CHANNEL

Development of the most cost-efficient hydrogen production unit based on anion exchange membrane electrolysis

Luis Colmenares-Rausseo

Batteries and Hydrogen Technologies

SINTEF Industry. Trondheim, Norway

www.channel-fch.eu

luis.colmenares@sintef.no

//EU HYDROGEN RESEARCH DAYS 15-16 NOVEMBER

CHANNEL

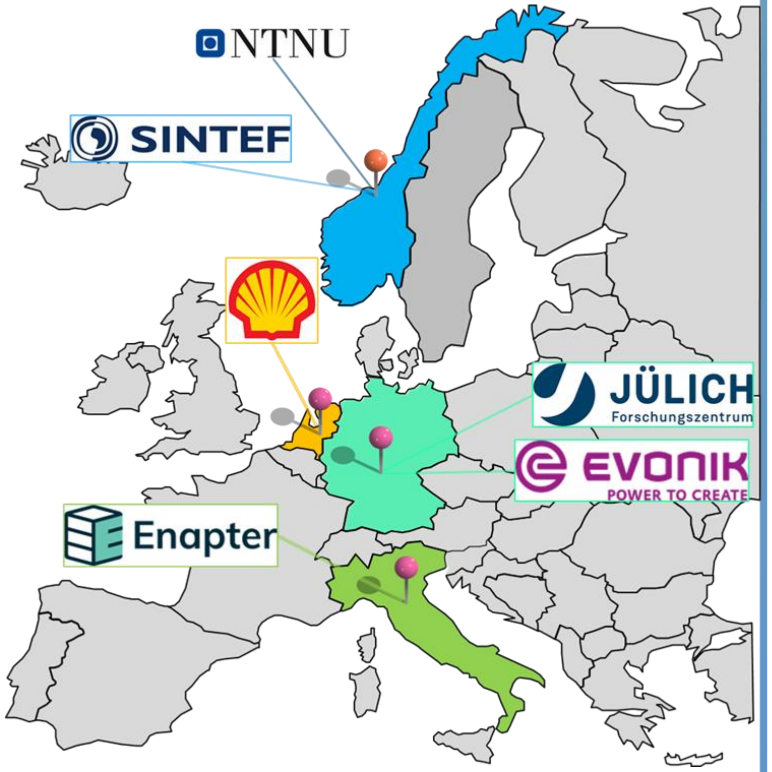
Clean Hydrogen Partnership

European Hydrogen Week

Co-funded by the European Union

Project Overview

- Call year: 2019
- Call topic: FCH-02-4-2019: New Anion Exchange Membrane Electrolyzers
- Project dates: 01.2020 – 30.2023
- Total project budget: 1 999 906,25 €
- Clean Hydrogen Partnership max. contribution: 1 999 906,25 €
- Partners: SINTEF; NTNU; FZJ; SHELL; EVONIK; ENAPTER



Project Objectives

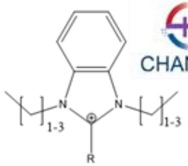
CHANNEL

Starting point

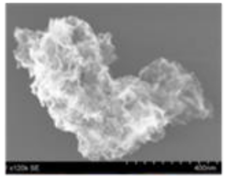
- SoA AEM membranes and ionomers
  EVONIK POWER TO CREATE
- SoA non-PGM HER and OER catalysts
  JÜLICH Forschungszentrum
  NTNU
  SINTEF
- SoA electrolyser designs, components and AEM systems
  Enapter
  SINTEF

Concepts developed within CHANNEL

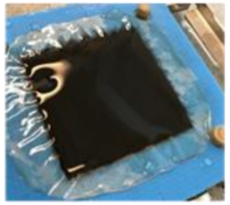
CHANNEL



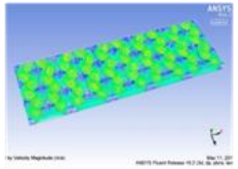
- **Optimisation cQA-PAEK based polymers** structural parameters, e.g. MW, block-co-polymer ratios, thickness.



- **Optimisation of Ni-based catalysts**, NiMo, NiFe by surface stabilisation, shape control and study of catalyst ionomer interactions.



- **Electrode optimisation** (ionomer and catalyst type and loadings), different coating methods and different MEA approches guided by electrochemical **AEM modelling**

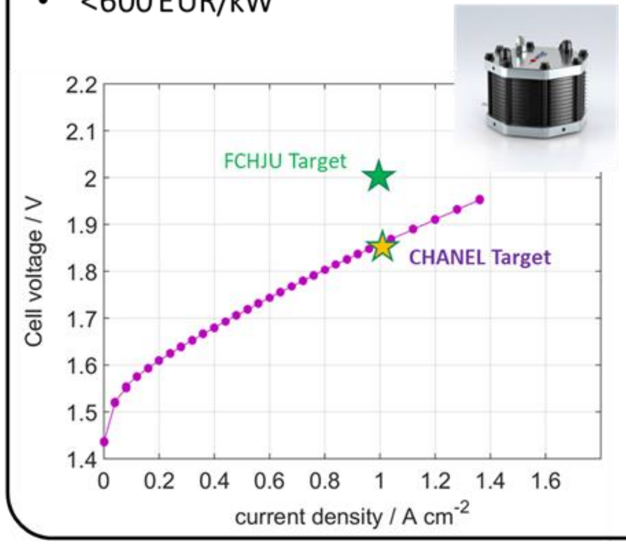


- New **AEM advanced pressurised electrolyser design**, low-cost PTLs, assisted by CFD flow simulations in porosu media.

Outcome

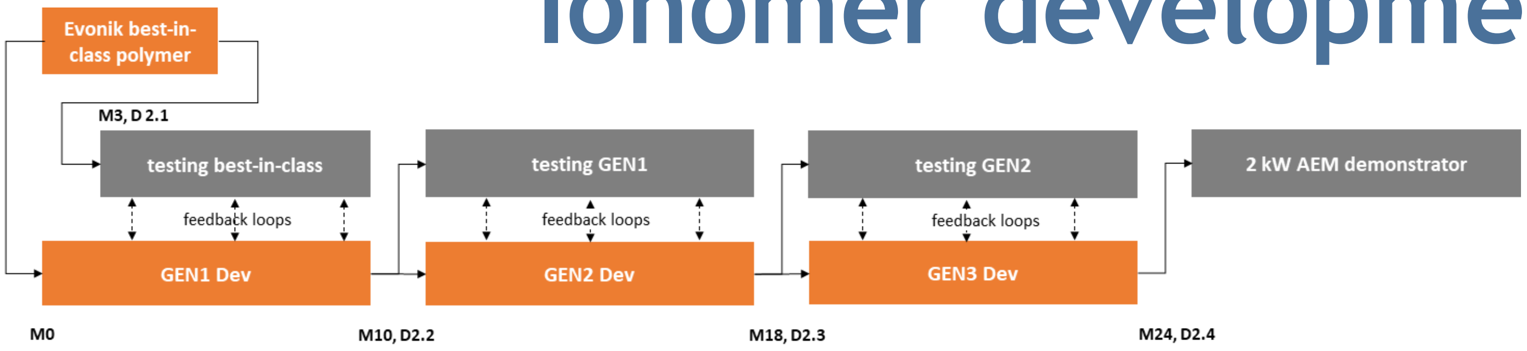
CHANNEL

- Beyond SoA 30 bar 2kW AEM electrolyser with performance of 1.85 V @ 1 A cm^{-2} in diluted electrolyte
- 2000 h operation < 50 mV degradation
- <600 EUR/kW



Clean Hydrogen Partnership
European Hydrogen Week
Co-funded by the European Union

Project results - Membrane and Ionomer development



KPI	UNIT	OBJECTIVE FCHJU 2.4-2019	OBJECTIVE CHANNEL
Area specific resistance ASR, T = RT	Ωcm²	< 0,07	< 0,06
OH conductivity, T = RT	mS/cm	50	> 50
OH conductivity, T = 60°C	mS/cm	not specified	> 90
Ex-situ stability (AST protocol, 1 M KOH, T = 60 °C, 600 hr)	mS/cm	not specified	> 80
hydrogen crossover (T = 60°C)	[mol/m.s.Pa] x 10^{-15}	not specified	< 15
water uptake, T = RT	w-%	not specified	< 10
Dry/wet swelling machine Direction (MD)	%	< 1	< 1
Dry/wet swelling traverse Direction (TD)	%	< 4	< 4
Mechanical strength (in dry conditions, T = RT, RH = 50%)	MPa	15	15
Elongation at break (in dry conditions, T = RT, RH = 50%)	%	100	100
Mechanical strength (DMTA, in fully hydrated, swollen conditions, T = 30°C)	MPa	not specified	> 0,1
Mechanical strength (DMTA, in fully hydrated, swollen conditions, T = 60°C)	MPa	not specified	> 0,1
Ionomer OH conductivity, T = 60°C	mS/cm	20	> 60
In-situ stability ASR remains	h	2000	> 5000

To Take Away:

1. AEM is good enough in terms of their KPIs, however, the question is related to their durability.
2. A better understanding of the in-operando membrane degradation mechanics is needed.
3. Thinner AEM can be manufactured, but questions concerning gas crossover, mechanical strength, and durability should be addressed properly.

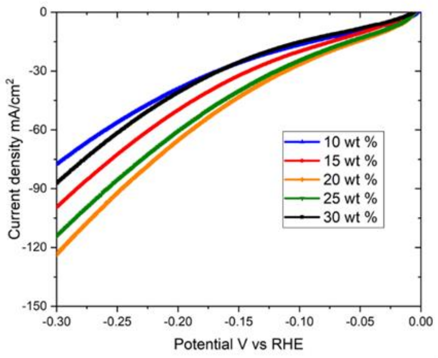
//EU HYDROGEN RESEARCH DAYS 15-16 NOVEMBER

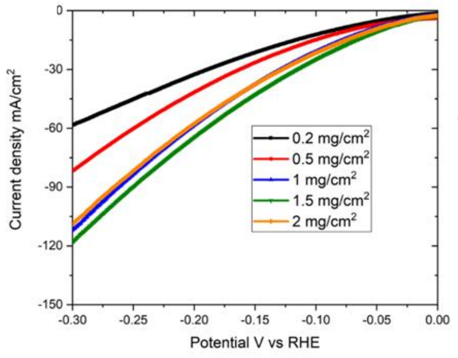
Project results - HER/OER Catalysts

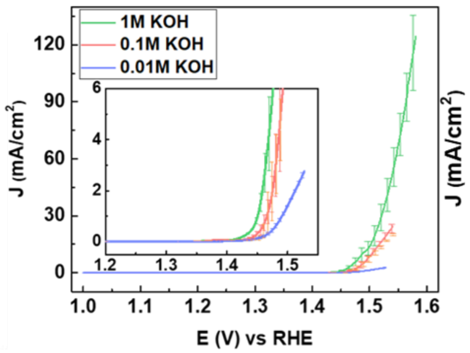
JÜLICH FORSCHUNGSZENTRUM NTNU

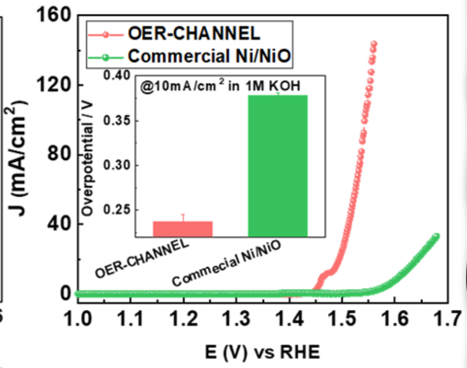
CHANNEL Catalysts Target at 10 mA.cm^{-2}:

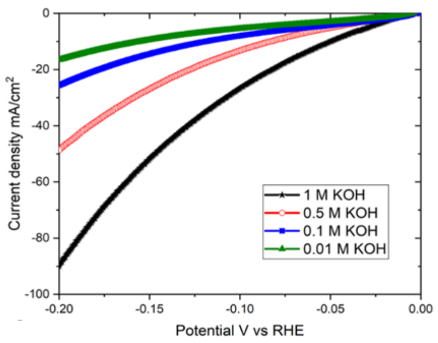
- **HER**: <150 mV overpotential and **OER**: <300 mV overpotential
- Both catalysts achieved performance and stability targets at 1M KOH besides to be scalable

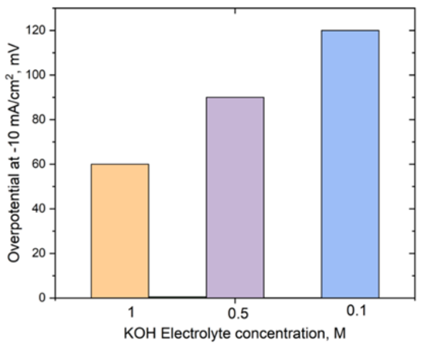


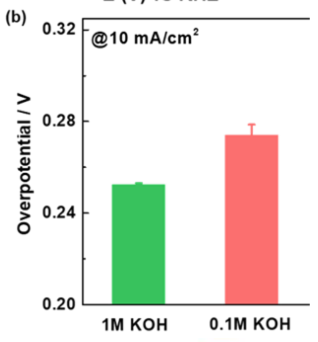


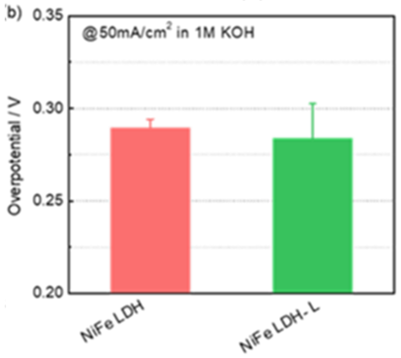












To Take Away:

1. A better understanding of the ionomer role and optimal ratio AEI-catalyst is needed as a function of the hydroxide concentration.
2. For PGM/CRM-free catalysts, the catalyst utilization would be more relevant than mass activity (cost-related), however high catalyst loading (thick electrodes) to compensate for lower mass activity (low-cost catalyst) needs to be carefully tuned to minimize mass transport constraints.
3. The development of in-situ methods for a better understanding of the catalyst activity and stability is recommended.

Clean Hydrogen Partnership

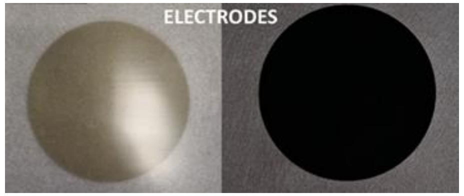
European Hydrogen Week

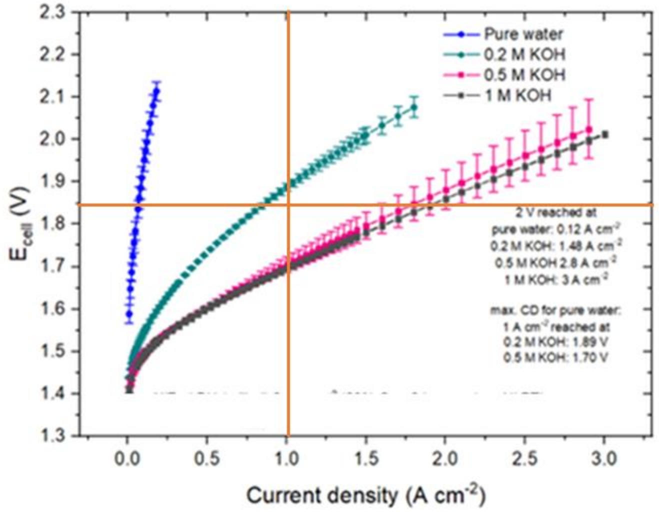
Co-funded by the European Union

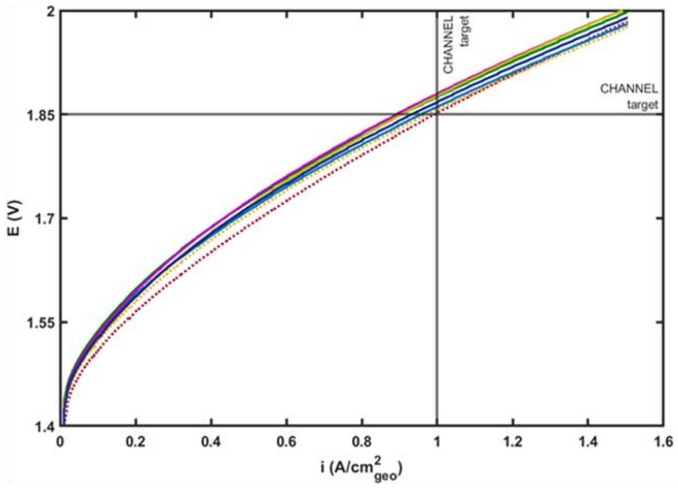
Project results -
Single Cell Performance

CHANNEL Target: 1.85 V at 1 A/cm², 60°C, 1M KOH

Components long-term stability demonstrated over 1000 h





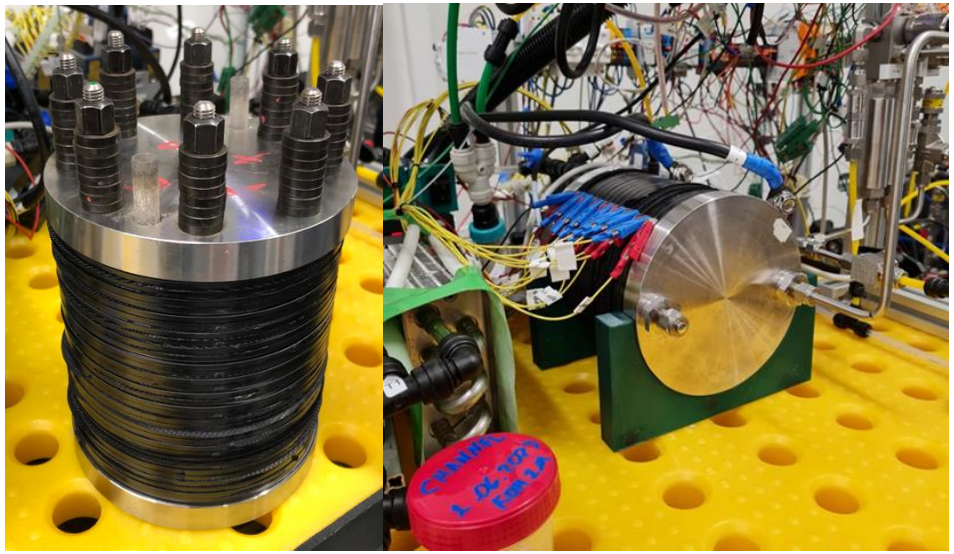


- Developing a AEMWE model to predict local effects (e.g. pH change, water concentration gradients, etc.), degradation (cat's dissolution)

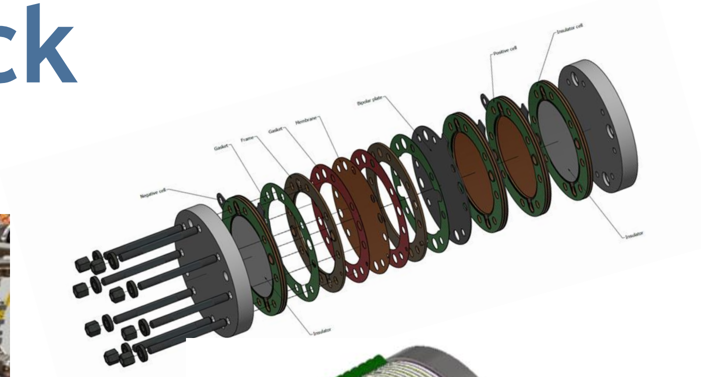
To Take Away:

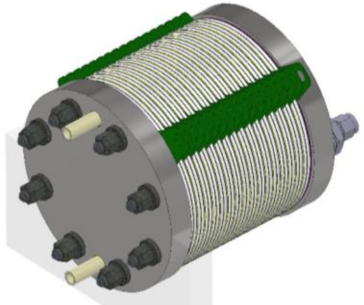
1. The electrode performance is quite sensitive to the ionomer content in the catalyst layer.
2. Crucial to understand the role of the AEI within the catalytic layer.
3. The electrodes to be used must be also optimized for the chosen KOH concentration since the optimal ratio AEI to catalyst may vary as a function of the hydroxide concentration.
4. The binding properties of the AEI must be considered as well.

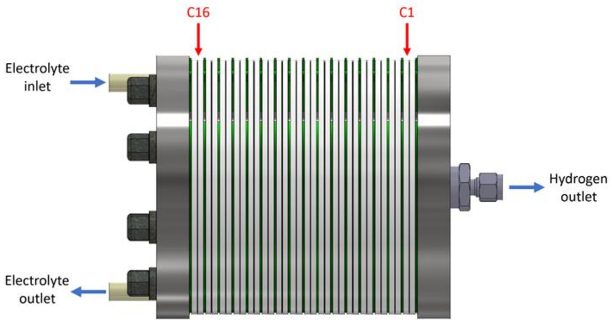
Project results - 2 kW Stack



16 cells with active area of 64 cm^2
BoP for stack testing was also designed and optimized







Enapter SINTEF

To Take Away:

1. CHANNEL stack demonstrator was validated over 260 h at atmospheric pressure, 0.25 A/cm^2 and 55 °C resulting in a degradation rate of 38 μV/h.
2. Unfortunately, the performances expected for the stack were not fully reached at the end of the project.
3. Components dimensioning and manufacturing, methodology transferring from lab scale to stack level, and design/engineering of the final prototype is not a simple task to commit.

CHANNEL

Project results - Dissemination

ACS APPLIED ENERGY MATERIALS
www.acsaem.org Article

Tuning Ni–MoO_2 Catalyst–Ionomer and Electrolyte Interaction for Water Electrolyzers with Anion Exchange Membranes

Alaa Y. Faid,* Alejandro Oyarce Barnett, Frode Seland, and Svein Sunde

Cite This: ACS Appl. Energy Mater. 2021, 4, 3327–3340 Read Online

ChemElectroChem — Chemistry Europe, European Chemical Societies Publishing

Research Article Open Access

The Influence of Loadings and Substrates on the Performance of Nickel-Based Catalysts for the Oxygen Evolution Reaction

Wulyu Jiang, Prof. Dr. Werner Lehnert, Dr. Meital Shviro

First published: 02 January 2023 | https://doi.org/10.1002/celc.202200991

ELSEVIER — International Journal of Hydrogen Energy
Volume 47, Issue 56, 1 July 2022, Pages 23483-23497

Ternary NiCoFe nanosheets for oxygen evolution in anion exchange membrane water electrolysis

Alaa Y. Faid [a], Alejandro Oyarce Barnett [b], Frode Seland [a], Svein Sunde [a]

Show more

Add to Mendeley Share Cite

https://doi.org/10.1016/j.ijhydene.2022.05.143 Get rights and content

ADVANCED FUNCTIONAL MATERIALS

Research Article Open Access

Composition-Dependent Morphology, Structure, and Catalytical Performance of Nickel–Iron Layered Double Hydroxide as Highly-Efficient and Stable Anode Catalyst in Anion Exchange Membrane Water Electrolysis

Wulyu Jiang, Alaa Y. Faid, Bruna Ferreira Gomes, Irina Galkina, Lu Xia, Carlos Manuel Silva Lobo, Morgane Desmau, Patrick Borowski, Heinrich Hartmann, Artjom Maljusch, Astrid Besmehn, Christina Roth, Svein Sunde, Werner Lehnert, Meital Shviro ... See fewer authors

First published: 13 July 2022 | https://doi.org/10.1002/adfm.202203520 | Citations: 8

Journal of Applied Electrochemistry (2022) 52:1819–1826
https://doi.org/10.1007/s10800-022-01749-z

SHORT COMMUNICATION

Unveiling hydrogen evolution dependence on KOH concentration for polycrystalline and nanostructured nickel-based catalysts

Alaa Y. Faid[1] · Faranak Foroughi[1,2] · Svein Sunde[1] · Bruno Pollet[2,3]

Received: 4 April 2022 / Accepted: 14 August 2022 / Published online: 2 September 2022
© The Author(s) 2022

- The results haven presented in 10 conferences
- A patent application has been submitted
- Creation of the AEM Hub for promoting the AEM technology in cooperation with the other EU granted AEMWE projects (NEWELY and ANIONE)

- Two more manuscripts under revision

Project - Summary

- ✓ CHANNEL successfully developed alternative low-cost non-PGM catalysts exhibiting excellent performance and durability. *A patent application on cathode catalyst was submitted by NTNU.*

- ✓ The project achieved a good generation of anion exchange membranes and ionomers with excellent chemical and mechanical properties.

- ✓ The optimized membrane and electrodes allowed to reach a full non-PGM single-cell performance target of <1.85 V at 1 A/cm^2 with a good stability after 1000 h (@1A/cm^2) long-term test.

- ✓ Due to the low TRL of the stack prototype, manufacturing strategies, and cost forecast for a 500kW system were calculated based on estimations of the stack manufacturer.

Clean Hydrogen Partnership
European Hydrogen Week
Co-funded by the European Union

Acknowledgements

//EU HYDROGEN RESEARCH DAYS 15-16 NOVEMBER

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (now Clean Hydrogen Partnership) under grant agreement No 875088. This Joint undertaking receives support from the European Union's Horizon 2020 research innovation programme and Hydrogen Europe and Hydrogen Europe Research.

Thank you for your attention

Clean Hydrogen Partnership

European Hydrogen Week

Co-funded by the European Union