/kg H ₂	2021
	1 LCA containing circularity + 1 s-LCA + 1 LCC of the X-SEED electrolyser	Number of studies	3		N/A	N/A
	Reduction of electricity consumption in comparison to AWEL and PEMEL, considering electrolysers powered by electrical grid	% of kgCO ₂ eq reduction respect AWEL and PEMEL	20		Carbon footprint is influenced by carbon footprint of electricity used; it varies from 25 KgCO ₂ /kg H ₂ (for AWEL and SOEL) to 20 KgCO ₂ /kg H ₂ for SOEL, considering grid electricity Germany 2018 (0.47 tn CO ₂ /MWh)	2020
	Non-use Pt, Ru, decrease use of CRM	mg/W	<0.3		0 m g of CRM/W	2021
	Feedback received from experts through one workshop or participatory activity, as part of the social assessment	Number of feedback	>15			
	Recovery > 50 % of internal heat and demonstrate the feasibility of meeting over 30% of the system's heat demand by utilising industrial waste heat	% of heat recovered	50			
	Contributions in peer reviewed open access articles and conference	Number	22			
	Patents	Number	2			
	Expand the use of renewable H ₂ technology among existing and potential end users	Number	5			
	External interactions through social media, workshops, and disclosure articles	Number	5 000			
	Synthesise and study of different classes of catalysts (perovskites, metal oxides and transition metal decorated nanoparticles)	Types of catalyst	3	✓	N/A	N/A