SHINE Project

Anurag Mohapatra[a], Verónica Díaz[b], Steffen Fahr[c], Gonzalo Tejera[d], Milagros Suárez[e], Juan Lezama*[f]

[a]anurag.mohapatra@tum.de, [b]verodiaz@fing.edu.uy, [c]steffen.fahr@tum.de, [d]gonzalot@fing.edu.uy, [e]msuarez@fing.edu.uy
[f]juan.lezama@fing.edu.uy

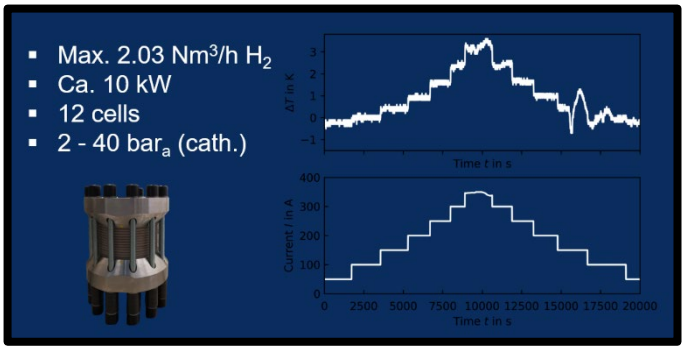


Figure 1: WP 2 10kW PEM stack main characteristics

This joint Uruguay–Germany research initiative, framed under the SHINE project, investigates PEM (Proton Exchange Membrane) electrolysis technology within the broader techno-economic context of future renewable energy systems. Bringing together institutions from Uruguay (UdelaR, UTEC), Argentina, and the Technical University of Munich (TUM), the project addresses a critical gap in the existing literature: most electrolyzer research operates at a single scale without connecting these scales in a coherent, experimentally grounded framework. SHINE is designed precisely to bridge that gap.

The project's central research question asks which experimentally validated PEM electrolyzer characteristics are decisive for hydrogen planning at the Uruguay energy system scale in four work packages.

The research agenda follows a two-stream structure in which experimental evidence and system-level planning inform and validate each other iteratively. Work Package 1 provides the foundational cell-level evidence: through aging and degradation studies conducted jointly with Uruguayan and Argentine partners, the team identifies how PEM cells lose performance over time and which diagnostic signatures carry the most predictive value. This produces credible degradation factors and bounded parameter sets for subsequent modeling stages.

Work Package 2 scales up to the full stack, using TUM's dedicated 10 kW PEM test stand to map part-load efficiency, pressure and temperature response. The outputs constitute the primary inputs for the digital twin.

Work Package 3 forms the technical core of the project, encoding both the cell degradation parameters from WP1 and the stack efficiency maps from WP2 into a high-fidelity real-time emulator. Through TUM's H2-Lab and the CoSES laboratory environment, Power Hardware-in-the-Loop (PHIL) integration enables grid-coupled operation and advanced control strategies to be validated without exposing real hardware to risk. Physical and real-time digital models are developed, rigorously validated against experimental data, and fed back into the system planning layer.

Work Package 4 closes the loop at the system level. Using tools such as urbs and SimSEE, the team models Uruguay's renewable supply scenarios, hydrogen export potential, and domestic energy impacts using the electrolyzer performance curves produced in the lower work packages.

Taken together, SHINE's central contribution is a validated electrolyzer model that translates cell degradation evidence and stack dynamics into actionable inputs for energy system planning and transforms system-level scenarios into experimentally grounded laboratory tests. This bidirectional methodology positions the project as a replicable framework for countries, like Uruguay, seeking to responsibly integrate green hydrogen production into high-renewable-penetration energy systems.

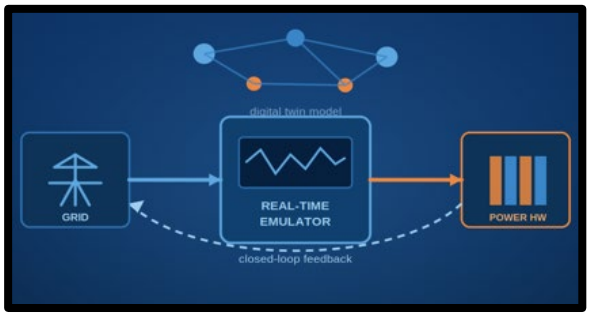


Figure 2: WP 3 conceptual map

*Presenting Author