# WINNER

## WORLD CLASS INNOVATIVE NOVEL NANOSCALE OPTIMIZED ELECTRODES AND ELECTROLYTES FOR ELECTROCHEMICAL REACTIONS

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| **Project ID** | 101007165 |
| **PRR 2024** | Pillar 2 – $H_2$ storage and distribution |
| **Call topic** | FCH-03-1-2020: HT proton conducting ceramic materials for highly efficient and flexible operation |
| **Project total cost** | EUR 2 931 788.75 |
| **Clean $H_2$ JU max. contribution** | EUR 2 931 788.75 |
| **Project period** | 1.1.2021–31.3.2024 |
| **Coordinator** | SINTEF AS, Norway |
| **Beneficiaries** | Consejo Superior de Investigaciones Científicas, Alleima Tube AB, CoorsTek Membrane Sciences AS, Danmarks Tekniske Universitet, ENGIE, Shell Global Solutions International BV, Universitetet i Oslo |

**https://www.sintef.no/projectweb/winner/**

### PROJECT AND GENERAL OBJECTIVES

The Winner project is contributing to the shift towards a future with more sustainable energy by developing an efficient and durable technology platform based on electrochemical proton ceramic conducting (PCC) cells designed to unlock a path towards commercially viable production, extraction, purification and compression of hydrogen at a small to medium scale through three process chains:

- cracking of ammonia to produce pressurised hydrogen or power, where PCC reactors provide an innovative solution for the flexible, secure and profitable storage and utilisation of energy in the form of green ammonia;
- dehydrogenation of ethane to produce ethylene and pressurised hydrogen, where PCCRs provide new sustainable pathways for electrically driven processes in the chemical industry;
- reversible steam electrolysis (using reversible protonic ceramic electrochemical cells), where PCC reactors allow the shifting of electric power generation to hydrogen production, enabling grid balancing, improved matching of the demand and supply of electricity, and more efficient use of renewable energy sources.

### NON-QUANTITATIVE OBJECTIVES

Winner is developing a multiscale, multiphysics modelling platform integrating various disciplines (atomistic, electrochemical, mechanical, fluid flow, reactor engineering, electric, heat), with the goal of establishing the rate-determining steps at a meso scale in the electrochemical cell, and the most efficient dimensioning and arrangement of the cells in the multitube reactor design. The work is supported by relevant experimental data and enhanced experimentation methodologies applied in the project.

### PROGRESS AND MAIN ACHIEVEMENTS

The project developed novel tubular cells using a production line established by CoorsTek Membrane Sciences, consisting of a Ni-BZCY72 electrode with BZCY81-dense electrolyte. The cells met performance criteria for reversible electrolysis of ammonia to hydrogen cells, with a cell area-specific resistance below 1 ohm.cm$^2$ at 650 °C, a faradaic efficiency of 80–90 % and a degradation rate below 1.2 %/kh under reversible operation. A tubular cell was successfully in reversible operation for over 4 000 h at 4 bar at 650 °C. The results of these research and development activities are reported in several public deliverables. A communication platform was established to link various models and competencies developed from the atomistic scale to the process scale. An engineering model was created for each of the Winner applications, which is now functioning alongside multiple other models integrated together. The construction of a computational fluid dynamics model has been initiated, with outputs including energy demand in relation to balance of plant and for the overall process for selected input parameters. A life-cycle assessment of three applications was conducted, showing the benefits of proton ceramic technologies in comparison with benchmark cases. In 2023, a multitube testing unit within Consejo Superior de Investigaciones Científicas was prepared, and upgrades and commissioning were initiated.

### FUTURE STEPS AND PLANS

The project was finalised at the end of March 2024 with the delivery of techno-economic analysis and life-cycle assessment results. A results exploitation workshop was also organised in March 2024.

### PROJECT TARGETS

| Target source | Parameter | Unit | Target | Achieved to date by the project | Target achieved? | SOA result achieved to date (by others) | Year for reported SOA result |
|---|---|---|---|---|---|---|---|
| Project's own objectives | Round-trip efficiency of reversible steam electrolysis | % at 650 °C | > 75 | N/A | ⚙ | Unclear as this is not well documented in the literature | 2019 |
| | Faradaic efficiency | % | > 95 | > 90 | | > 90 | 2021 |
| | Durability | hours | 3 000 | > 4 000 | ✓ | < 1 000 | 2021 |
| | Area-specific resistance of cell | ohm.cm$^2$ at 650 °C | < 1 | < 1 | | 2.5 | 2022 |
| Project's own objectives and MAWP (2018–2020) | Levelised cost of hydrogen produced | €/kg | 5 | N/A | ⚙ | > 6, based on GAMER technology with several scaling up assumptions | 2022 |



Clean Hydrogen Partnership
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