WEBINAR - ANION EXCHANGE MEMBRANE ELECTROLYSERS
Fuel Cell and Hydrogen Joint Undertaking (FCH JU)

Anion Exchange Membrane Electrolysis for Renewable Hydrogen Production on a Wide-Scale

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PROJECT CONTEXT

ANIONE project is a research and innovation project (under the Fuel Cells and Hydrogen 2 Joint Undertaking) aiming at developing ***high-performance, cost-effective and durable anion exchange membrane (AEM) water electrolysis*** *technology.*

ANIONE technology combines the advantages of proton exchange membrane and liquid electrolyte alkaline electrolysis

Innovative reinforced anion exchange membranes are developed in conjunction with non-critical raw material electrocatalysts and membrane-electrode assemblies.

A cost-effective stack is designed to contribute decreasing capital costs of electrolysis systems

PROJECT OBJECTIVES

Overall objective:

To develop **high-performance** (energy consumption < 50 kWh/kg H_2), **cost-effective** (0.75 M€ / t/d H_2) and **durable** (degradation <5 µV/h at 1 A cm^{-2}) anion exchange membrane water electrolysis technology.

Approach:

Advanced CRM-free electrocatalysts, anion exchange membrane (AEM) and ionomer dispersion in the catalytic layers for hydroxide ion conduction in a system operating with diluted KOH.

ANIONE aims to validate, as proof-of-concept, a 2 kW AEM electrolyser with a hydrogen production rate of approximately 0.4 Nm^3 H_2/h .

Goal:

Allow a **scalable production of low-cost hydrogen** from renewable sources through a **reduction of capital costs**, while assuring **high conversion efficiency** and proper **life-time**.

ELECTROLYSIS TARGETS

- Achieving current density **> 1 A cm^{-2}** in AEM technology whilst maintaining the cell potential in a safe and efficient region (**E_{Cell}<1.8 V**) together with the exclusive use of non-critical raw materials

- Validate a **2 kW AEM electrolysis stack** with a hydrogen production rate of about **0.4 Nm^3/h** (TRL 4) operating at **30 bar** (>100 cm^2 cell area, > 10 cells).

- Energy consumption **< 50 kWh/kg** at stack level with a stack **efficiency** of about **80 % vs. HHV H_2**.

- Durability will be validated under steady and intermittent duty cycles conditions in time studies of at least **3,000 hours cumulative (2,000 h steady-state, 1,000 h cycled operation)** with targeted **degradation rate lower than 5 µV/h at a fixed current density of 1 A cm^{-2} and < 10 µV/h under cycled operation →**

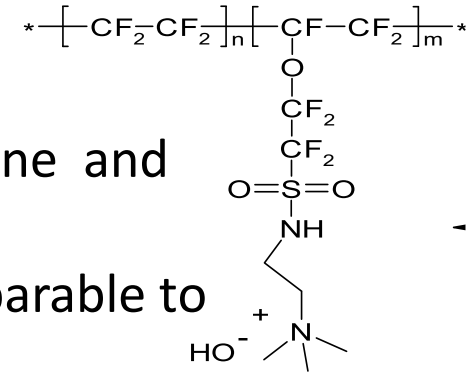
  → *limit to one the number of stack replacements in a typical 20 year life-span of the electrolyser*

- Perspective reduction of **capital costs, in large scale production, to less than 0.75 M€ / (t/d H_2)**

combined with a low renewable electricity cost ~0.04 €/kWh → reduction of the green hydrogen cost by electrolysis from ~10 to 2-3 €/kg **H_2**

PROJECT FOCUS

Focus on two parallel approaches for the anion exchange membrane:



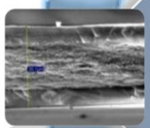
- ✓ Short side chain **perfluorinated AEM** comprising a perfluorinated backbone and pendant chains, covalently bonded to the perfluorinated backbone, with quaternary ammonium groups to achieve conductivity and stability comparable to their protonic analogous (Nafion ®)
- ✓ **Hydrocarbon AEM membranes** consisting of either poly(arylene) or poly(olefin) backbone with quaternary ammonium hydroxide groups carried on tethers anchored on the polymeric backbone

And a back-up solution:

- ✓ Modify commercial hydrocarbon membranes and ionomers based on DABCO (1,4-diazabicyclo[2.2.2]octane $N_2(C_2H_4)_3$) cross-linked poly(sulfone) resins as alternative membranes (back-up solution).

Stack components optimization for AEM electrolysers

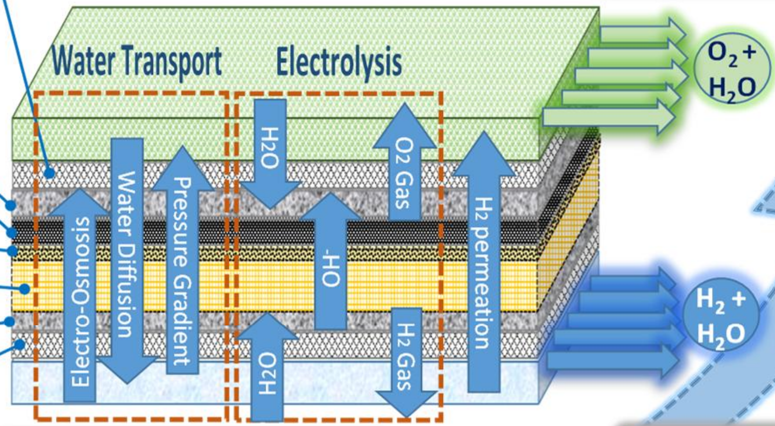
TRL 2

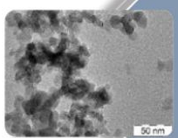


Reinforced AEM membrane with lower thickness to reduce ohmic drop and improve mechanical stability

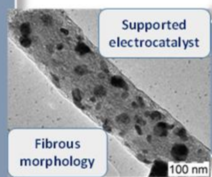
Redesign diffusion layers to improve gas diffusion and overcome reversible degradation

Flow-field free stack design amenable to scale up; protective coatings of steel plates to achieve low cost and durable stack components



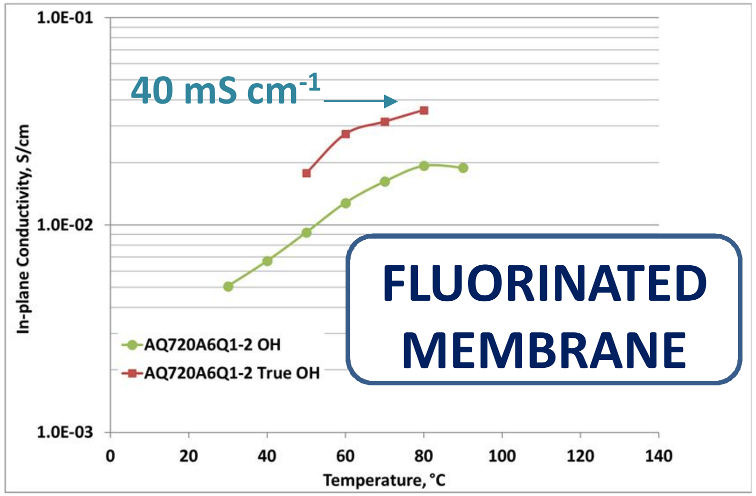


Cross-over management through recombination catalyst; Use of radical scavengers



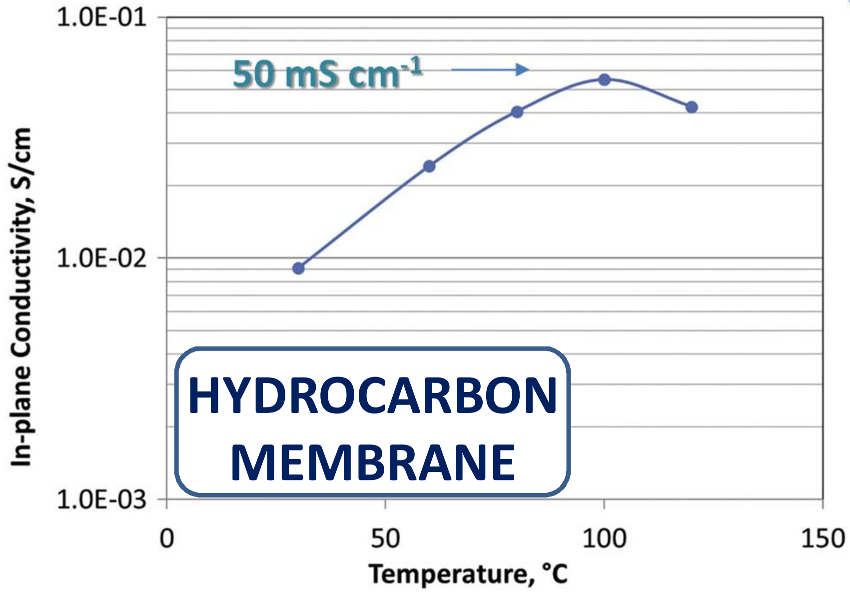
CRM-free nanostructured catalysts to increase intrinsic activity and stability, reducing mass transport

Increase current density to reduce capital costs, allow compact stack design and efficient use of materials



IEC, meq/g	λ	w.u.,%	ΔL/L, %	A, %	V_{wet}/V_{dry}
0.6	20.3	21.9	9	21.0	1.2

- Reduced swelling at 90°C
- "True OH^-" conductivity higher than raw OH^- conductivity
- Ion conductivity of ~40 mS/cm achieved despite the low IEC

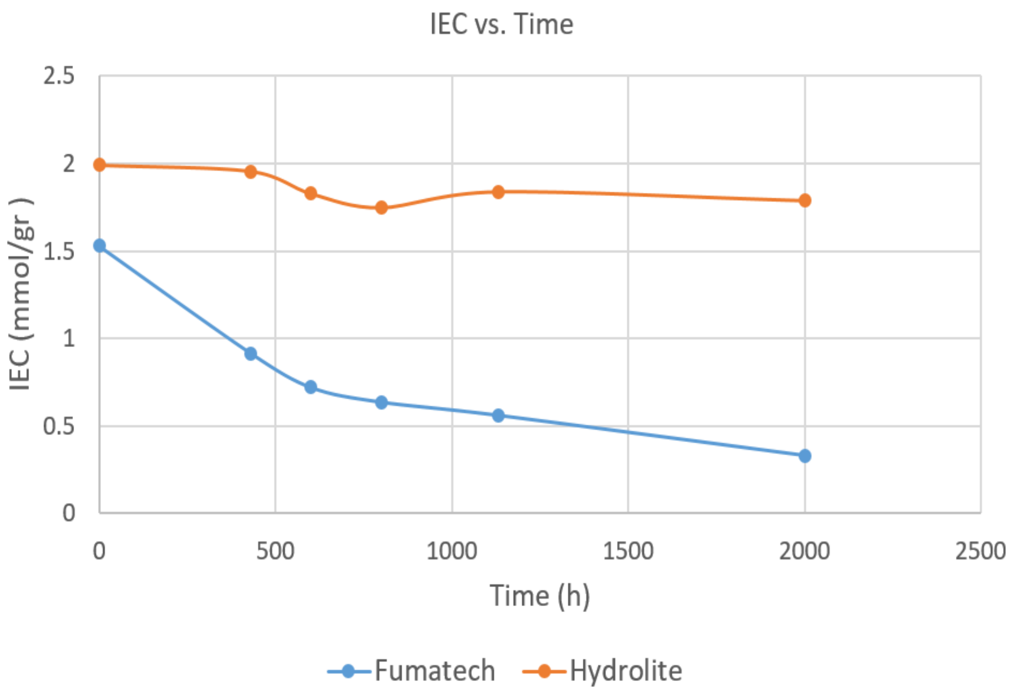


IECexp.	IECnom.	% active groups
1.59	1.85	86
1.85	1.85	100

Wup, %	ΔL/L, %	λ	[ion], M	μ_{eff}, cm^2/Vs	D_σ, cm^2/s
17	9	6	1.5	$6.27\ 10^{-5}$	$1.63\ 10^{-6}$
70	19	25	1.1	$8.83\ 10^{-5}$	$7.17\ 10^{-6}$

MEMBRANE DEVELOPMENT IN ANIONE

HYDROLITE MEMBRANE VS. BENCHMARK MEMBRANE



IEC vs. Time (1 M KOH 80 °C)

Type of membrane/time in 1M KOH 80 °C (Hour)	0	430	600	800	1130	2000
IEC (mmol/gr) of FAA3-	1.53	0.915	0.72	0.635	0.56	0.33
IEC (mmol/gr) of Hydrolite	1.99	1.955	1.83	1.75	1.875	1.79

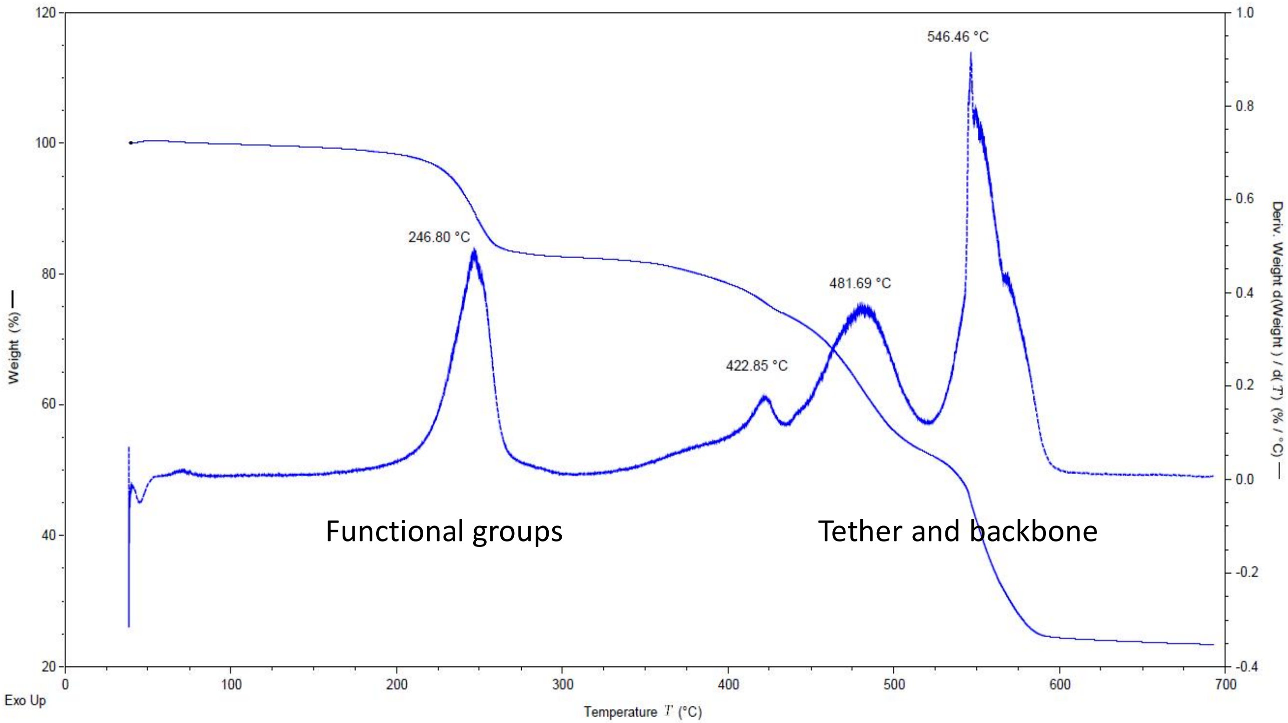
Excellent retention of the IEC for the Hydrolite membrane after prolonged immersion in KOH

- % of IEC remained after 2000h using Fumatech membrane is: 21.56
- % of IEC remained after 2000h using Hydrolite membrane is: 89.94

Hydrolite hydrocarbon membrane

Thermal Behavior

Thermal Stability-TGA



Description:

- TGA experiment was conducted, in the temperature range of 30-700°C
- The rate was defined to 10°C per min.
- N_2 environment.

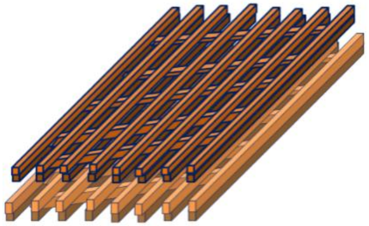
Observations:

- Loss of functional groups is observed at 246°C.
- Loss of tether and backbone are seen at 422°C and above .

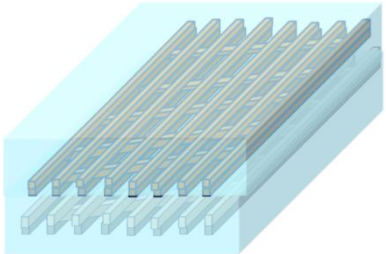
Reinforced composite membranes

Morphology

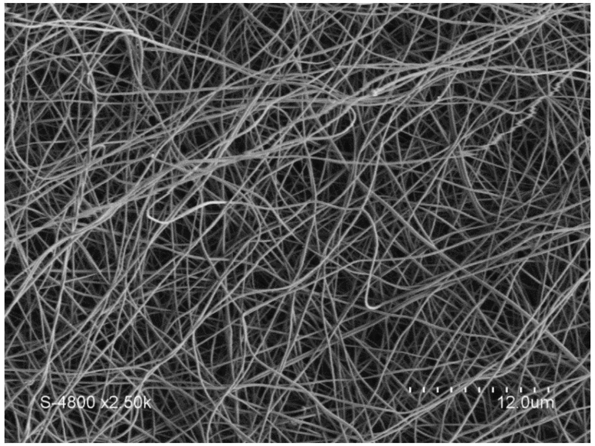
Membranes are reinforced by active polymer fibre webs prepared by electrospinning

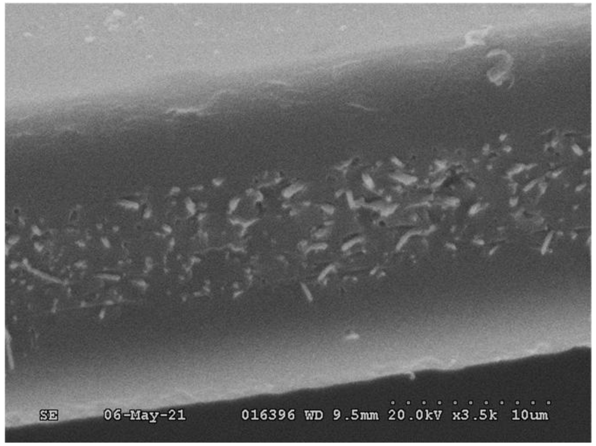


Electrospun fibre web



Reinforced membrane

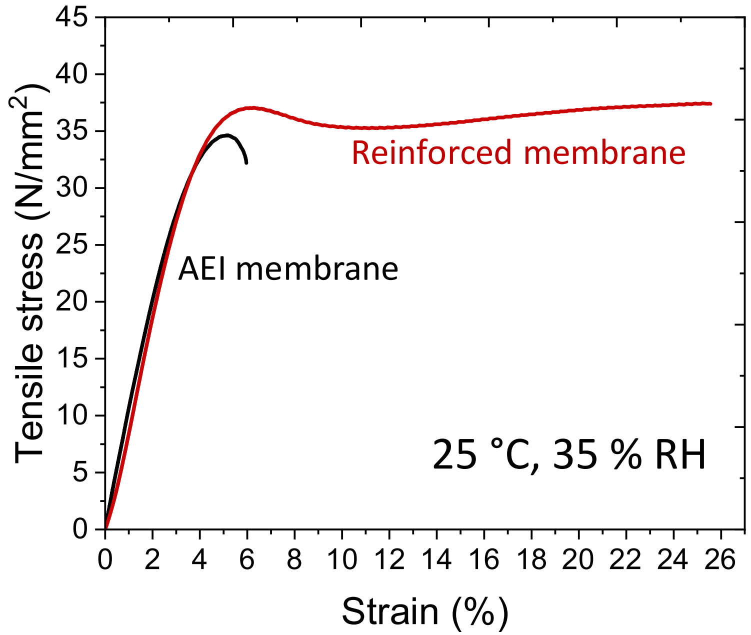




Composite membrane with nanofibre reinforcement

Reinforced composite membranes

Mechanical properties

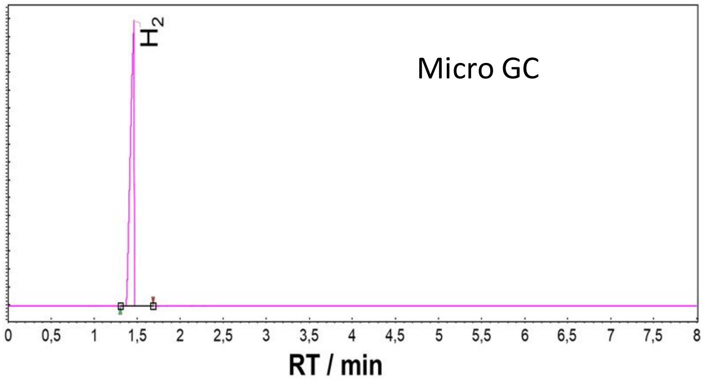


The used AEI is a stiff polymer, with low elongation at break but a high E-modulus

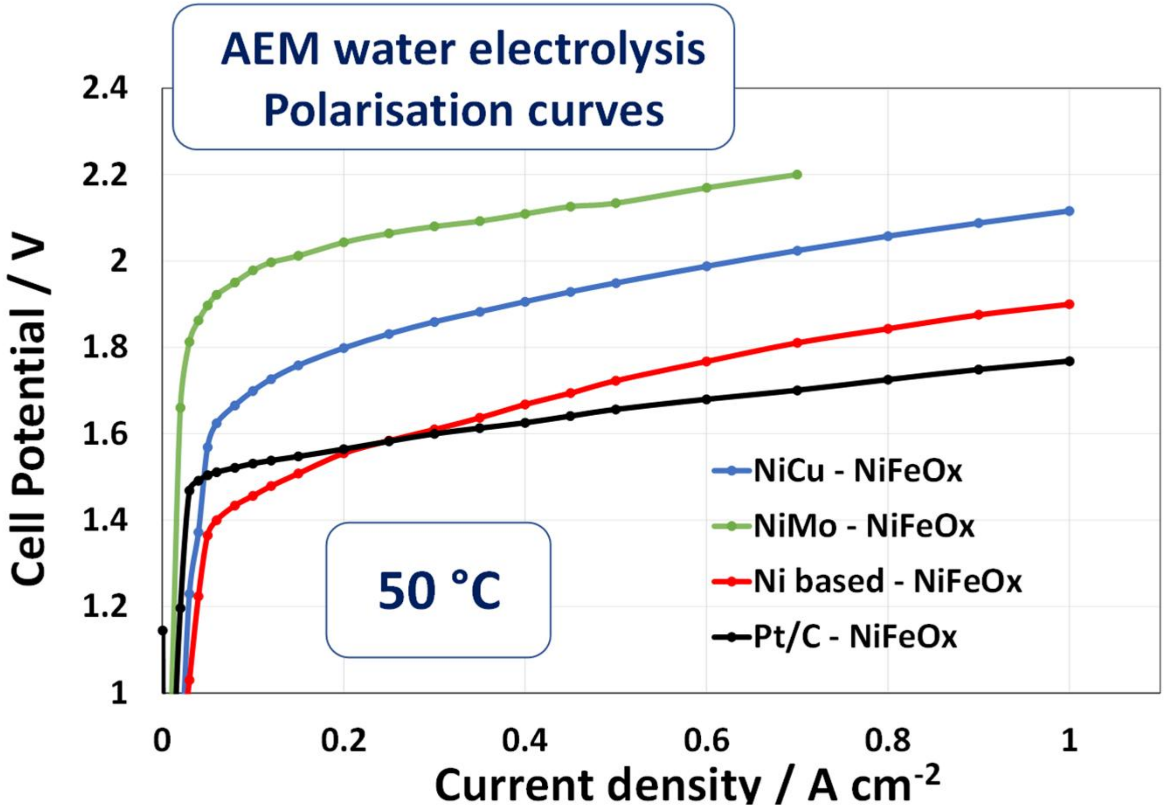
Composite reinforced membrane: similar E-modulus, but elongation at break is increased

AEM Polarisation curves faradaic efficiency and hydrogen quality

AEM ELECTROLYSIS single cell testing in ANIONE

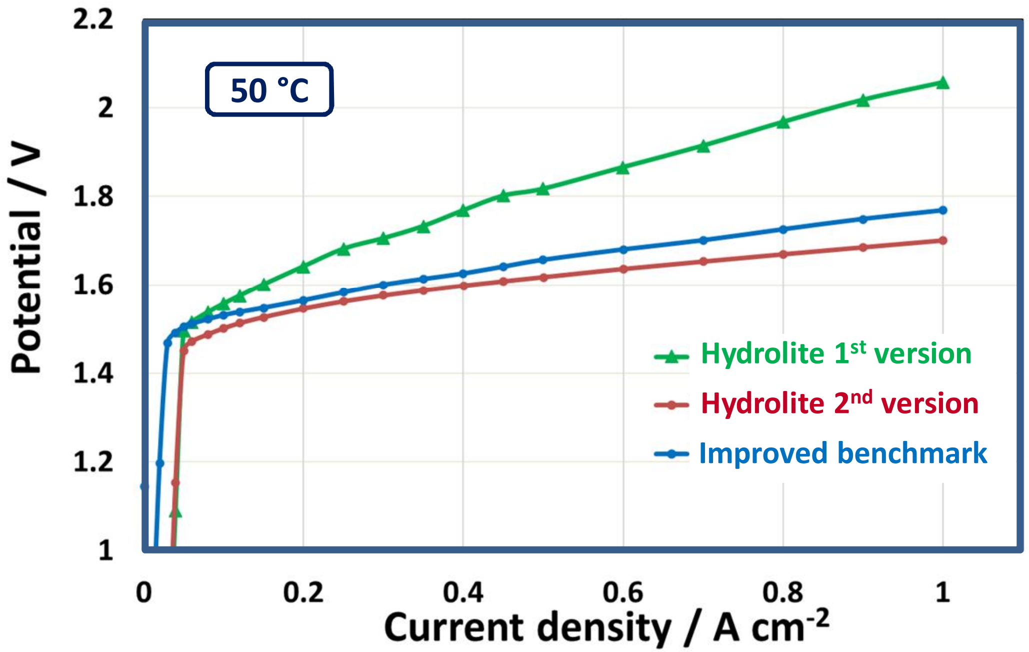


Effect of cathode catalyst composition

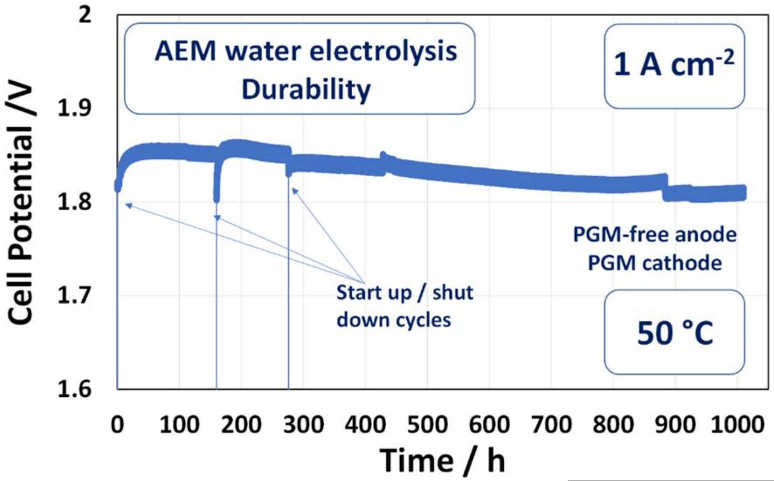


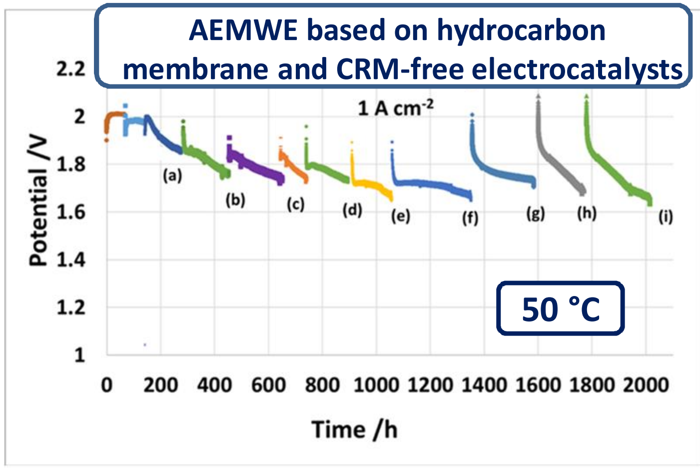
Hydrocarbon membrane development

Performance of 1.7 V at 1 A cm^{-2} achieved

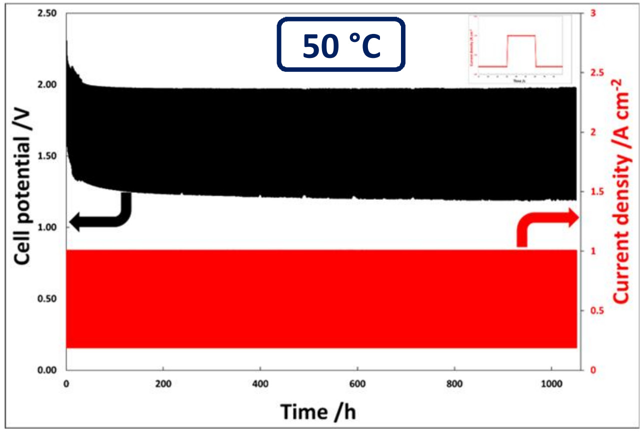


AEM durability





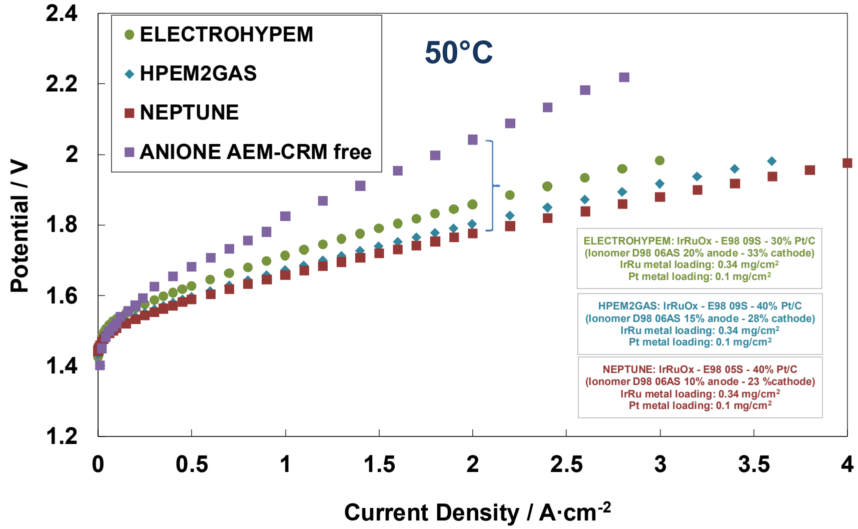
Steady-state operation at 1 A cm^{-2}



Cycled operation
Step cycles between 0.2 and 1 A cm^{-2}

ANIONE

Comparison of PEMWE and AEMWE performance

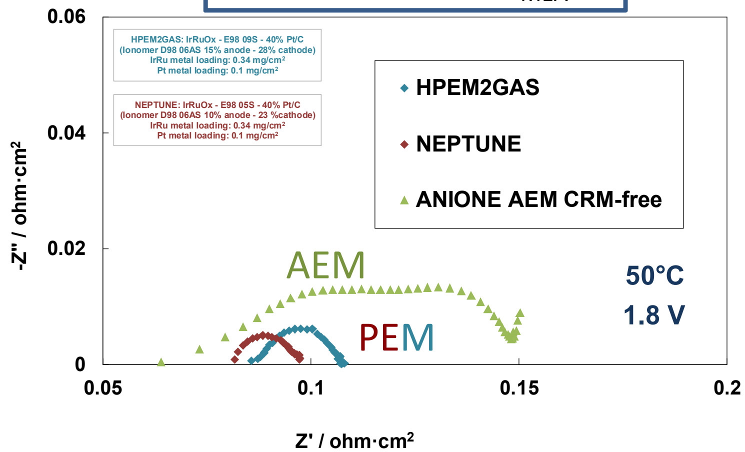


300 mV performance gap between AEM and PEM at 2 A cm^{-2}

ANIONE AEM technology:
- ✓ Non-PGM eletrocatalysts
- ✓ CRM-free materials,
- ✓ Hydrocarbon membrane
- ✓ Titanium-free

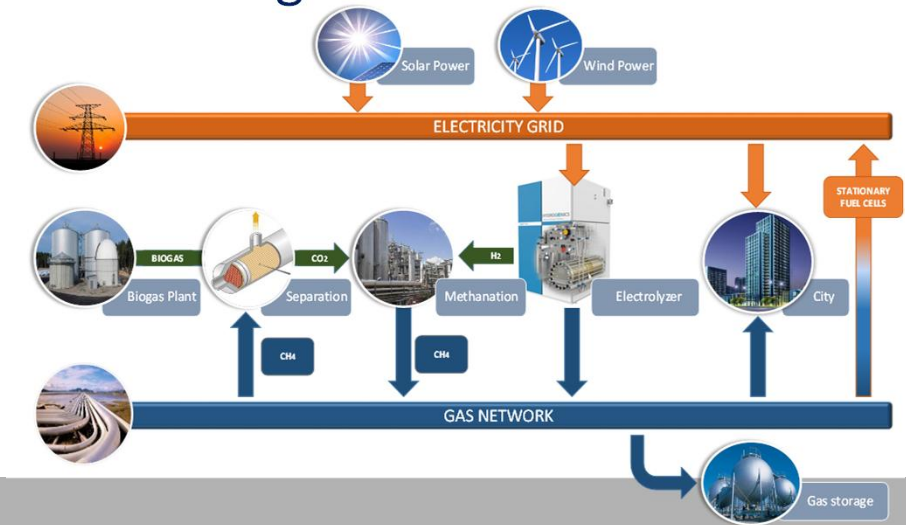
PGM content in PEMWE <0.5 mg PGM $cm^{-2}{}_{MEA}$

Performance gap associated to larger polarisation resistance for AEM compared to PEM



CONCLUSIONS

- ✓ Achievement of a wide scale decentralised hydrogen production infrastructure using AEM technology with the long-term goal to reach net zero CO_2 emissions in EU by 2050
- ✓ Contribute significantly to reducing the AEM electrolyser CAPEX and OPEX costs while keeping the advantages of PEM electrolysers in terms of performance and dynamic behaviour
- ✓ Deliver a techno-economic analysis and an exploitation plan for successive developments with the aim to bring the innovations to market



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