FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

HPEM2GAS – High Performance PEM Electrolyzer for Cost-effective Grid Balancing Applications

HPEM2GAS

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Emden, 12 February 2019

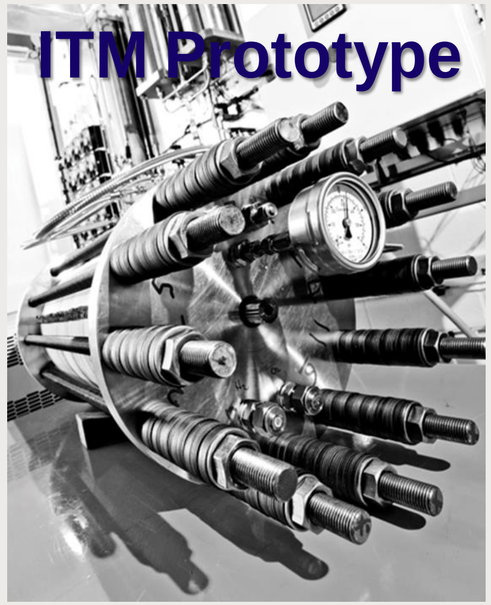
PROJECT OVERVIEW

- **Call year:** 2015
- **Call topic:** FCH-02.2-2015 IMPROVED ELECTROLYSIS FOR DISTRIBUTED HYDROGEN PRODUCTION
- **Project dates:** 01/04/2016 – 31/03/2019
- **Total project budget:** 2,654,250.00 €
- **FCH JU max. contribution:** 2,499,999.00 €
- **Other financial contribution:** balanced by ITM
- **Partners:** CONSIGLIO NAZIONALE DELLE RICERCHE (CNR-ITAE); ITM POWER (TRADING) LIMITED; SOLVAY SPECIALTY POLYMERS ITALY S.P.A.; IRD FUEL CELLS; STADTWERKE EMDEN GmBH; HOCHSCHULE EMDEN/LEER; UNIRESEARCH BV

CONTEXT

HPEM2GAS – High Performance PEM Electrolyzer for Cost-effective Grid Balancing Applications

- **As more renewables are being integrated to the grid, there is a need to develop high performance electrolysers to provide superior grid-balancing services and to produce "green" hydrogen for fuel cell vehicles and other applications.**
- **Hydrogen appears the most appropriate choice for at-scale decarbonization of selected segments in transport, industry, and buildings.**
- **HPEM2GAS is addressing these aspects to contribute in making hydrogen the future energy carrier.**



Wind turbine power profile

PROJECT SUMMARY & OBJECTIVES

HPEM2GAS's ambition is to realise breakthroughs in PEM water electrolysis for Distributed Hydrogen Production

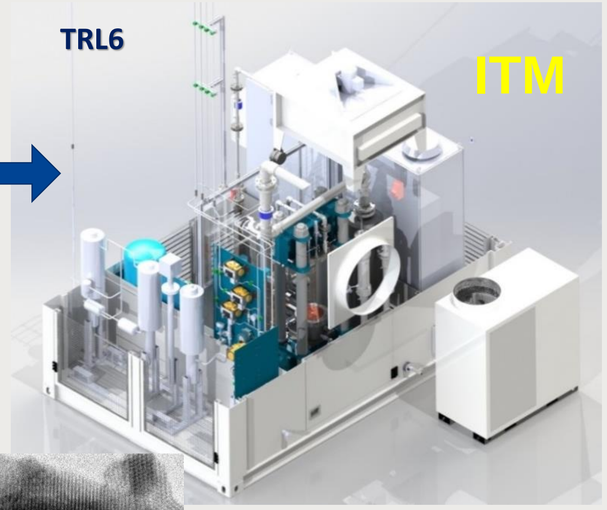
- **The concept and approach are targeted to improve stack performance (180 kW; 75 cells, 3 A cm^{-2} @ 1.8 V/cell), energy efficiency (82% or 48 kWh/kg H_2) , stack lifetime (degradation rate <5 µV/h during 1000 hrs) and reduce system costs (CAPEX < € 1,000/kW for systems of >1 MW) while meeting the technical requirements of electrolysers for the interaction with the grid and renewable energy sources (100% of nominal load per second; minimum load range 5-10%).**

Positioning vs. SoA

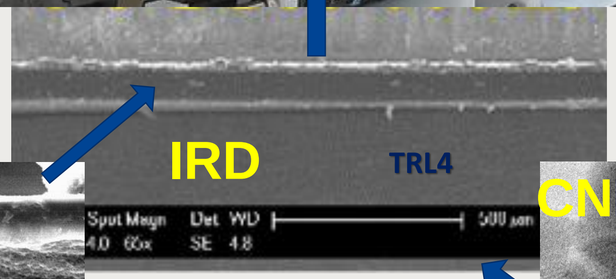
Parameter	HPEM2GAS	SoA
Current density A cm^{-2} @ 1.8 V	3	2
Energy consumption kWh/kg H_2	48 (54)	57
Degradation %/1000hrs	0.25 (0.2)	0.25
PGM loading mg/W	0.07 (0.3)	0.5-1.5
CAPEX € /(kg H_2/day)	< 2,250	< 2,900

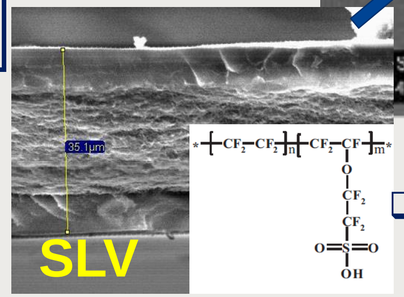
❑ Improved stack design

❑ Advanced BoP and safety integrated system

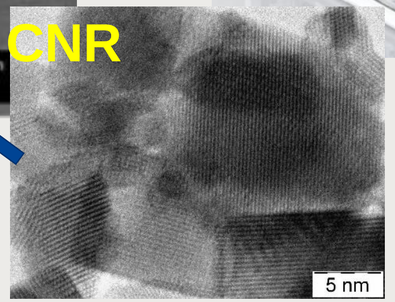


❑SSC Aquivion® membranes





❑ Enhanced MEAs



❑ Nanostructured electro-catalysts

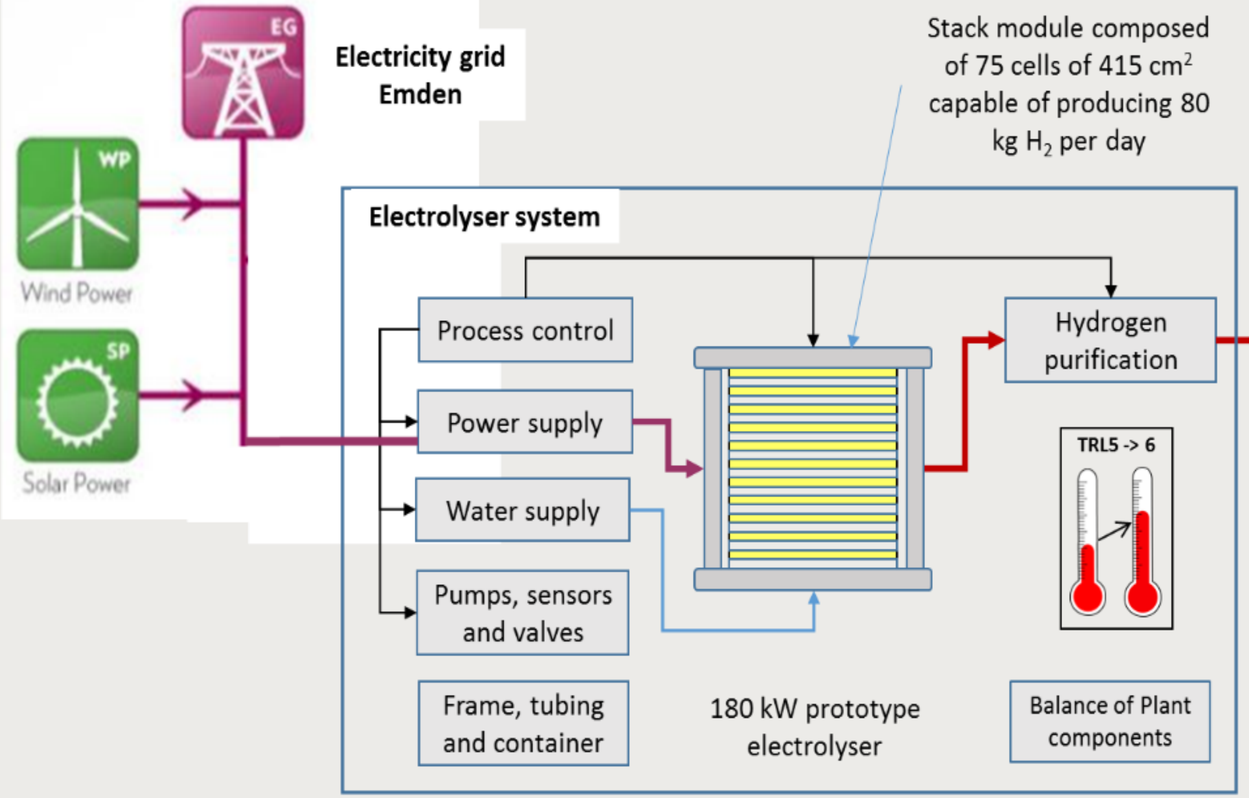
PROJECT SUMMARY

Field testing at Emden (Germany) and follow-up plan

- ❑ Stadtwerke Emden (SWE) is the local supplier for electricity, water and gas.
- ❑ Two wind farms have been built in the city of Emden which provides 117% (240 MWh/y) of the electric energy for homes

- ✓ Need for utilizing excess wind power;
- ✓ Need to address the congestion of transmission;
- ✓ Need to stabilize the electricity grid from frequent fluctuations;

System design, system optimization, prototyping and validation in a field test at Emden



Power-to-gas

HPEM2GAS

Activities

- Performance monitoring
- System engineering and assessment for cost reductions in system components
- Cost and life cycle analysis on system level
- Techno-economic assessment on grid balancing level

Design and cost calculation for a 10 MW system and market research → Assessment of the CAPEX and OPEX for various system sizes and production capacities → Drafting of an exploitation plan and technology roadmap → Follow-Up plan

PROJECT PROGRESS/ACTIONS – Stack Efficiency

Achievement to-date % stage of implement.

PROJECT START VALUE
Eff. 77 %
@ 0.83 A cm^{-2}

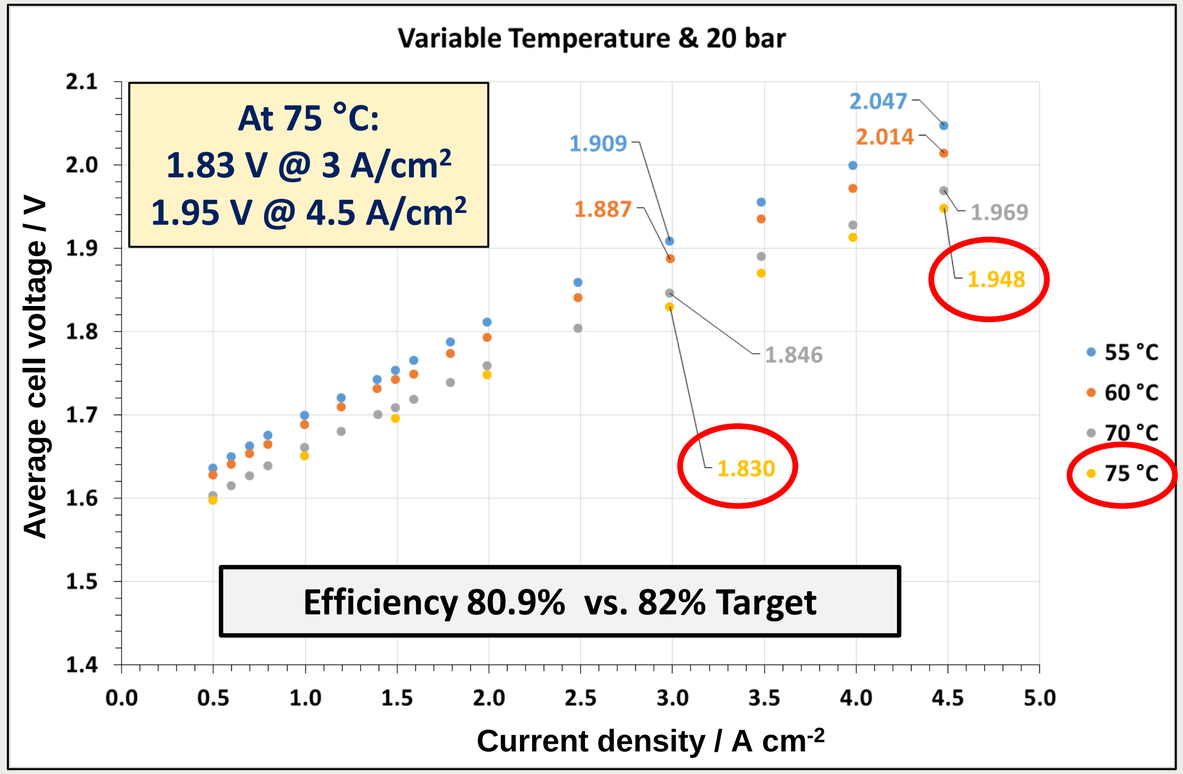
Efficiency: 81% at 3 A cm^{-2} and 75 °C

25% 50% 75%

TARGET SYSTEM EFFICIENCY
82 %

PEM electrolysis stack

Parameter	HPEM2GAS	SoA
Stack efficiency / %	81	75
Current density A cm^{-2} @ 1.8 V	3	2
PGM loading mg/W	0.3	0.5
Temperature °C	75	-



PROJECT PROGRESS/ACTIONS – System Energy Consumption

Achievement to-date % stage of implement.

PEM electrolysis system

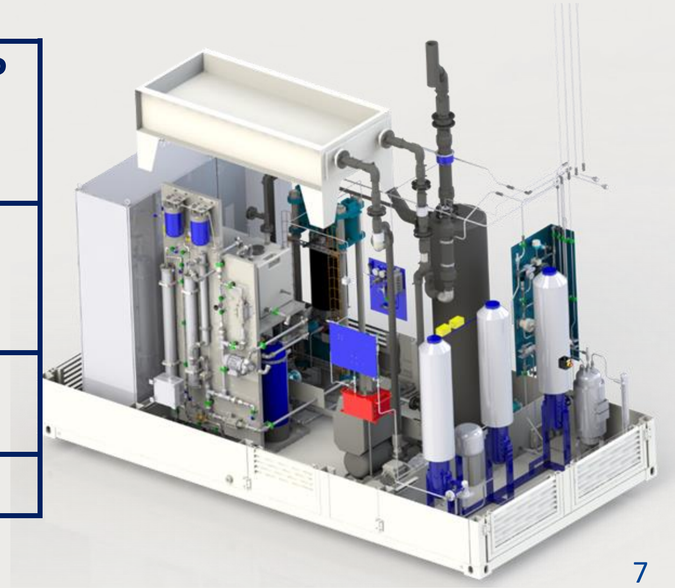
Energy consumption: 54.2 kWh/kg H_2 at 3 A cm^{-2} and 55 °C

PROJECT START VALUE **Energy Consumption 53.2 kWh/kg H_2 @ 0.83 A cm^{-2}**

25% 50% 75%

TARGET SYSTEM ENERGY CONSUMPTION 48 kWh/kg H_2

Parameter	HPEM2GAS High current density	HPEM2GAS Low current density	SoA	AWP2015 target	MAWP 2020 target
System energy consumption kWh/kg H_2	54	47	57	48	55
Current density A cm^{-2} @ 1.8 V	3	1	2	-	2.2
Temperature	54-56 °C	54-56 °C	-	-	-



PROJECT PROGRESS/ACTIONS – Stack degradation rate

Degradation rate: 0.2 %/1000 hrs at 3 A cm^{-2} and 55 °C

Achievement to-date % stage of implement.

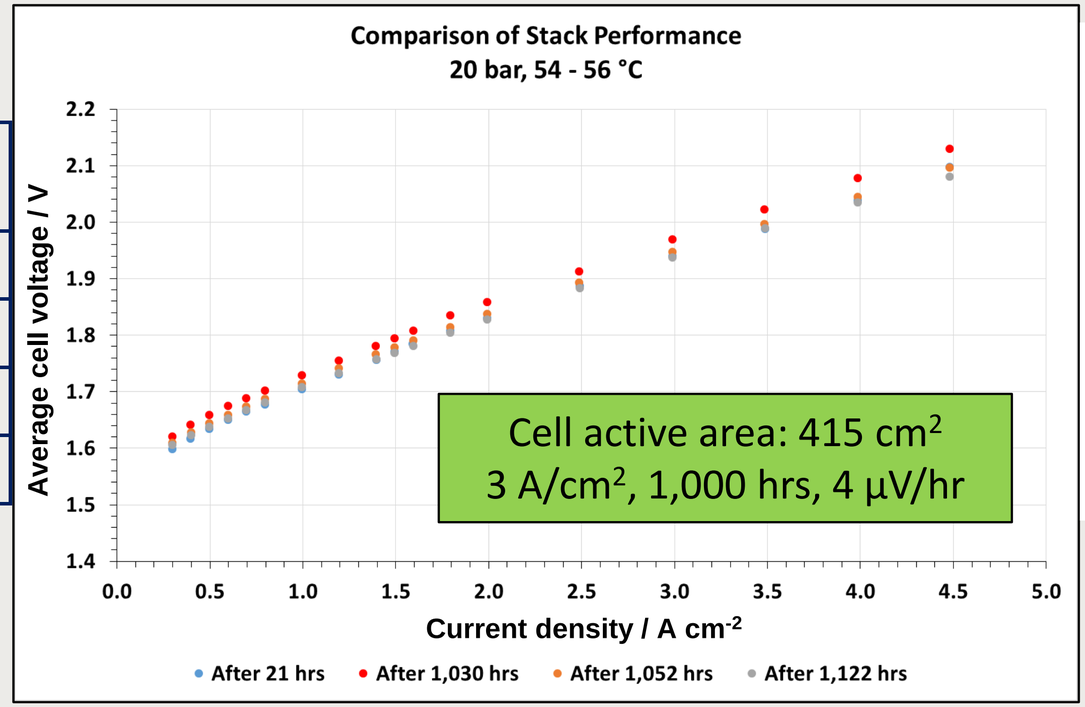
PROJECT START VALUE
0.55 %/1000 hrs @ 0.83 A cm^{-2}

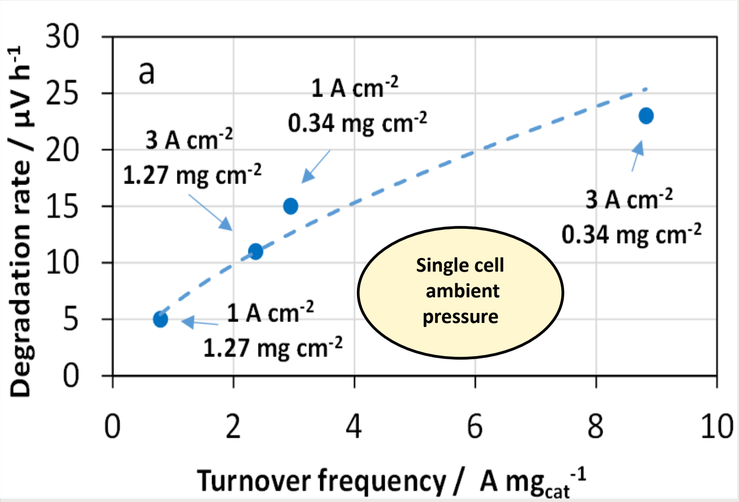
25% 50% 75%

TARGET Degradation rate <0.25 %/1000 hrs

PEM electrolysis short stack

Parameter	HPEM2GAS	SoA	MAWP 2020 target
Stack degradation %/1000 hrs	0.2	0.25	0.19
Current density A cm^{-2} @ 1.8 V	3	2	2.2
PGM loading mg/W	0.3	0.5-1.5	2.7
Temperature °C	55	-	





The degradation rate increase proportionally with the operating turn-over frequency (TOF) of the anode electrocatalyst

Nano Energy 40 (2017) 618–632

PROJECT PROGRESS/ACTIONS – Operating pressure

Achievement to-date % stage of implement.

PEM electrolysis short stack

Gas cross-over

2.5% H_2 in O_2 @ 3 A/cm^2 observed at 50 bar

New strategies: Recombination catalyst (not yet implemented at stack level)

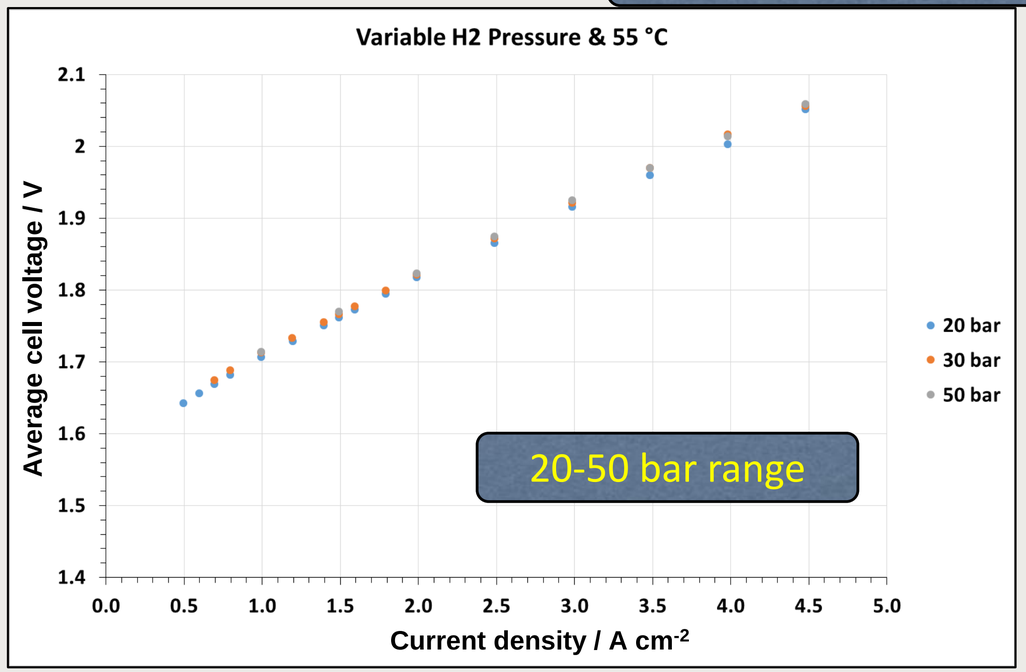
Max. operating pressure 50 bar at 3 A cm^{-2} and 55 °C

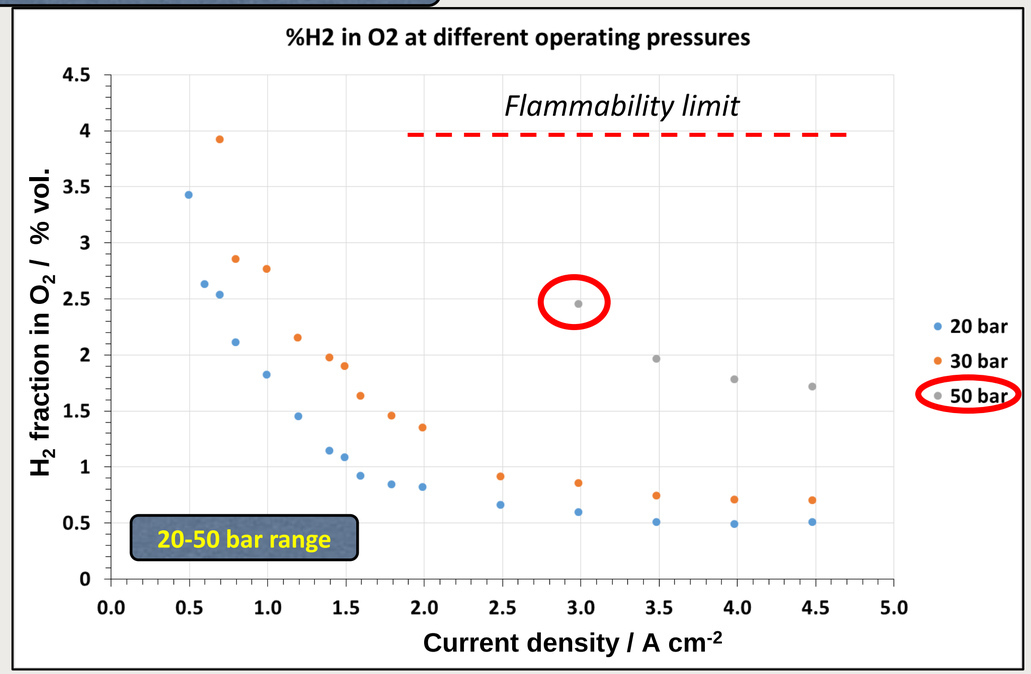
PROJECT START VALUE **15 bar @ 0.83 A cm^{-2}**

25% 50% 75%

TARGET Operating pressure up to 80 bar

90 µm thick Aquivion® membranes





PROJECT PROGRESS/ACTIONS – Dynamic behaviour

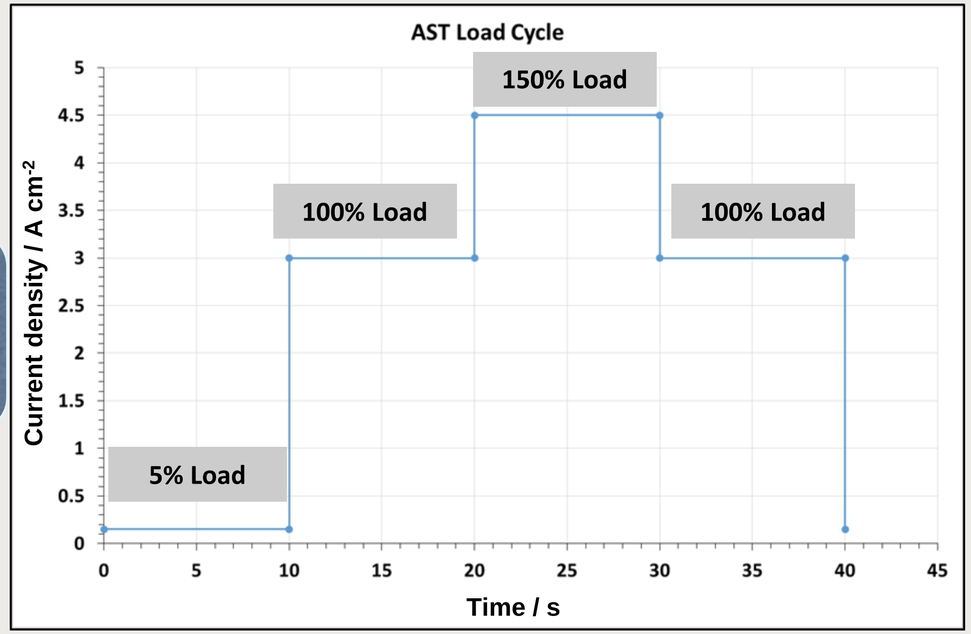
Achievement to-date
% stage of implement.

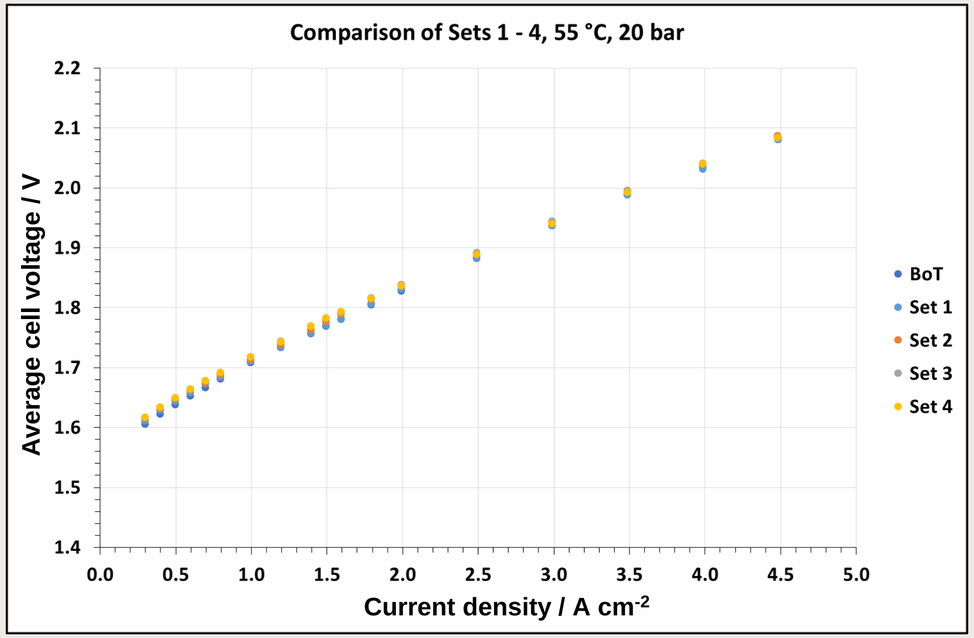
7500 cycles with variable load (from 0.15 to 4.5 A cm^{-2})

25% 50% 75%

TARGET
Ramp rates of up to 100% of nominal load per second and a load range 5%-150%

No relevant performance degradation during cycled operation



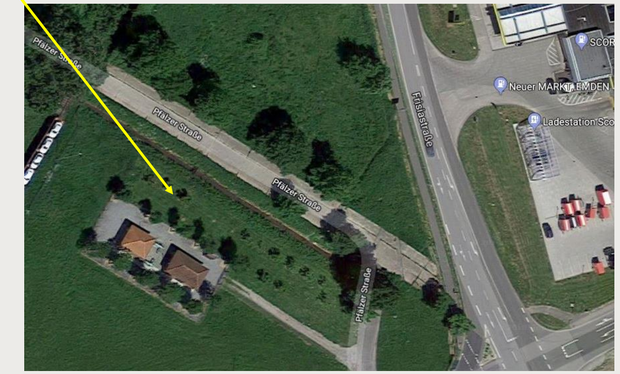


Dynamic response: Short Stack Testing at Full-scale (415 cm^2 active area)

20 bar, ~55 °C, 4 sets of cycles, total of 7500 cycles; Sets 1 & 2: 1530 cycles, Sets 3 & 4: 2220 cycles

PROJECT PROGRESS/ACTIONS – Setting-up field testing site

Emden, Germany



Location for the installation of the electrolyzer:
→ Pfälzer Straße, 26725 Emden

A transformation station has been installed to switch from high voltage to low voltage;
The ground has been covered with foil and a gravel layer

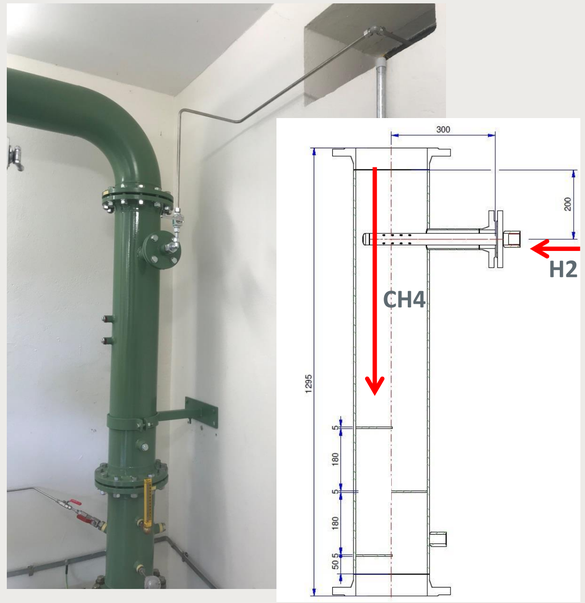
Control station

The pressure is reduced to 10 bar at the electrolysis system before the outlet

✓ After the check, the hydrogen leaves the control station and enters the gas transfer station
✓ Above-ground pipeline with a DN12 pipe

Hydrogen is fed into the natural gas grid

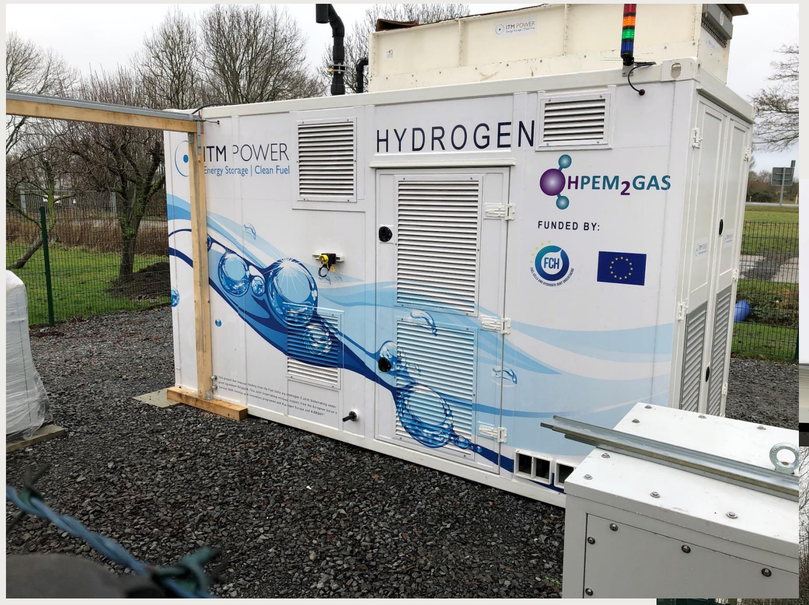
Mixer has built-in lamellas, so the gas mixture flow is turbulent
The gas grid is operated at 8.5 bar, the hydrogen is fed in with a slight overpressure of 10 bar



More information in the successive presentations

PROJECT PROGRESS/ACTIONS –

Installation of the PEM electrolyser in Emden for field testing activities



More information in the successive presentations

Progress in field testing

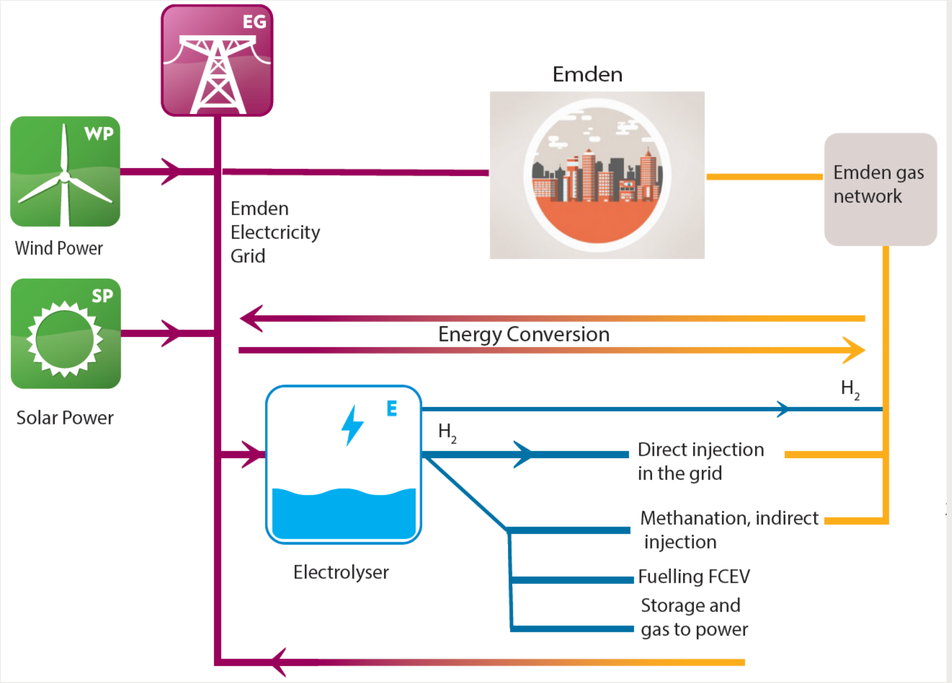
- ✓ Factory acceptance test was completed for the electrolysis system at ITM POWER in Sheffield (UK)
- ✓ The system was delivered to STADTWERKE EMDEN for field testing in Emden (Germany)
- ✓ Due to some previous delay in supplying of stack components and FAT, there is a shift of about 3 months in the overall planning
- ✓ Due to some limitations in maximum operating temperature for the ion exchange cartridges and the specific certification required for HT operation of some BoP components such valves, pipelines, pumps, the system can not be operated above 55-60°C
- ✓ This lower operating temperature represents a limitation for the achievement of the efficiency target that was planned taking into account operation at higher temperatures

EXPLOITATION PLAN/EXPECTED IMPACT

- **Exploitation plans of industrial partners** (highlights):
  - **ITM** → new electrolyser system with increased operating current density (3 A cm^{-2}) and lower cost.
  - **Solvay** → commercialisation of ionomer membranes for PEM water electrolysis application
  - **IRD** → extending the portfolio of products for electrochemical systems and the development of components and MEAs for this application
  - **SWE**→ the results of the project will be used to implement renewable power sources with cost-competitive electrolysis plants for power-to-gas and especially as a means of storage of surplus energy.
- Demonstration of the PEM electrolyser for operation with grids sharing renewable power energy e.g. wind turbines in Emden, will also bring new knowledge that can exploited by the consortium.

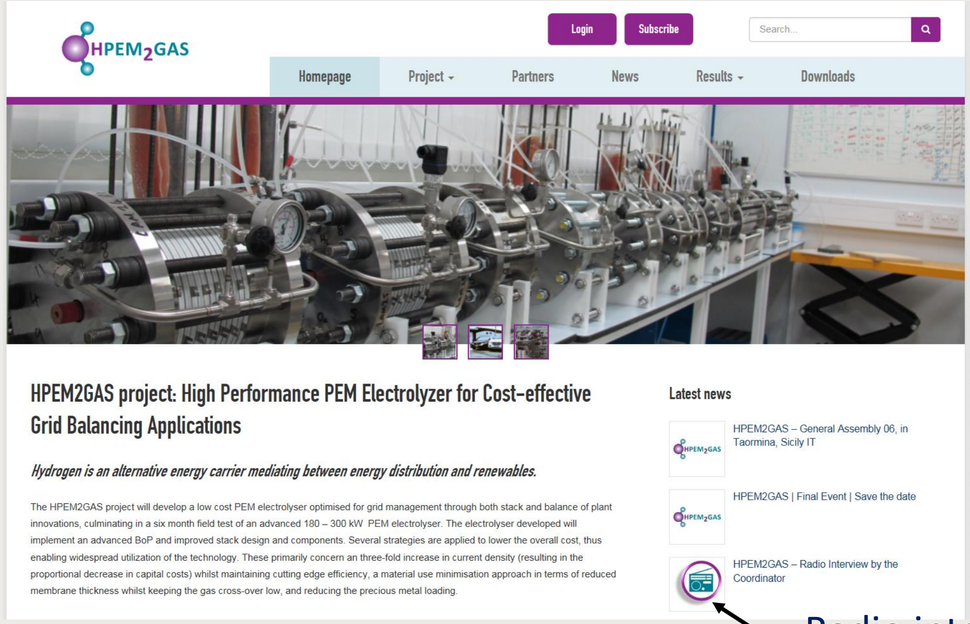
Impact

- Expected project impact:
  - sustainable hydrogen production which can meet an increasing share of the hydrogen demand for energy applications from carbon-free or lean energy sources.
  - to carry materials research, technology development and to reduce the total life cycle costs related to present PEM electrolysers.



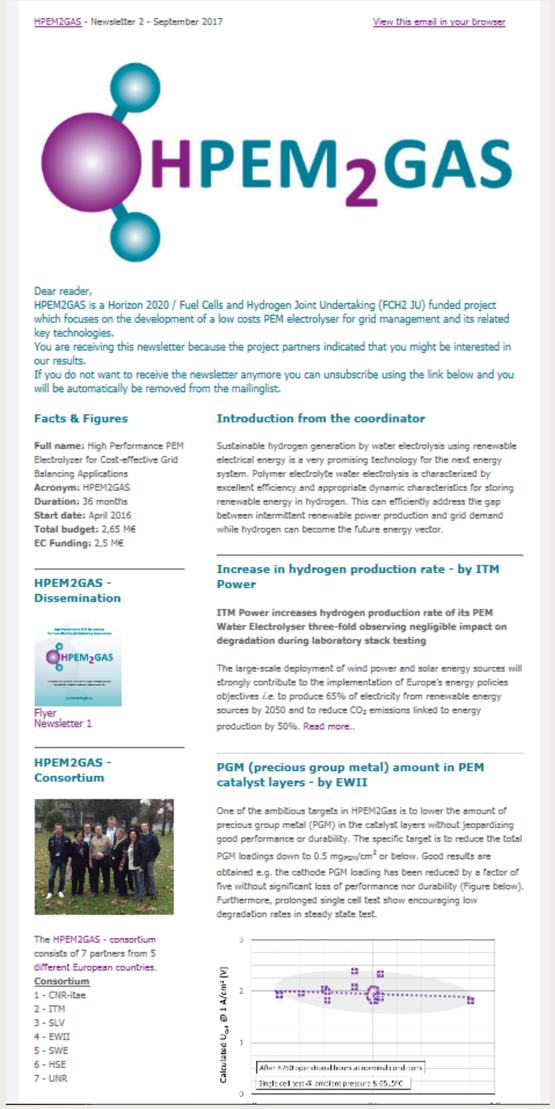
Communications Activities

www.hpem2gas.eu



Workshop in Emden (Germany)
12th February 2019

Newsletters



Brochure

Radio interview to a netwwork with national audience

Publication on a divulgative journal (planned)

Dissemination Activities

Conferences / workshops

- ❑ 20 Presentation at conferences
- ❑ 2 workshops
- ❑ 1 workshop organised in Emden

Publications in international peer-reviewed scientific Journals

- ❑ > 5 Publications

Public deliverables

- ❑ 4 Deliverables published in the project web-site:

http://hpem2gas.eu/

Publication Title	Journals / Year/ DOI	Main authors
Enhanced performance and durability of low catalyst loading PEM water electrolyser based on a short-side chain perfluorusulfonic ionomer	**Applied Energy** 192, 2017, 477-489 (DOI)	S. Siracusano, V. Baglio, N. Van Dijk, L. Merlo, A. S. Aricò
New insights into the stability of a high performance nanostructured catalyst for sustainable water electrolysis	**Nano Energy** 40, 2017, 618-632 (DOI)	S. Siracusano; N. Hodnik; P. Jovanovic; F.Ruiz- Zepeda; M. Šala ; V. Baglio; A. S. Aricò
The Influence of Iridium Chemical Oxidation State on the Performance and Durability of Oxygen Evolution Catalysts in PEM Electrolysis	**Journal of Power Sources** 366, 31 2017, 105–114 (DOI)	S. Siracusano; V. Baglio; S. A. Grigoriev; L. Merlo; V. N. Fateev; A. S. Arico

SYNERGIES WITH OTHER PROJECTS AND PROGRAMMES

Interactions with projects funded under the FCH JU EU program:

- **ELY4OFF: PEM electrolyser for operation with off grid renewable installations**

Presentation and discussion of project results in teleconferences, synergy for off-grid and grid-connected electrolysis systems; presence of common partners

- **QualyGrids - Standardized qualifying tests of electrolysers for grid services:**

Joint discussion of testing protocols in a workshop in Lucerne 2017 in the presence of JRC; presence of common partners

- **Neptune: Next Generation PEM Electrolysers under New Extremes**

Sharing results with respect to component testing and operating strategies; presence of common partners

Thank you for you kind attention!

Acknowledgement

Financial support from the FCH JU through the HPEM2GAS project.
This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 700008.
This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme and Hydrogen Europe and Hydrogen Europe