FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

HPEM2GAS –

High Performance PEM Electrolyzer for Cost-effective Grid Balancing Applications

HPEM$_2$GAS

Antonino S. Aricò

CONSIGLIO NAZIONALE DELLE RICERCHE – CNR-ITAE

http://hpem2gas.eu/

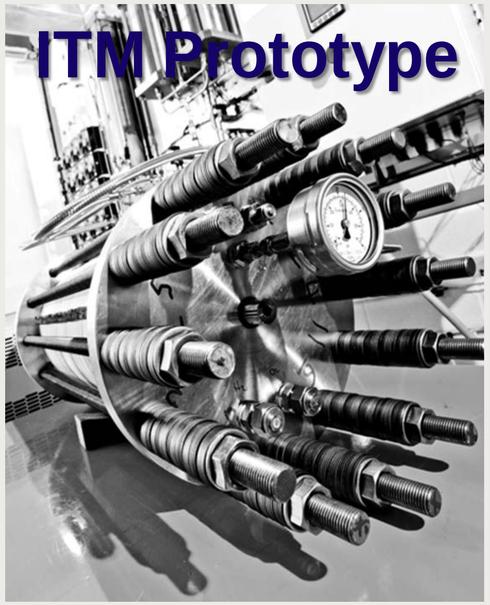
arico@itae.cnr.it

Emden, 12 February 2019

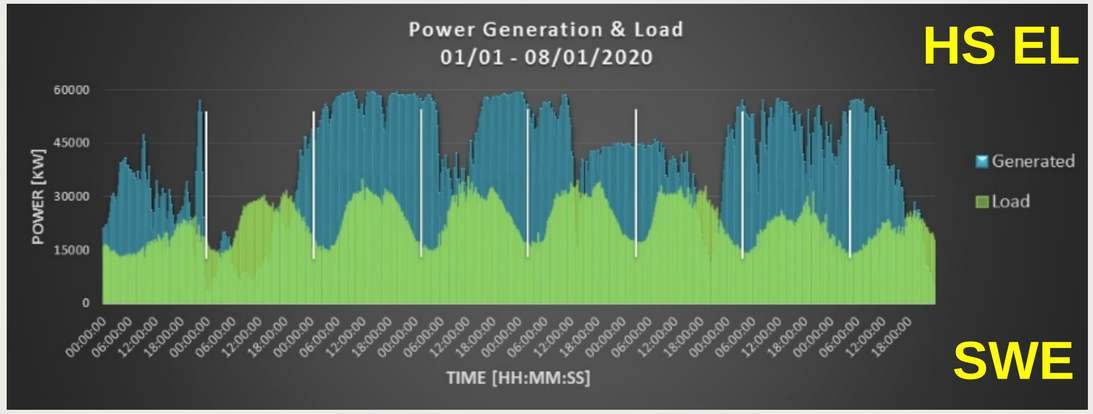
CONTEXT

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 and R&D NEEDS

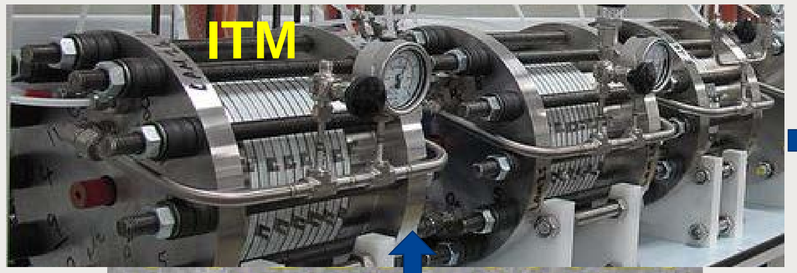
HPEM2GAS's ambition is to realise breakthroughs in PEM water electrolysis for Distributed Hydrogen Production

➢ **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

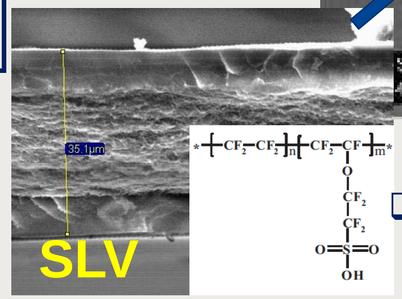
Parameter	HPEM2GAS	SoA
Current density A cm^{-2} @ 1.8 V	3	2
Energy consumption kWh/kg H_2	48 (54)	57
Degradation %/1000hrs	0.25 (0.2)	0.25
PGM loading mg/W	0.07 (0.3)	0.5-1.5
CAPEX € /(kg H_2/day)	< 2,250	< 2,900

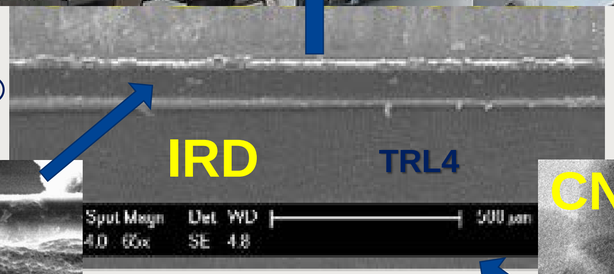
❑ Improved stack design



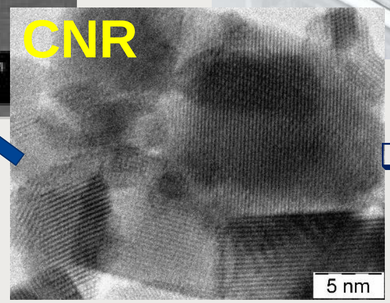
❑ Advanced BoP and safety integrated system

❑SSC Aquivion® membranes





❑ Enhanced MEAs



❑ Nanostructured electro-catalysts

PROJECT PROGRESS/ACTIONS – Stack Efficiency

Achievement to-date
% stage of implement.

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

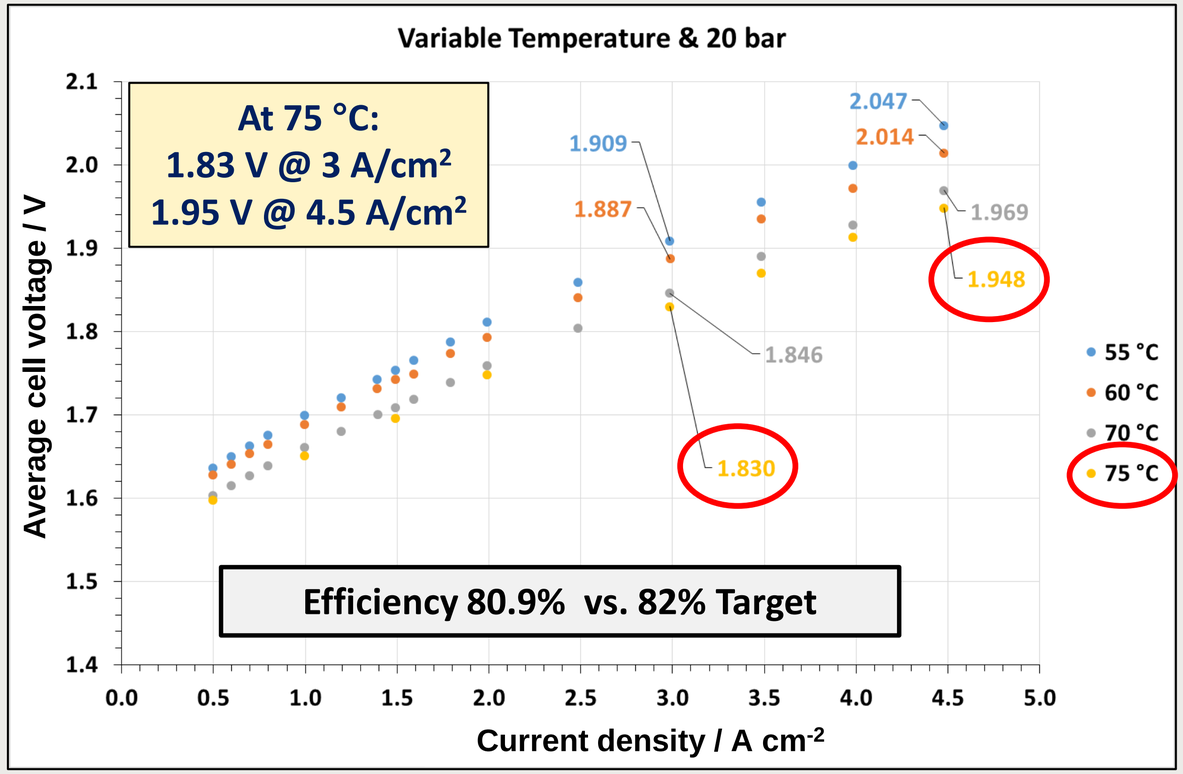
Efficiency: 81% at 3 A cm^{-2} and 75 °C

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

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

Achievement to-date
% stage of implement.

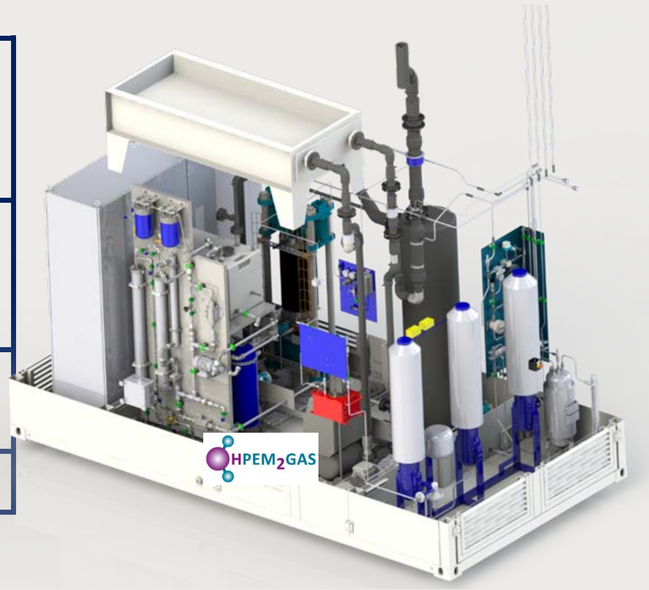
PEM electrolysis system

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	HPEM2GASS High current density	HPEM2GASS 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.

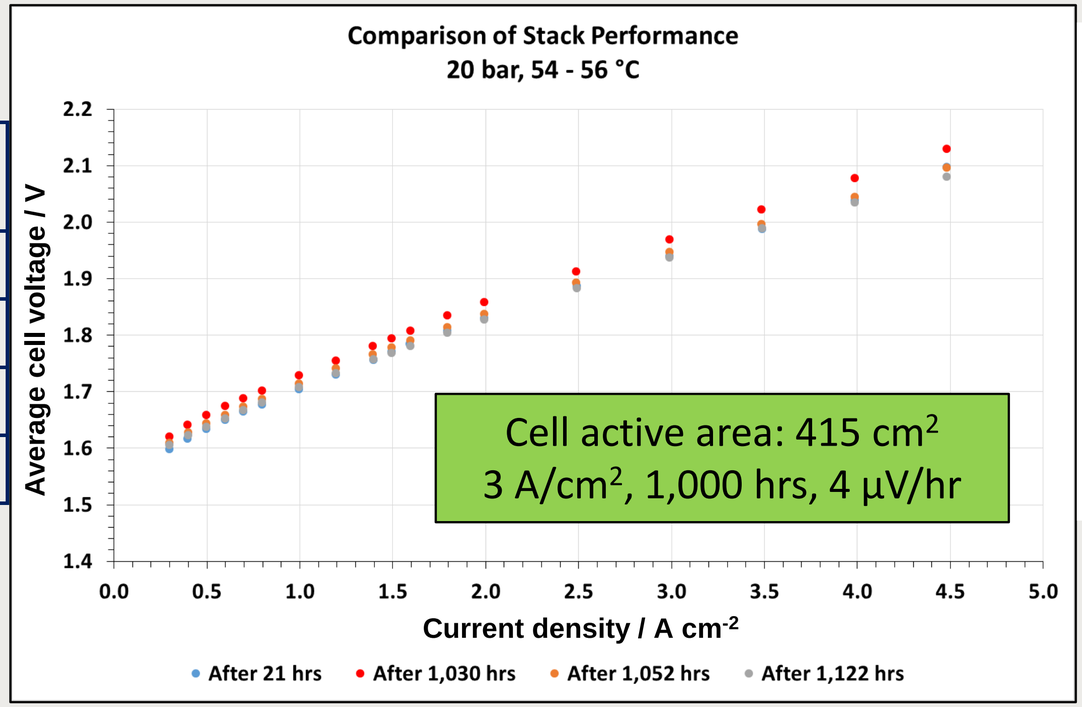
PROJECT START VALUE
0.55 %/1000 hrs
@ 0.83 A cm^{-2}

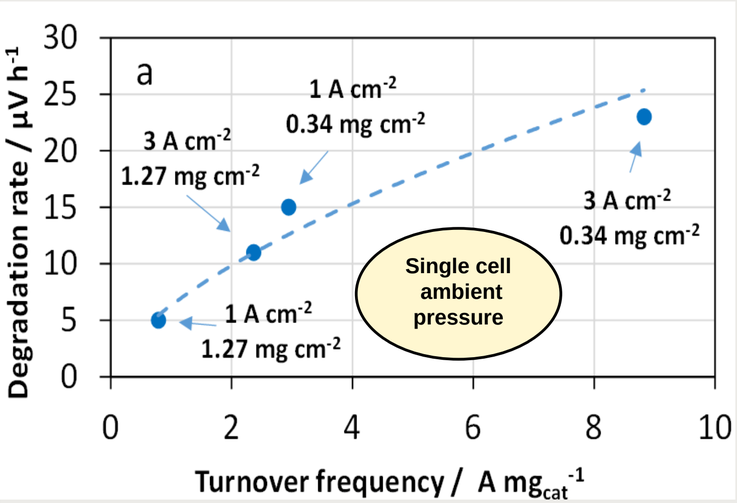
25% 50% 75%

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

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

Achievement to-date
% stage of implement.

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

25% 50% 75%

TARGET
Operating pressure up to 80 bar

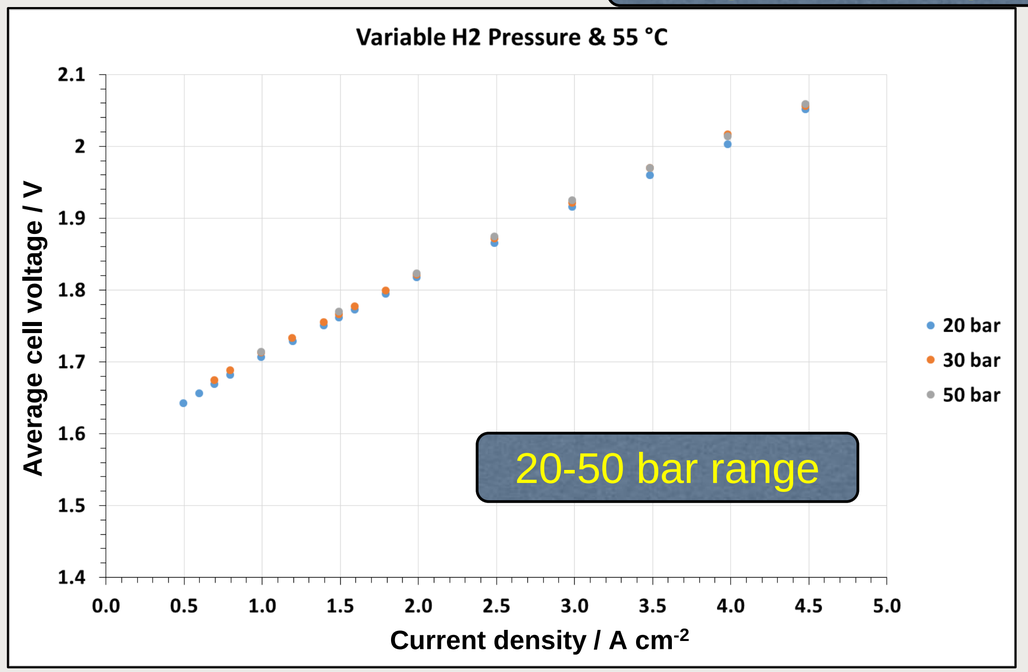
90 µm thick Aquivion® membranes

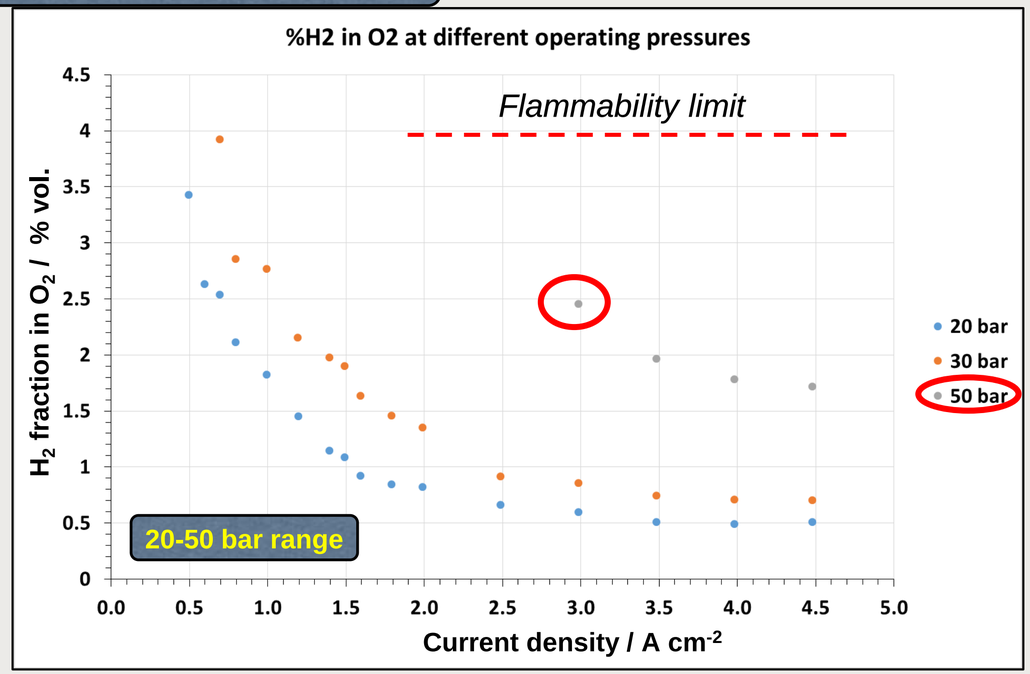
PEM electrolysis short stack

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)





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**

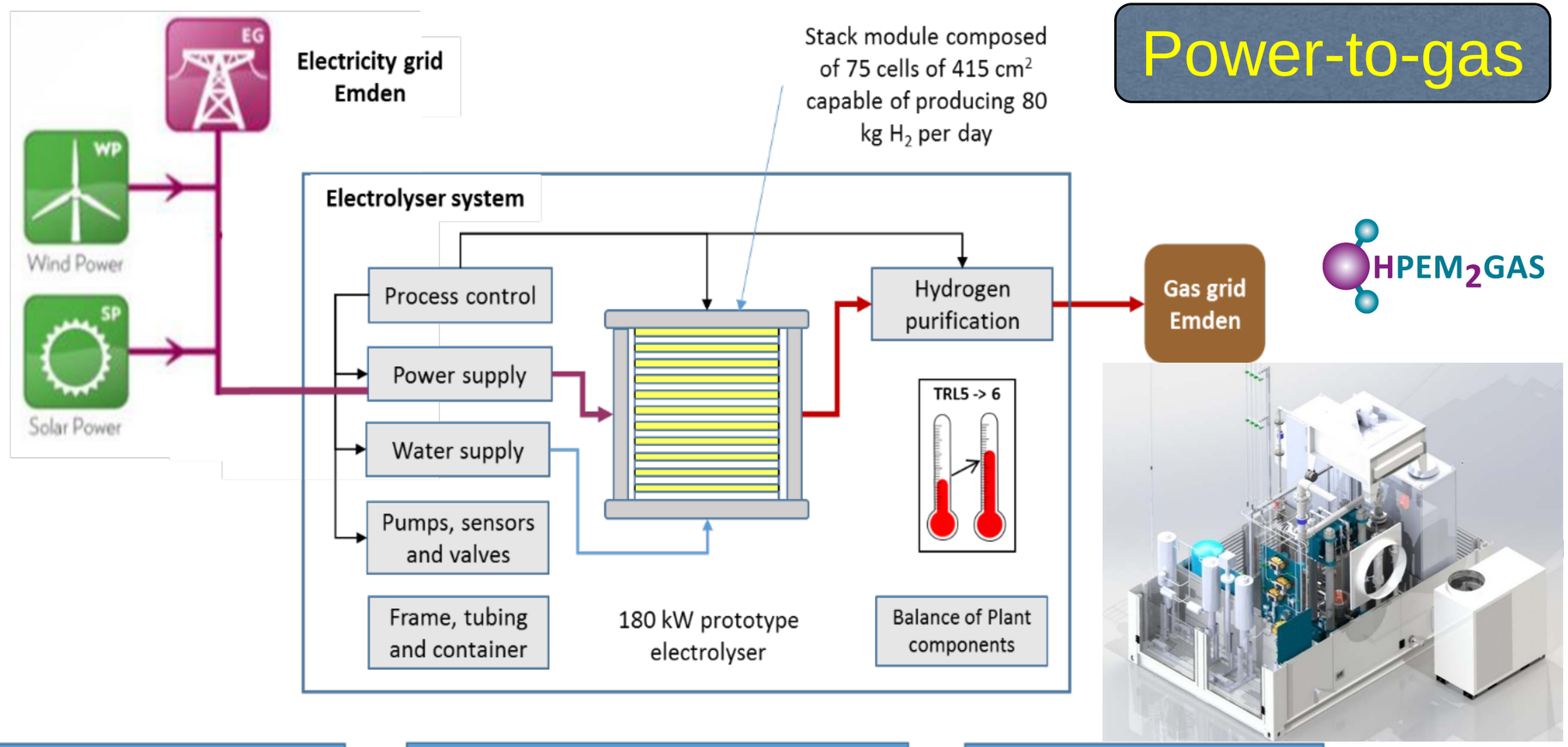
✓ **Need for utilizing excess wind power;**

✓ **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

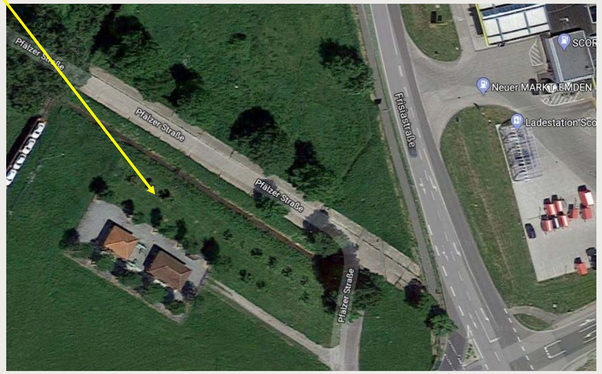
Power-to-gas



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 – 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

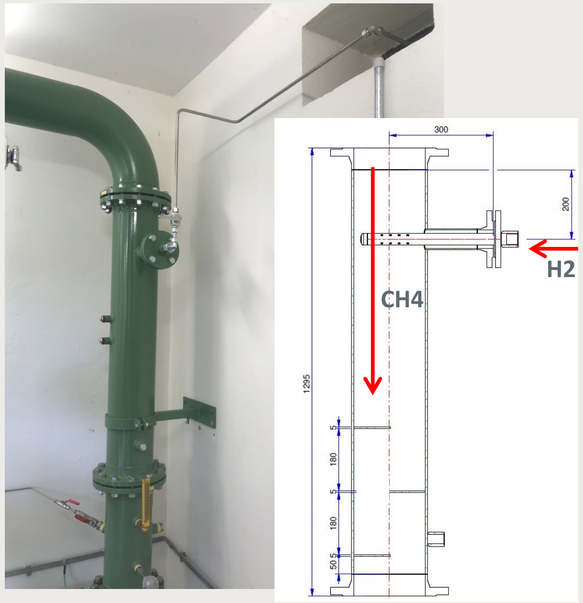
Control station

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

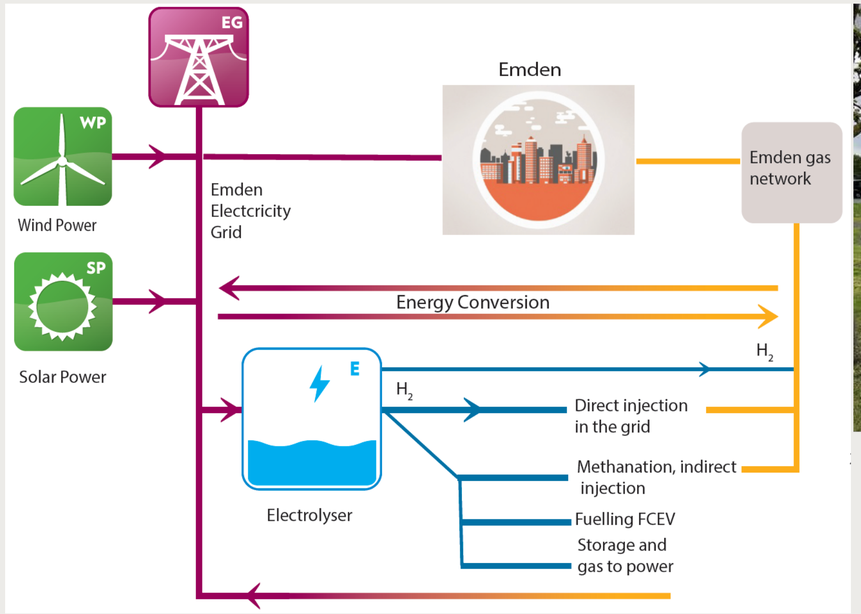
Mixer has built-in lamellas, so the gas mixture flow is turbulent
The gas grid is operated at 8.5 bar, the hydrogen is fed in with a slight overpressure of 10 bar



PROJECT PROGRESS/ACTIONS –

Power to gas field testing activitiesin Emden

- **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.**



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