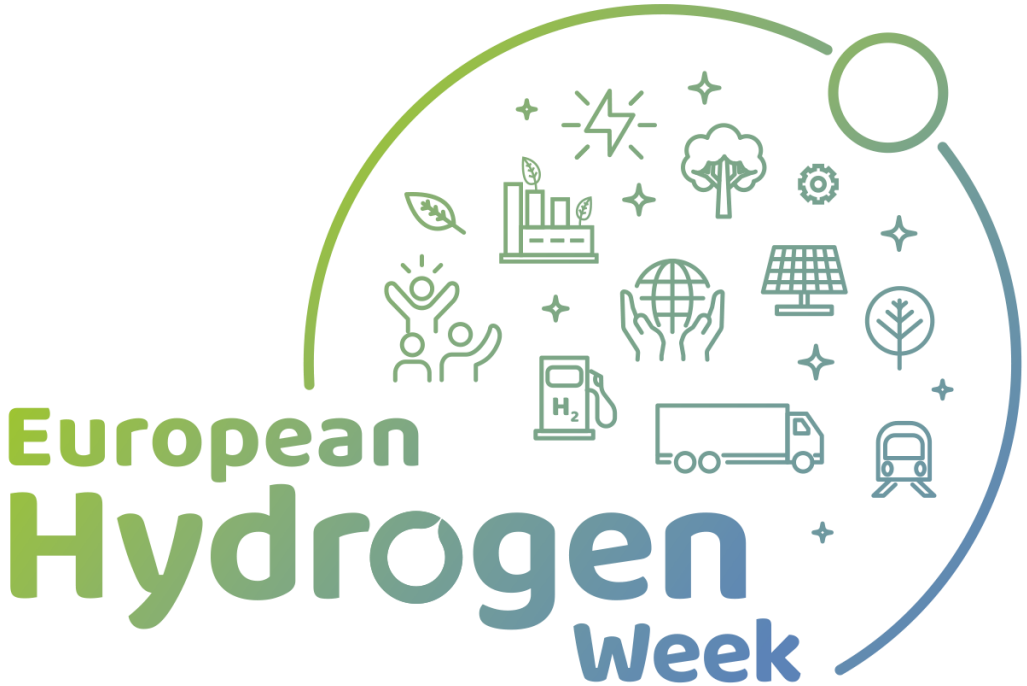

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#EUResearchDays
#PRD2022
#CleanHydrogen

NEPTUNE
Next Generation PEM Electrolysers under New Extremes

Daniel Greenhalgh, Work Package 6 Leader
ITM Power
28 October 2022

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Project Overview

- Call year: 2017
- Call topic: FCH-02-1-2017 — Game changer Water Electrolysers
- Project dates: 01/02/2018 – 30/04/2022
- % stage of implementation 01/02/2018: 100%
- Total project budget: 1,927,335.43 €
- FCH2JU max. contribution: 1,926,221.25 €
- Other financial contribution: 0 €

NEPTUNE

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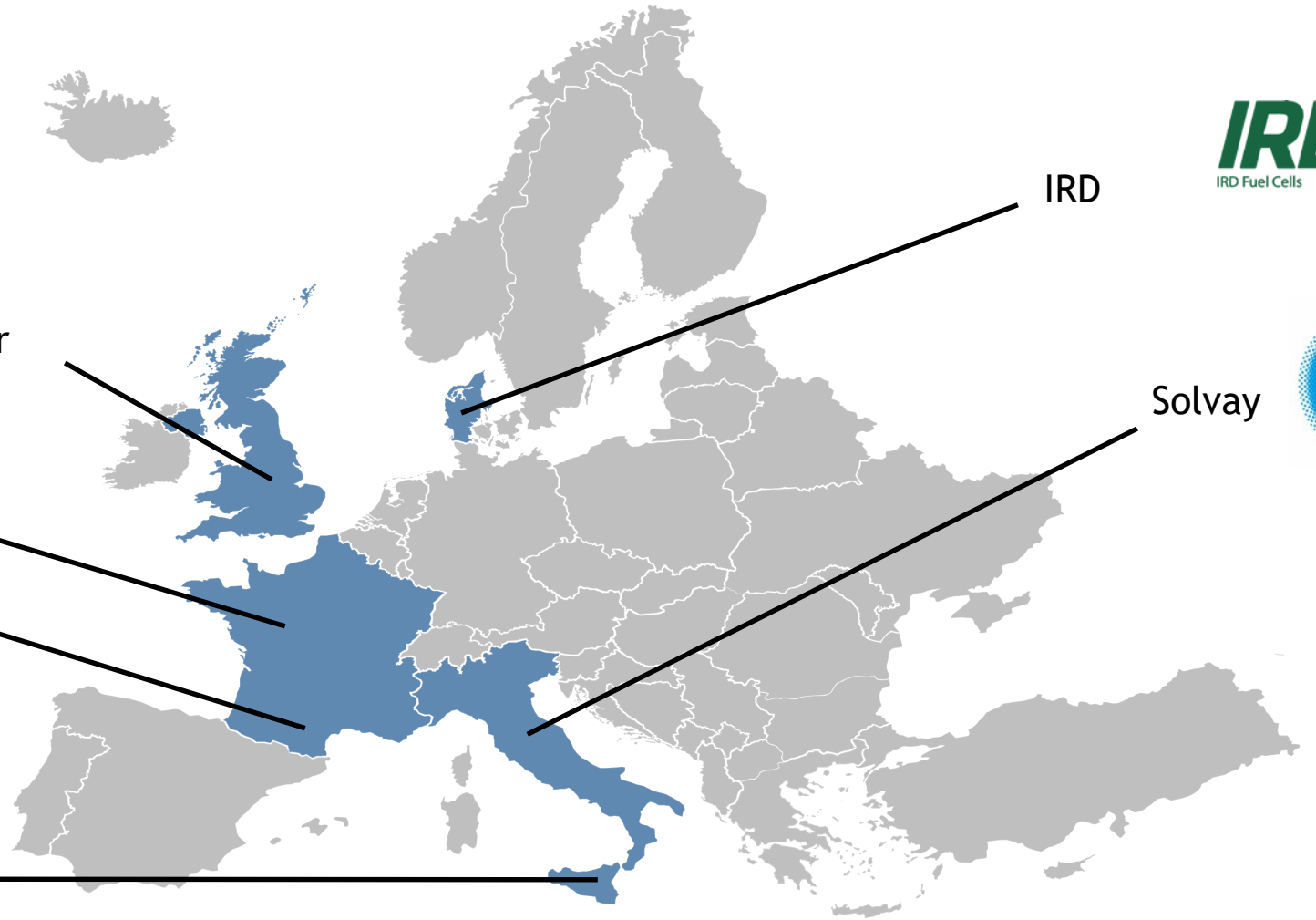
Partners



IRD Fuel Cells

ITM POWER Energy Storage | Clean Fuel

SOLVAY PROGRESS BEYOND

ENGIE Lab

PRETEXO

Consiglio Nazionale delle Ricerche

ITAE

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Aims and Objectives

MAWP 2017 – Topic 02-1-2017 Game changer Water Electrolysers

Challenge	Scope	Impact
• Higher pressure • Rapid response • Increased current density • Reduced critical raw materials • Elevated temperature	• P ≥ 100 bar, • I ≥ 4 A/cm^2, • T ≥ 80°C • 10-50 kW, • ≥ 2,000 Hours of operation	• Develop and validate prototype game-changer electrolyser • Knowledge on designing and operating such an electrolyser • Assessment of commercial opportunities

TRL 3 → TRL 5

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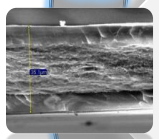
Concept and Approach

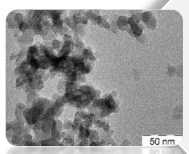
Development of MEA and Stack Components

TRL 3

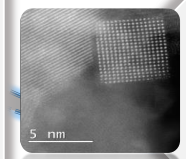


Reinforced membrane with lower thickness to reduce ohmic drop and improve mechanical stability

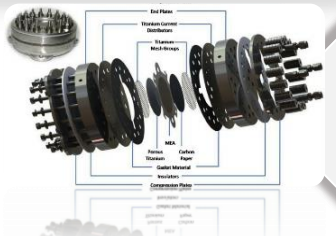
Redesign diffusion layers to improve gas diffusion and overcome reversible degradation



Cross-over management through dual recombination catalysts (membrane filler and integrated in the anode)

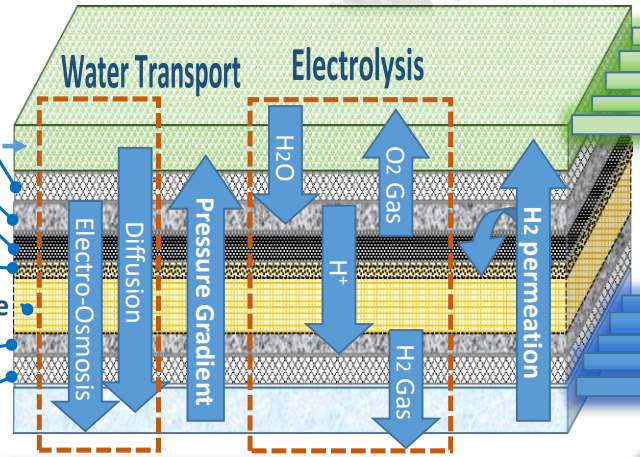


Nanostructured catalysts to increase intrinsic activity and stability, lower precious metal content; reducing mass transport



Hydraulic compression (high P), flow-field free design and protective coatings of Ti plates to achieve low cost and durable stacks

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



TRL 4

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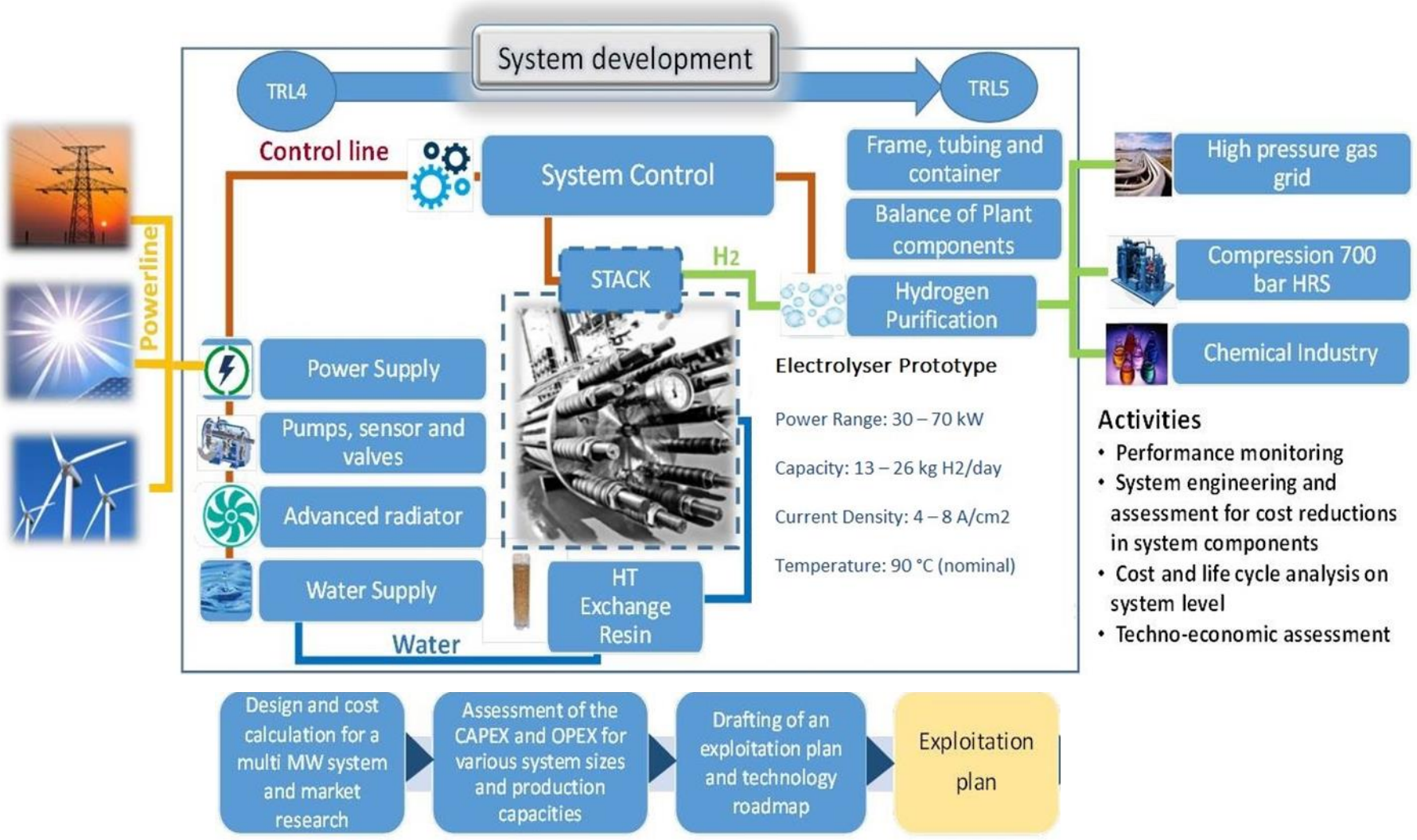
Concept and Approach



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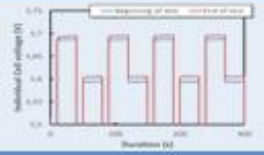
Partner Responsibilities

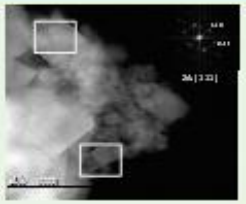
CNR - Specifications & harmonisation of test protocols



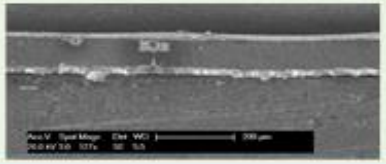
ENGIE - Market analysis, implementation of policies & regulations

SLV – Polymer electrolyte membrane & ionomers

CNR – Electro-catalysts & recombination catalyst



EWII – Membrane-electrode assembling

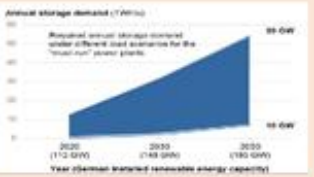


ITM – Stack design & assembling

ITM – System building & testing

ENGIE – End-user' techno-economic assessment

PXO – Dissemination

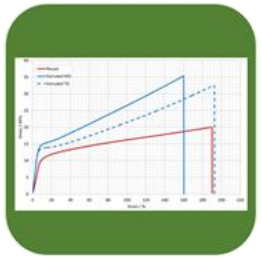


ENGIE – Exploitation

Project Progress – Innovative Membranes

Several Aquivion-based membranes were evaluated for Neptune.

EXTRUDED MEMBRANE

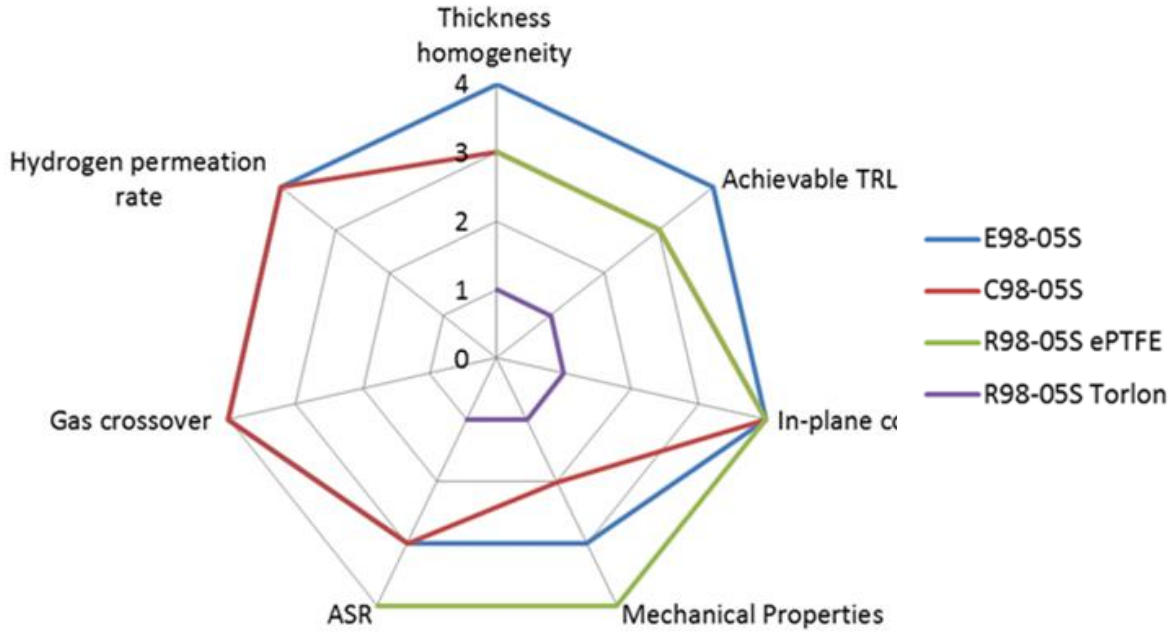


CAST MEMBRANE

TORLON REINFORCED MEMBRANE

ePTFE REINFORCED MEMBRANE

Selection of the final product was based on a number of metrics;



- Siracusano, S.; Oldani, C.; Navarra, M.A.; Tonella, S.; Mazzapioda, L.; Briguglio, N.; Aricò, A.S. J. Memb. Sci. 2019, 578, 136-148.
- Gatto, I.; Carbone, A.; Saccà, A.; Passalacqua, E.; Oldani, C.; Merlo, L.; Sebastiàn, D.; Aricò, A.S.; Baglio, V. J. Electroanal. Chem. 2019, 842, 59-65.

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Project Progress - Innovative Membranes

Reinforced membrane, low ASR and H_2 crossover, large area, meeting specifications

PROJECT TARGET VALUES

ASR <25 mΩ.cm²

<0.5 vol.% H_2 in O_2 @ 100 bar

>415 cm²

Achievement to-date

25% 50% 75%

4: best --> 1: worsed

Membrane	E98-05S	C98-05S	R98-05S ePTFE	R98-05S Torlon	Target
Type	Extruded	Cast	Reinforced	Reinforced	-
ASR (@ 80° C)	3	3	4	1	<25 mΩ.cm²
Gas crossover @ 4 A cm^{-2}, 90 degC	1	1	-	-	<0.5 vol.%
Achievable TRL	>5	4	4	3	5

Down-selected membrane

Aquivion E98-05S Membrane

Membrane type: Extruded

Equivalent Weight (EW): 961 g/mol

Thickness: 55 µm

Chemically stabilized

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Project Progress - MEAs

Achievement to-date

PROJECT START VALUE
2 A cm^{-2}
2.5 mg cm^{-2}

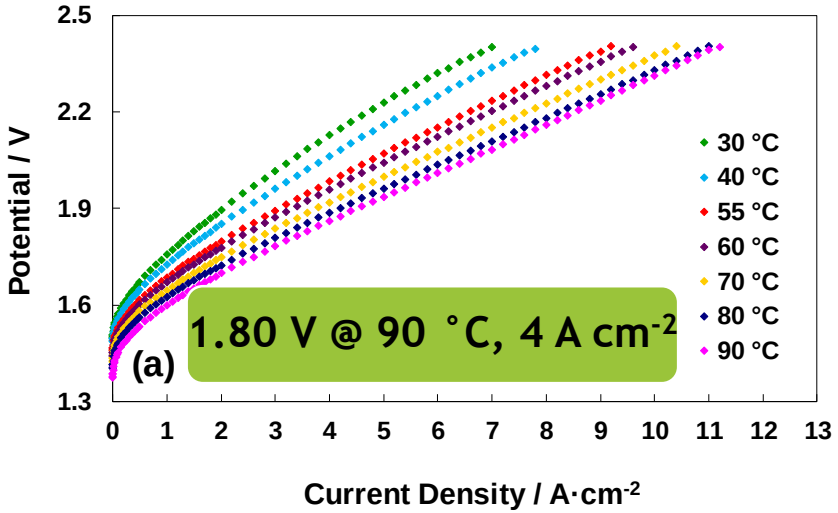
Anode: IrRuOx 0.3 mg·cm^{-2}
PtCo 0.2 mg·cm^{-2}
Cathode: 40% Pt/C 0.1 mg·cm^{-2}

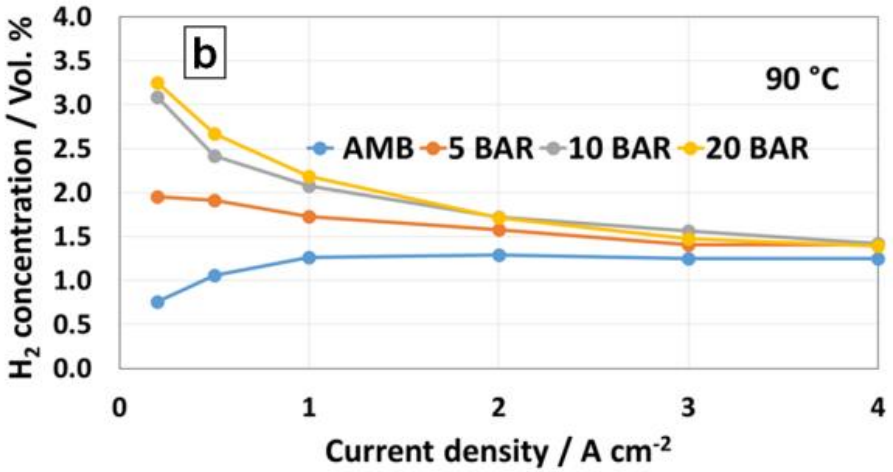
Total
0.6 mg cm^{-2}

PROJECT TARGET VALUES
4 A cm^{-2}
<0.4 mg cm^{-2}
<0.5 vol.% H_2 in O_2
@ 100 bar

25% 50% 75%

Target @ 90 °C, 4 A cm^{-2}: 1.75 V





- N. Briguglio, S. Siracusano, G. Bonura, D. Sebastián, A. S. Aricò. Applied Catalysis B: Environmental 246 (2019) 254-265
- F.Pantò, S.Siracusano, N.Briguglio, A.S.Aricò. Applied Energy 279 (2020) 115809

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Project Progress - MEAs

Achievement to-date

PROJECT START VALUE
2.5 mg cm^{-2}

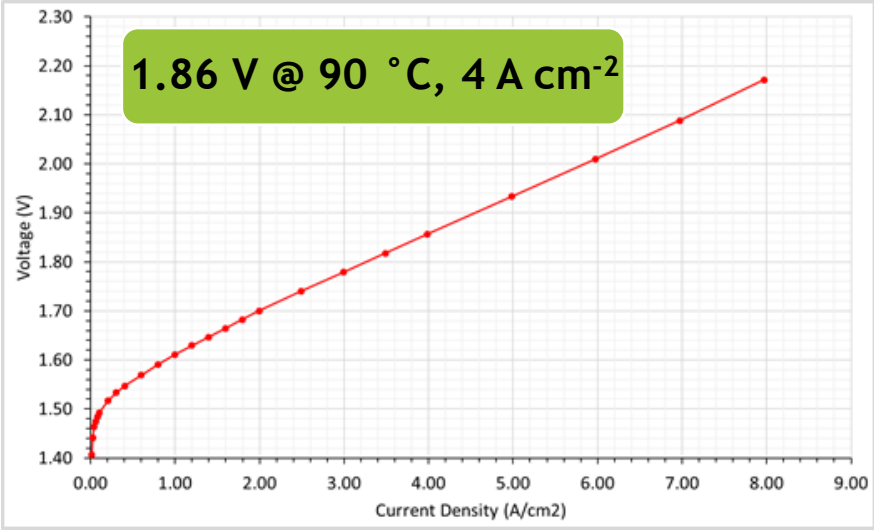
Anode: IrRuOx 0.9 mg·cm^{-2}
PtCo 0.1 mg·cm^{-2}
Cathode: 40% Pt/C 0.2 mg·cm^{-2}

Total
1.2 mg cm^{-2}

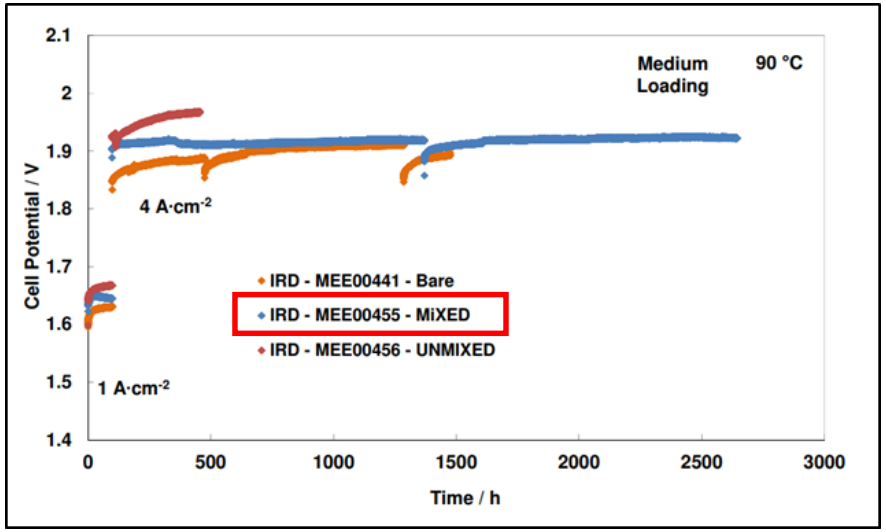
PROJECT TARGET VALUES
<0.4 mg cm^{-2}
5µV/h over 2,000 h

25% 50% 75%

Target @ 90 °C, 4 A cm^{-2}: 1.75 V



4 µV/h over 2,000 h @ 90 °C, 4 A cm^{-2}



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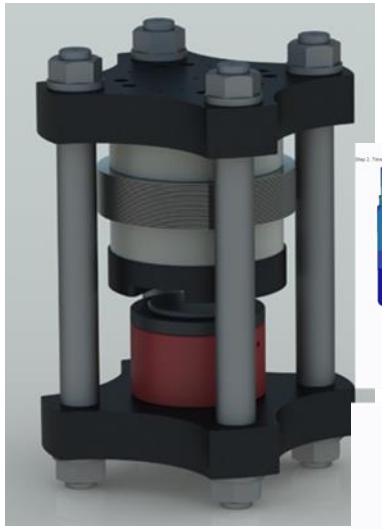
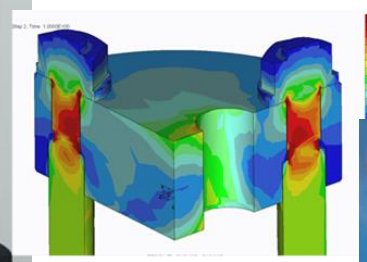
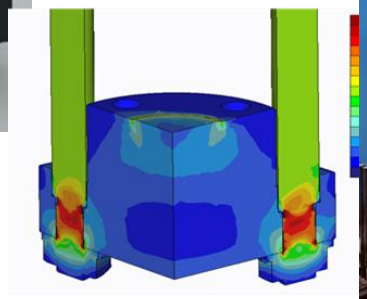
Project Progress – Stack Design







New PEMWE stack module designed at ITM to achieve the project targets.

Stack module consists of:

- composite cell-plate assemblies,
- end-plates,
- retention structure (referred to as a ‘Skid’).

Designed to act as a pressure vessel - self-pressurizing to save energy & cost in compression of gases.

Low-cost, single acting hydraulic cylinder to provide compression for the stack module.

Stack design based on:

- a ‘filter press assembly’, in a bipolar arrangement,
- utilising injection-moulded parts.
- flow-field free architecture to eliminate expensive machining costs
- efficient, compact design for lean manufacture.

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Project Progress – Stack Design

Achievement to-date

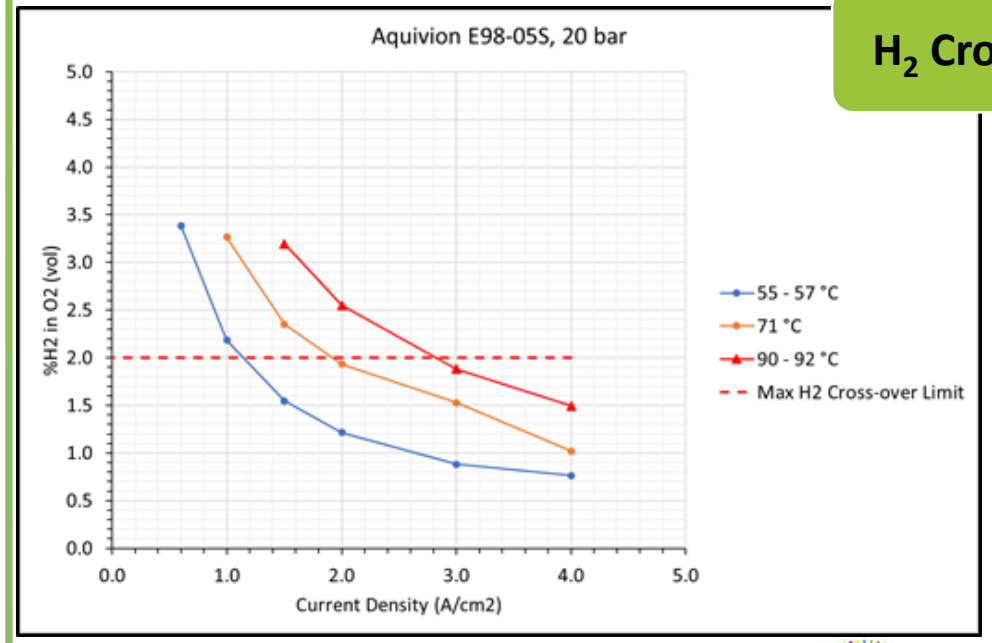
PROJECT START VALUE
20 bar_g
55 °C

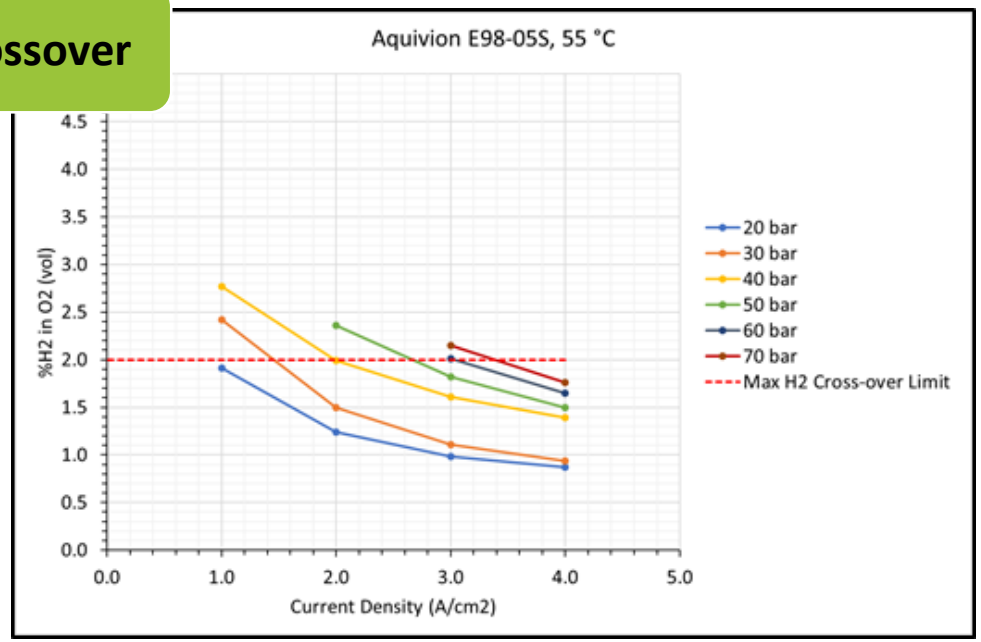
Max. working pressure 120 bar_g
Max. working temperature 92 °C

PROJECT TARGET VALUE
100 bar_g
>80 °C

25% 50% 75%

H_2 Crossover





Stack operated at 4 A cm^{-2}, ~70 °C, 30 bar_g to provide a reasonably wide range of operation

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Challenges and Lessons Learned

Activities planned during the second half of the project were significantly disrupted due to the Coronavirus outbreak.

Covid-related delays meant that the final stages of the project also coincided with the timing of ITM's move into its new facility, leading to a significant disruption to final testing.

Despite these challenges, the stack and system were successfully designed, procured, and assembled. However, testing on the final stack was significantly limited.

As a mitigation strategy, the project MEAs were fully characterised and tested at the single cell level while the balance of plant was verified using a reference stack.

Project results indicate the potential for optimization of PEM electrolysis, the challenge is scaling up from the laboratory to make the changes a commercial reality.

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Exploitation Plan/Expected Impact

Exploitation

Exploitation plans of industrial partners (highlights):

ITM → High performing stack operating at high temperature and pressure.

CNR → New intellectual property from developing new components.

Solvay → Reinforced Aquivion membranes.

IRD → MEA engineering and automated multilayer catalyst-coated membrane (CCM) methods.

Engie → Implementing regulations together with policy makers for using electrolyser in HRS and grid services

Impact

This ambitious targets will allow the market opportunity for PEM electrolysis to be exploited, particularly in the sectors of hydrogen for transport, and of energy storage and Power-to-Gas applications.

Sustainable hydrogen production which can meet an increasing share of the hydrogen demand for energy applications from carbon-free or lean energy sources.

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Communications Activities

PREXTEXO

Website

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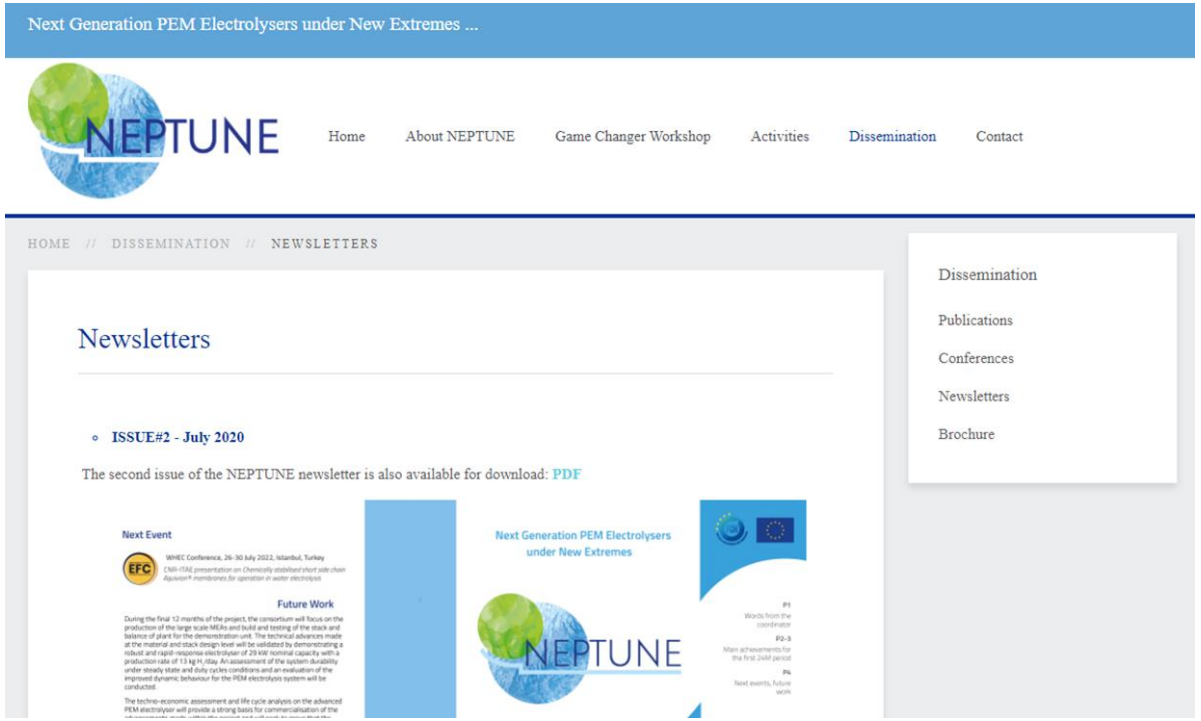

http://neptune-pem.eu/en/dissemination/newsletters

Dissemination Activities

Public Reports - 11

Covering; Test Protocols, Membranes, Catalysts, MEAs, Stacks, Dissemination

Publications - 6

Reinforced short-side-chain Aquivion® membrane for proton exchange membrane water electrolysis, S. Siracusano, F. Pantò, S. Tonella, C. Oldani, A. S.Aricò, International Journal of Hydrogen Energy, Volume 47, Issue 35, 26 April 2022, Pages 15557-15570

Conferences - 10

- WHEC2022 - 26-30 June 2022, Istanbul
- European Hydrogen Energy Conference 2022, 18-20 May 2022, Madrid, Spain
- ICH2P-2021, 19-23 September 2021, Online
- EFCF 2021: Low-Temp. Fuel Cells, Electrolysers & H_2 Processing, 29 June - 2 July 2021, Online
- ICE webinar 2021, 18 June 2021, Online

Dissemination Activities

Game Changer Proton Exchange Membrane Water Electrolysers - Online Workshop - 17th June 2021

https://neptune-pem.eu/en/workshop2

Aim: To discuss next generation PEM electrolysers, with novel solutions at intermediate Technology Readiness Level, contributing to step changes in performance.

59 participants from both industry and academia.

Presentations from international experts in the field.

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Acknowledgements

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement N° 779540 - NEPTUNE. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme, Hydrogen Europe and Hydrogen Europe research.

Further Information

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