X-SEED

EXPERIMENTAL SUPERCRITICAL ELECTROLYSER DEVELOPMENT

Project ID	101137701
PRR 2024	Pillar 1 – Renewable hydrogen production
Call topic	HORIZON-JTI-CLEANH2-2023-01-01: Innovative electrolysis cells for hydrogen production
Project total costs	EUR 2 989 495.00
Clean H_2 JU max. contribution	EUR 2 989 495.00
Project period	1.1.2024–30.6.2027
Coordinator	Acondicionamiento Tarrasense Associacion, Spain
Beneficiaries	Danmarks Tekniske Universitet, Industrie De Nora SpA, Particular Materials SRL, Snam SpA

https://cordis.europa.eu/project/id/101137701

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 (SPWCs) (> 374 °C, > 220 bar), generating high-quality H_2 at pressure over 200 bar. Novel catalysts and electrodes are designed, synthesised and characterised to ensure high levels of efficiency. Multiscale modelling and cell design ensure laminar fluid flows, allowing H_2 and O_2 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 H_2), current density (> 3 A/cm^2) and robustness (degradation rate < 1 %/1 000 h). X-SEED also integrates circularity and sustainability assessments in decision-making, limiting the use of critical raw materials (CRMs) (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. In conclusion, the X-SEED project's relevance and added value extend beyond the technological dimension: X-SEED will accelerate the H_2 ecosystem, supporting Europe in meeting climate targets and maintaining its leadership position as a technological developer, producer and exporter of green energy.

NON-QUANTITATIVE OBJECTIVES

- Maximise the efficiency, sustainability and stability of the innovative nanostructured catalysts and electrodes for anodes and cathodes based on Earth-abundant materials.
- Improve the efficiency, cost and durability of the electrolyser by developing an innovative cell and short stack that do not use an electrolysis membrane, based on use in SPWCs.
- Gather evidence of the sustainability and circularity benefits of the 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.

PROGRESS AND MAIN ACHIEVEMENTS

- The SPWC electrolyser framework was defined. It covers state-of-the-art (SOA) catalysts and electrodes, a survey of industrial waste water to be used as a source of catalysts and electrolytes and a survey of industrial thermal waste appropriated for the operation of the SPWC electrolyser (no Innovation Radar / no Horizon Results Platform).
- The SPWC cell and stack design was modelled using 2D and multiphysics simulation.
- The first batch of nanostructured catalysts stable at SPWCs was synthesised. Catalysts are based on perovskites, metal oxides and transition-metal-decorated nanoparticle structures.

FUTURE STEPS AND PLANS

- Selection of waste water suitable for catalyst synthesis via hydrothermal supercritical processes (continuous hydrothermal flow synthesis).
- Selection of electrolyte to use in the SPWC electrolyser.
- Selection of waste thermal energy from industries that is suitable to operate the SPWC.
- Electrochemical and physico-chemical characterisation of the catalyst and synthesis of improved ones.
- Electrode design and development based on high-stability materials and synthesised catalysts.
- Start of the design and preparation of the test bench to operate and evaluate the SPWC electrolysis cell.

Clean Hydrogen Partnership
Co-funded by the European Union

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	Feedback received from experts	number	> 15		N/A	–
	Separation of products (O_2 and H_2)	% of H_2 at O_2 gas stream	< 4		Not reported for SPWC electrolyser	–
	High operational flexibility: load range	% (start-up and cold down time, seconds)	5–110 %, with fast start-up and cold down (< 600 seconds)		Load range is 5–120 % for PEMEL, 15–110 % for AWEL or 30–125 % for SOEL; the start-up and cold down time ranges from < 60 seconds for PEMEL to > 10 hours for SOEL	2020
	Synthesis and study	types of catalyst	3		N/A	–
	Assessments	number	3		N/A	–
	Electricity consumption @ nominal capacity	kWh/kg of H_2	42		47–66 for PEMEL and AWEL and 35–50 for SOEL at the stack level	2020
	Nominal power of a short-stack supercritical electrolyser integrated into five cells of 25 cm^2	kW	0.5		For the SPWC electrolyser, only a single cell has been tested	–
	Degradation rate < 1 %/1 000 h, demonstrated by ageing stress tests at the SPWC cell and stack levels	%/1 000 h	< 1		Not reported for the SPWC electrolyser	–
	Heat recovered	%	50		N/A	–
	Production capacity synthesis of catalysts using upscalable processes	kg/h	1		1 t per day is possible for different manufacturing techniques and types of catalyst	2018, 2016, 2017, 2011
	External interactions through social media, workshops and disclosure articles	number	5 000		N/A	N/A
	Cell and stack electrolyser work at current density	A/cm^2 at 1.8 V in SPWCs	3		35 A/cm^2; 3 A/cm^2 at 2.5 V	2023; 2022
	Performance loss in the electrochemical, thermal, and chemical ageing tests)	%/1 000 h	< 0.8		Not reported for SPWC electrolyser	–
	Reduction of electricity consumption in comparison with AWEL and PEMEL	% kg CO_2	20		Carbon footprint varies from 25 kg CO_2/kg H_2 (for AWEL and SOEL) to 20 kg CO_2/kg H_2 for SOEC, based on grid electricity consumption in Germany in 2018 (0.47 t CO_2/MWh)	2020
	Production of H_2 at > 200 bar	bar	> 200		30 bar at the cell level (PEMEL, AWEL); tests in SPWCs at 300 bar have been carried out	2020; 2022; 2022
	Interactions with end users	number	5		N/A	N/A
	Catalyst and electrodes with high electrolytic efficiency	mV η_{10} at NTP	< 100 for HER; < 150 for OER;		90 mV at η_{10} for HER and 150 mV η_{10} for OER	2021
	Potential cost of production	€/kg	3		Without optimisation, the production cost of supercritical electrolysis is USD 7.5/kg H_2; with CAPEX, cost of electricity, etc. optimised, high-pressure high-temperature water electrolysis is expected to produce H_2 at USD 3.10/kg	2021
	Scientific contributions	number	22		N/A	–
	Metals (Ni, Co, Cu, etc.) for the catalyst come from waste water	%	50		N/A	–
	Patents and exploitation of the materials and systems developed in related industrial sectors	number	2		N/A	N/A
	Non-use of Pt and Ru, decreased use of CRMs	mg/W	< 0.3		0	2021
	Catalysts with high surface areas	m^2/g	10		> 100 m^2/g	2020

Clean Hydrogen Partnership
Co-funded by the European Union