Hydrogen Research & Innovation Days

24-25 November 2025

Clean Hydrogen Partnership

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HYSCALE – ECONOMIC GREEN HYDROGEN AT SCALE WITH CRM & PFAS FREE AEM ELECTROLYSERS

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From Targets to Technology – Why HYScale Matters

EU Hydrogen Strategy

- **2030 Target:** 40 GW of electrolyser installations planned.
- **HYScale Contribution:** Provides scalable, cost-effective green hydrogen technology that directly supports achieving this deployment.

TRL Advancement

- **System Demonstration:** 100 kW AEM stack integrated into an electrolyser demonstrator.
- **TRL Progression:** Technology maturity increased from TRL 3 to TRL 5 in an industrially relevant environment.

Scalable Building Block

- **Scalable Architecture:** The 100 kW demonstrator is designed as a modular building block for MW-scale electrolyser systems.
- **Path to Higher TRL:** Supports progression toward TRL 6 and beyond through straightforward scaling and system integration.

Tackling Key Barriers

- **Cost Reduction:** Tackles high CAPEX barriers.
- **Material Independence:** Reduces reliance on CRM
- **High-Performance Operation:** Enables stable 2 A/cm² operation with low degradation.
- **Low-KOH Compatibility:** Supports efficient performance in highly diluted KOH electrolyte.

A Distinctive, CRM-Free, PFAS-Free AEM Technology

HYScale represents a breakthrough in sustainable electrolyser design, combining regulatory compliance with technical excellence through innovative material choices and system architecture.

AionFLX™ Membranes

- **PFAS-Free Design:** Fluorine-free with high hydroxide conductivity and strong gas separation.
- **Durable:** Mechanically, chemically, and thermally stable.
- **Scalable & Green:** Cost-effective synthesis using recycled, eco-friendly materials.

CRM-Free Catalysts

- **CRM-Free Catalysis:** Optimised catalysts and porous transport layers remove critical raw material dependence.
- **Improved Transport:** Enhanced mass-transport efficiency through tailored catalyst–PTL pairing.

Full Value Chain

- **Full Value-Chain Integration:** From membranes, ionomers, catalysts, and PTLs to stack design, system integration, and LCA/TEA.
- **Aligned with Targets:** Ensures technical progress matches cost and sustainability requirements.

From Lab Scale to 900 cm² – Upscaling AionFLX Membranes & Ionomers

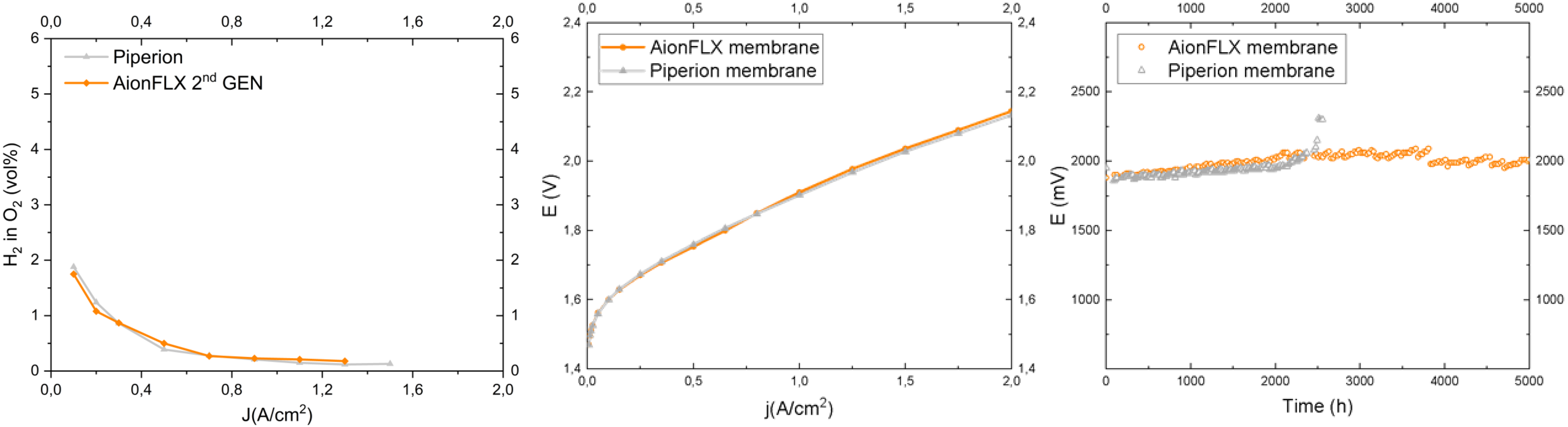
Polymer & Ionomer Synthesis Scale-Up

- Ionomer Synthesis: Scaled from ~5 g to 75 g and 150 g batches with IEC ~1.7 meq/g.
- Polymer Synthesis: Increased scale from 15 g to 300 g while maintaining IEC stability (1.06–1.15 meq/g).
- A 300 g batch yields ~70 membranes (70 μm thick), sufficient for a 100 kW stack.

Large-Area Membrane Casting

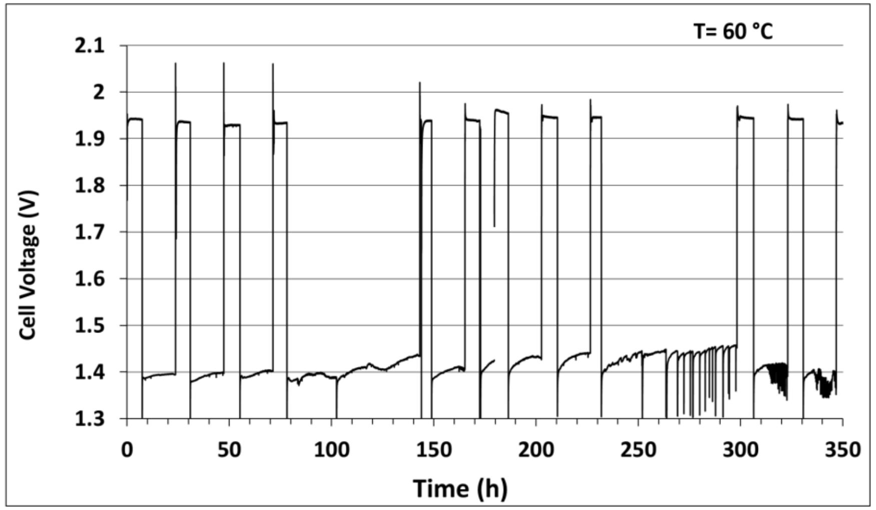
- Increased casting width from 5 cm to 20 cm and 30 cm.
- Large-Area Membranes: Achieved 30 × 30 cm (900 cm²) AionFLX membranes.
- Performance Maintained: Scaling preserved membrane performance.

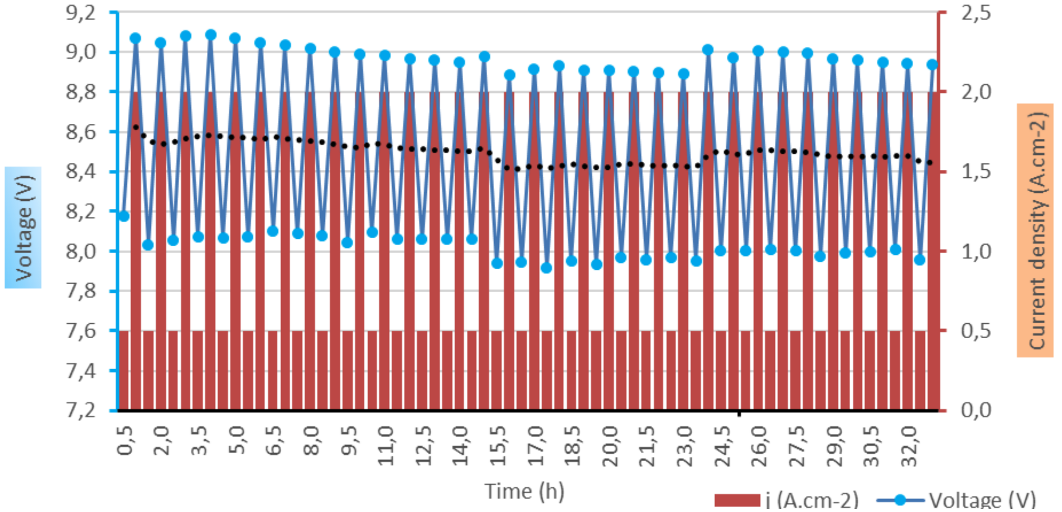
High-Performance, Durable and Safe Cells



All results: with CRM-Free CENmat catalysts in 0.1M KOH and at 50°C. AionFLX equipped cell : ca. 20µV/h degradation, Piperion equipped cell: ca. 170µV/h degradation

Scaling Up – Large-Area Cells and Short-Stack Operation





Large-Area Base Cell

- **~400 cm² Base Cell Validation:** Demonstrated performance comparable to small cells at low current density and improved behavior at high current density.
- **High Efficiency:** Faradaic efficiency >98%.
- **Stable Operation:** ~110 h continuous run plus 350 h duty-cycle testing between OCV and 1 A/cm².

Demonstrated Stack Performance

- **120 h Stability:** Chronopotentiometry at 1 A/cm² shows stable operation.
- **Duty-Cycle Robustness:** 0.5–2 A/cm² cycling (~30 cycles) maintains consistent performance.
- **Idle Recovery:** Essentially full reversibility after a 20-day idle period.

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Designing the 100 kW Stack and Flexible Demonstrator

Stack Design Foundation

- **Performance Targets:** 2 A/cm² at 1.85–2.0 V per cell and 4 W/cm² power density.
- **Cell Format:** Large-area 400 cm² cells used as the core unit.
- **Stack Size:** ~70 cells required to achieve ~100 kW at 2 A/cm² and 2 V per cell.

Mechanical Architecture

- **Compact Design:** 300 × 300 × 850 mm stack footprint.
- **Robust Hardware:** Integrated compression system with corrosion-resistant components.
- **Cost-Effective Concept:** Flow-field-free design simplifies manufacturing and lowers costs.

System Integration

- **Flexible Demonstrator:** 100 kW stack integrated into a system supporting dry/wet cathode and equal/differential pressure operation.
- **Operational Testing:** Enables evaluation of multiple operating strategies.
- **Economic Assessment:** Allows comparison of CAPEX/OPEX trade-offs under varying conditions.

Data-Driven Scale-Up

- **Data Foundation:** Primary data from the prototype to build LCI and techno-economic models.
- **Scalable Modelling:** Models will be extrapolated to MW-scale systems.
- **Robust Methodology:** Ensures reliable and validated scaling from prototype to large-scale deployment.

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HYScale – Delivering the Next Generation of AEM Electrolysers

Breakthrough Technology Performance

- **Sustainability:** PFAS-/Fluorine-/CRM-Free
- **High Performance:** Achieves 2 A/cm² at ~2.0 V per cell.
- **Low Degradation:** <5 µV/h demonstrated at single-cell level.
- **Large-Area Efficiency:** >98% faradaic efficiency in large-area cells.
- **Low-KOH Operation:** Stable and efficient performance due to highly diluted KOH cabablity.

Industrial-Scale Validation

- **Upscaled Materials:** AionFLX membranes and ionomers produced at batch and area scales suitable for a 100 kW stack.
- **Validated Across Scales:** Proven performance from 4 cm² cells to 400 cm² cells and a 4-cell short stack.
- **Stack Design Ready:** Compact 100 kW stack design defined for integration into a flexible demonstrator.

Competitive Economics & Sustainability

- **Low Impact:** Preliminary LCA shows strong potential for a low carbon footprint.
- **Cost Target:** TEA points to CAPEX around 400 €/kW.
- **Material & Design Benefits:** CRM-free materials and simplified architecture support these gains.
- **Strategic Alignment:** Direct contribution to EU hydrogen and climate objectives.

Clear Path to Market

- **Clear Roadmaps:** Exploitation plans and KER pathways defined for membranes, CCS, short stack, and LCA/TEA data.
- **Targeted Deployment:** Clear target markets and time-to-market identified.
- **Strong Engagement:** Supported by active communication, industrial involvement, and a growing ecosystem.

Call to Action

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We invite policymakers, industry and investors to collaborate on piloting and scaling HYScale technology from the 100 kW demonstrator to MW-scale plants. Together, we can accelerate the transition to affordable, sustainable green hydrogen production.

ΔEH (Demo Site/ Renewable Power)

CENmat (**Coordinator**/ Catalysts/ Membrane/ Ionomer)

DLR (Stack/ Testing/ Analysis)

ITAE Consiglio Nazionale delle Ricerche (Stack/ Testing/ Analysis)

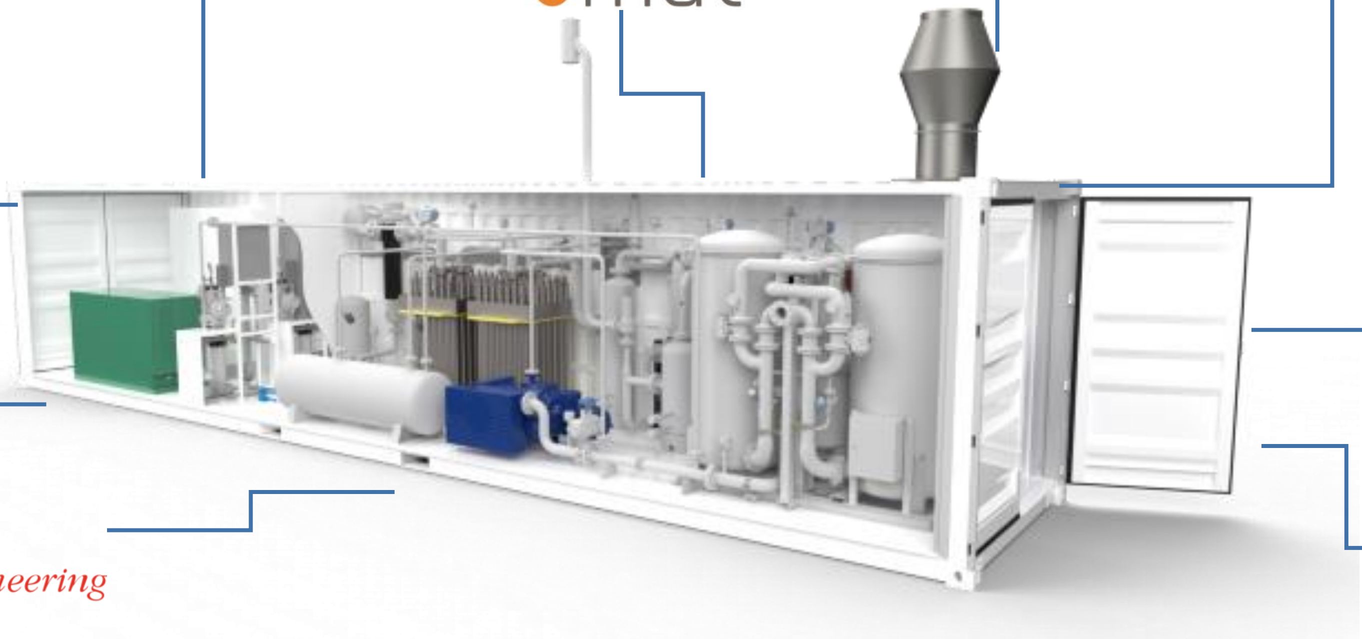
Bekaert (PTL)

cea (Material Analysis)

HYGEAR THE GLOBAL HYDROGEN SOURCE (BOP)

University of Ljubljana Faculty of Mechanical Engineering (LCA/TEA)

META knowledge to market (C&D&E)



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- EU funded project: 2023 - 2027

HERAQCLES™

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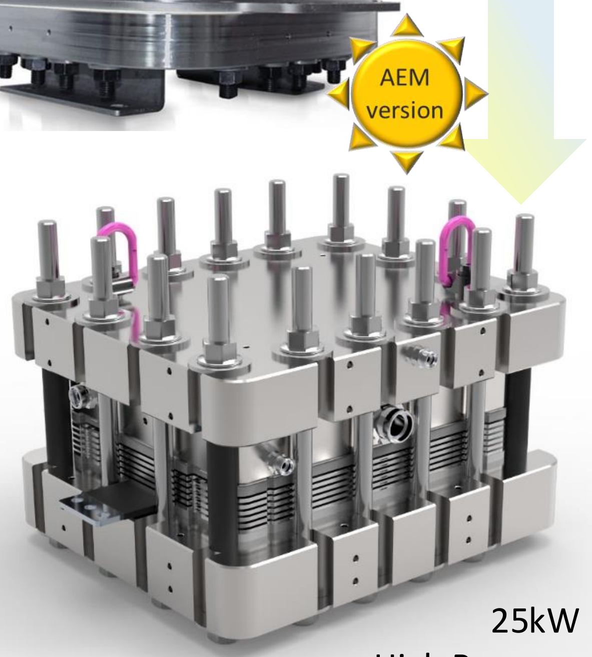
AEM system development:

Based on PEM stack learnings

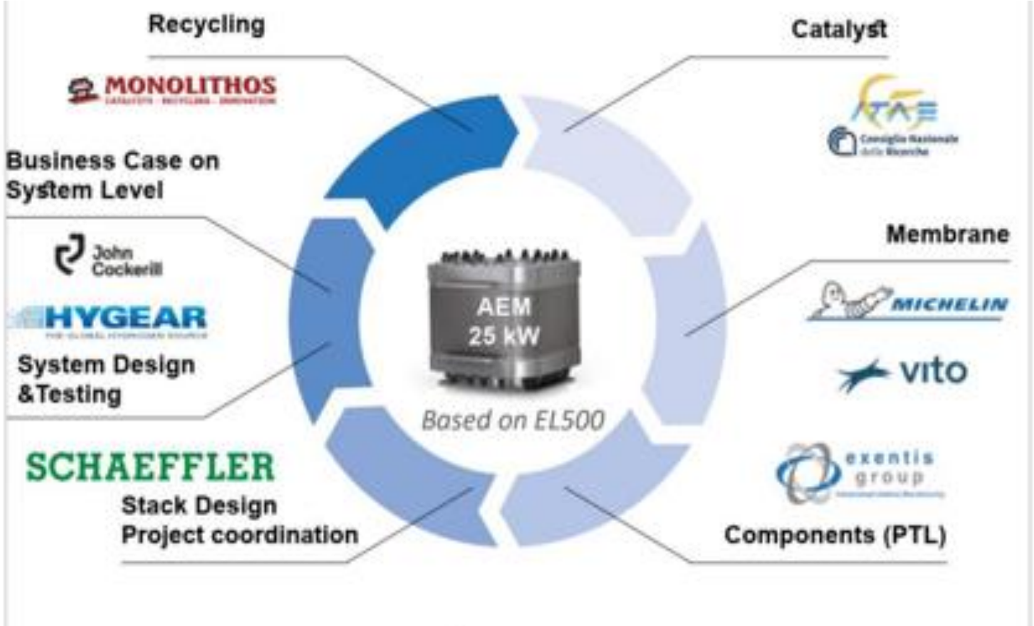


25kW AEM High Pressure stack

Project HERAQCLES delivers:

- **Innovative components** developed for automated production processes
- **Latest polymer technology** integrated into durable membrane
- **Novel design-for-manufacturing** architecture and stack design
- **Dedicated 25kW AEM stack** capable of achieving 50 bar pressure
- **Efficient Balance-of-Plant system** including separate cooling loop

Target: 48 kWh/kg @ 1A/cm²



Focus is on developing a cost-effective stack architecture combined with advanced automated sequential manufacturing processes delivering a qualified 25 kW stack with quantifiable high performance, sufficient durability at low capital costs.

Upcoming AEM electrolyser technology will take market share next to PEM and AEL, provided maturity is proven sufficient.