//EU HYDROGEN RESEARCH DAYS 15-16 NOVEMBER

ANIONE

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

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Project Overview

- Call year: **2019**
- Call topic: **FCH-02-4-2019 New Anion Exchange Membrane Electrolysers**
- Project dates: **01-01-2020 - 30-09-2023**
- % stage of implementation 01/11/2023: **100%**
- Total project budget: **1 999 995.00 €**
- Clean Hydrogen Partnership max. contribution: **1 999 995.00 €**
- Other financial contribution: **0 €**
- Partners: CNR-ITAE, CNRS, HYDROLITE (formerly POCELLTECH), TFP (formerly PV3), IRD, CUMMINS (formerly HYDROGENICS), UNIRESEARCH BV

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Project Summary

- ***Overall objective:***
  - ✓ 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**, **hydrocarbon anion exchange membrane** (AEM) and ionomer dispersion in the catalytic layers for hydroxide ion conduction in a **system operating with diluted KOH**.
  - ✓ ANIONE has validated, 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**.

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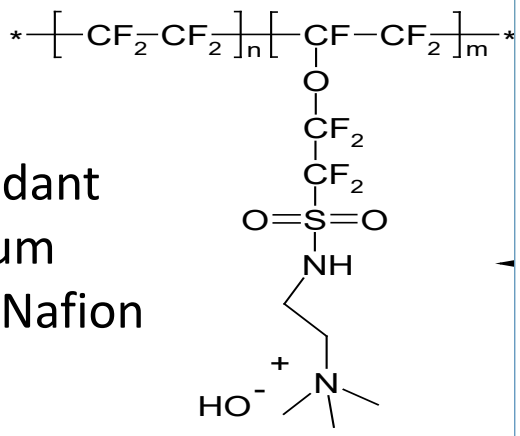
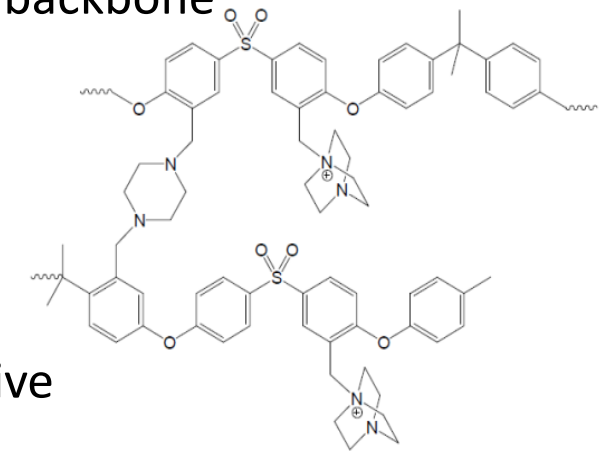
Project Focus on AEM

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



- ✓ **Modified 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).

Tal-Gutelmacher et al., Membranes 2021, 11, 686

Carbone et al. Chemical Engineering Journal (2022) 140765

Project Progress/Actions:
Cell performance and faradaic efficiency

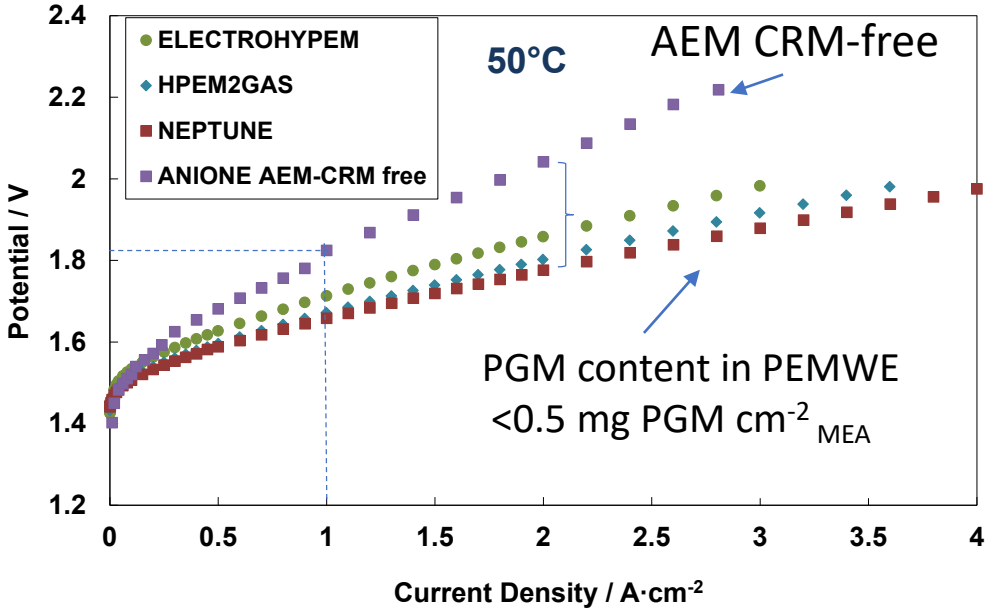
Project start value

Achievement to-date **0.3 A cm^{-2} at 1.8 V /cell**

25% 50% 75%

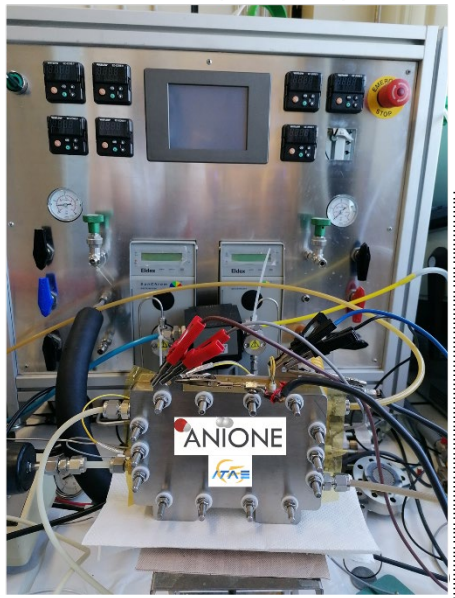
Project target value

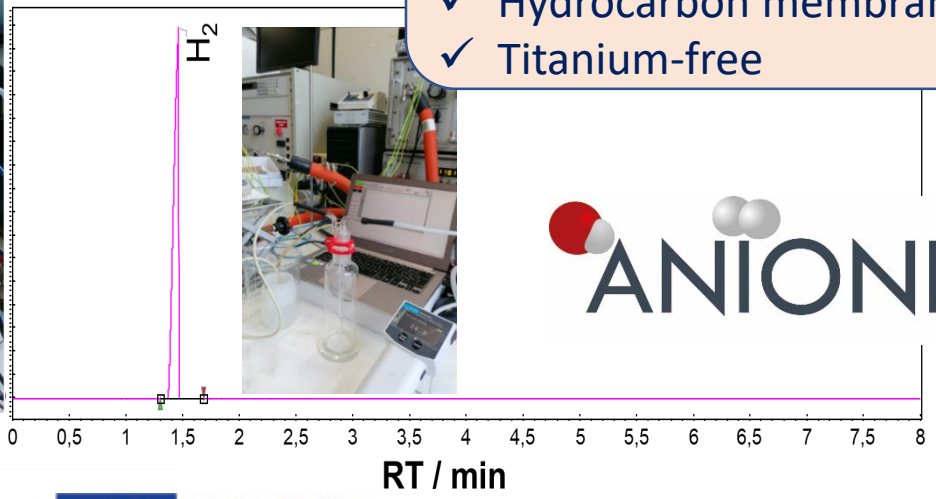
1 A cm^{-2} at ~1.8 V /cell 99% faradaic efficiency



Zignani et al. Electrochim. Acta 413 (2022) 140078

AEM ELECTROLYSIS single cell testing in ANIONE





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

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Project Progress/Actions:
Cell performance and faradaic efficiency

Project start value

Project target value

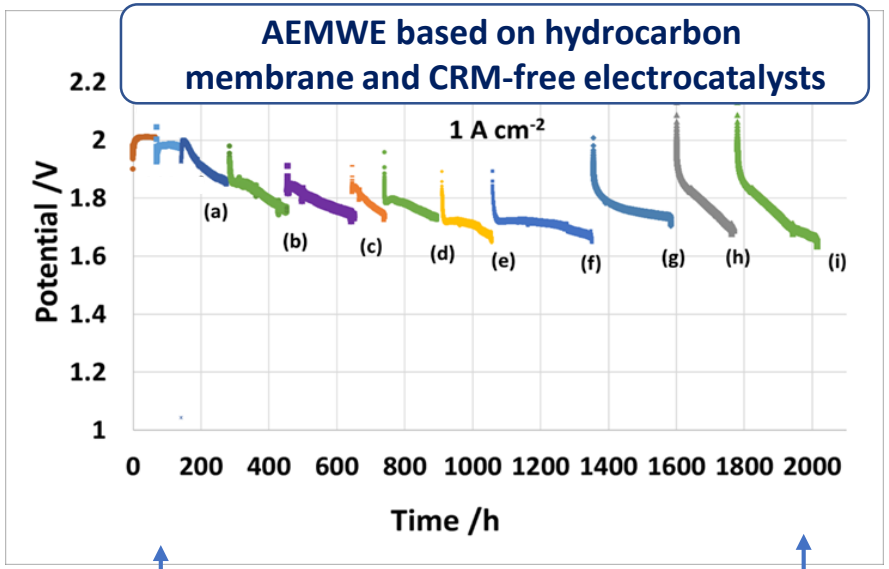
Achievement to-date

Degradation >20 µV/h at 1 A cm^{-2}

25% 50% 75%

Degradation <5 µV/h at 1 A cm^{-2}

AEMWE based on hydrocarbon membrane and CRM-free electrocatalysts



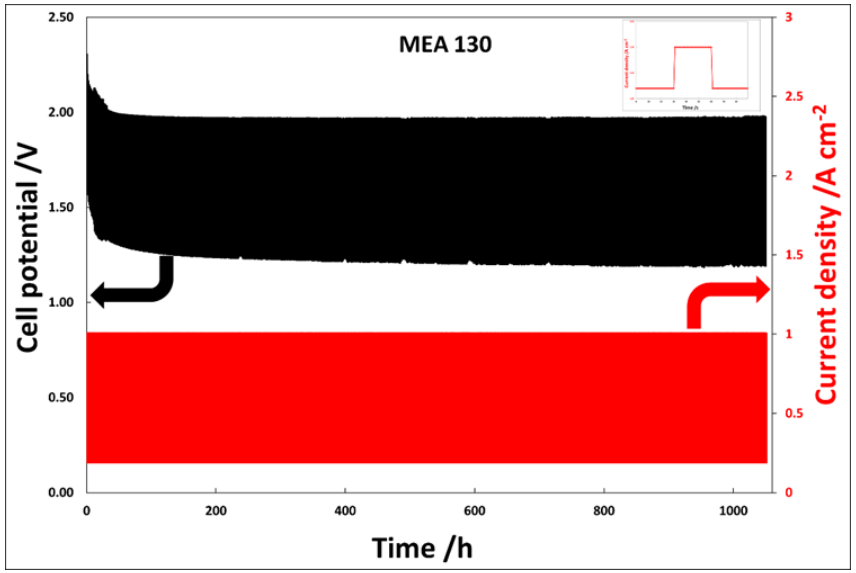
Faradaic efficiency >99%

Faradaic efficiency >96%

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

Reversible losses recorded during shut down and start-up cycles

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



Zignani et al. Electrochim. Acta 413 (2022) 140078

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Project Progress/Actions: MEA scaling-up and stack engineering

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Project start value — *Project target value*

Achievement to-date

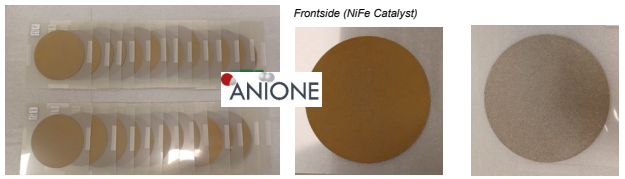
Small 5 cm² Single cell → **~2 kW stack ~0.4 Nm³ H_2/h**

25% 50% 75%

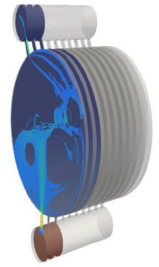
Compact stack configuration: 10 cells of 100 cm² operating at 1 A cm⁻², 50°C and pressurised mode

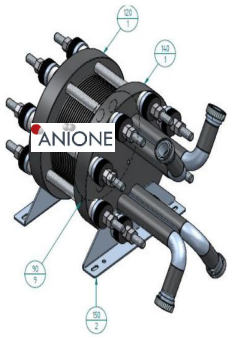
27 wet membranes for stack assembly

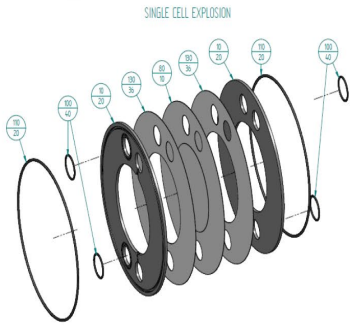
25 Anodes: NiFe unifomly coated on 1 side



- Computational Fluid Dynamics
  - Pressure drop
  - Porous properties
  - Flow
- Full stack assembly
  - MEA received
  - Pressure drop to be measured
  - Leack & pressure test
    - External (Hydrostatic)
    - Internal (N_2)
    - Short stack







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Project Progress/Actions: Stack testing

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Achievement to-date

Project start value

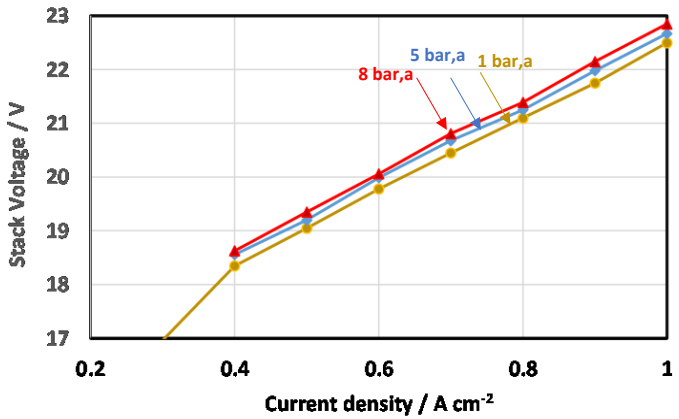
Efficiency <60% @1 A cm^{-2}

25% 50% 75%

Project target value

~2 kW stack ~70% efficiency @1 A cm^{-2}

Differential pressure
Horizontal Stack, anode feed 1 M KOH, flow 0.5 l/min



Parameter	Result	Target
Stack Performance	21 V for the stack (i.e. ~2.1 V/cell) at 1 A cm^{-2} (100 A) at ~ 50 °C with recirculation rate of 1M KOH 1.25 ml/min/cm^2	1.8-2 V/cell at 1 A cm^{-2} –MS10
Voltage efficiency	71% vs. HHV at 1 A cm^{-2} (100 A) at temperatures up to 50 °C with recirculation rate of 1M KOH 1.25 ml/min/cm^2	86% vs. HHV –MS10
Stack Capacity	0.398 ± 0.0.05 Nm^3/h at 1 A cm^{-2} (100 A)	Hydrogen production rate > 0.4 Nm^3/h –MS10
Faradaic efficiency	97 % at 1 A cm^{-2} (100 A)	>99 % at 1 A cm^{-2} –MS7
Stack Energy efficiency	69 % vs HHV	80 % vs HHV –MS11
Stack energy consumption of about 57 kWh/kg H_2	57 kWh/kg H_2	50 kWh/kg H_2 –MS11
Stack power	>2 kW	2 kW (10-cells with 100 cm^2 active area) –MS10

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Risks, Challenges and Lessons Learned

- **Gas cross-over management for thin anionic membranes in the presence of high differential pressure.**
  - ✓ ***Mitigation strategies: membrane and MEA engineering to include a recombination catalyst integrated in the anode layer and membrane reinforcement increasing the tortuosity path for gas permeation.***
- **Demonstrating the capability of advanced membrane-electrode assemblies and related components to operate in a wider operating temperature and pressure ranges.**
  - ✓ ***MEA performance and durability has been assessed at 50°C and moderate pressures (<20 bar). Operation above 50°C has been demonstrated ; however it may compromise stability of AEM ionomers; performance targets have been already achieved at 50°C.***

Synergies With Other Projects And Programmes

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The AEM-HUB webpage is available via each of the project websites.

- Ongoing collaboration with other FCH JU AEM projects: NEWELY, CHANNEL
- Horizon Booster activities with Project Group:
  - Completed Module A - Identification of R&I results and creation of portfolio → report available on METT
  - April – Nov 2021: Module B - Portfolio dissemination plan and execution

- Activities with Project Group:
  - Visual identity → logo + colour scheme
  - AEM Hub Webpage
  - Flyer
  - Video
  - Joint webinar (July 2021, March 2023, Sept. 2023)
    - Latest development in AEM field
    - Definition of common vocabulary for the field
    - Possible interactions with industry on technology adaptation and future partnerships
  - Harmonised MEA assessment in single cell (ANIONE, CHANNEL and NEWLY)

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Thank you for your kind attention!

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