



FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

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



Antonino S. Aricò

**CONSIGLIO NAZIONALE DELLE
RICERCHE – CNR-ITAE**

<http://hpem2gas.eu/>

arico@itae.cnr.it

Programme Review Days 2018

Brussels, 14-15 November 2018

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**
- **% stage of implementation 01/11/2017: 86%**
- **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.; EWII FUEL CELLS; STADTWERKE EMDEN GmBH; HOCHSCHULE EMDEN/LEER; UNIRESEARCH BV**

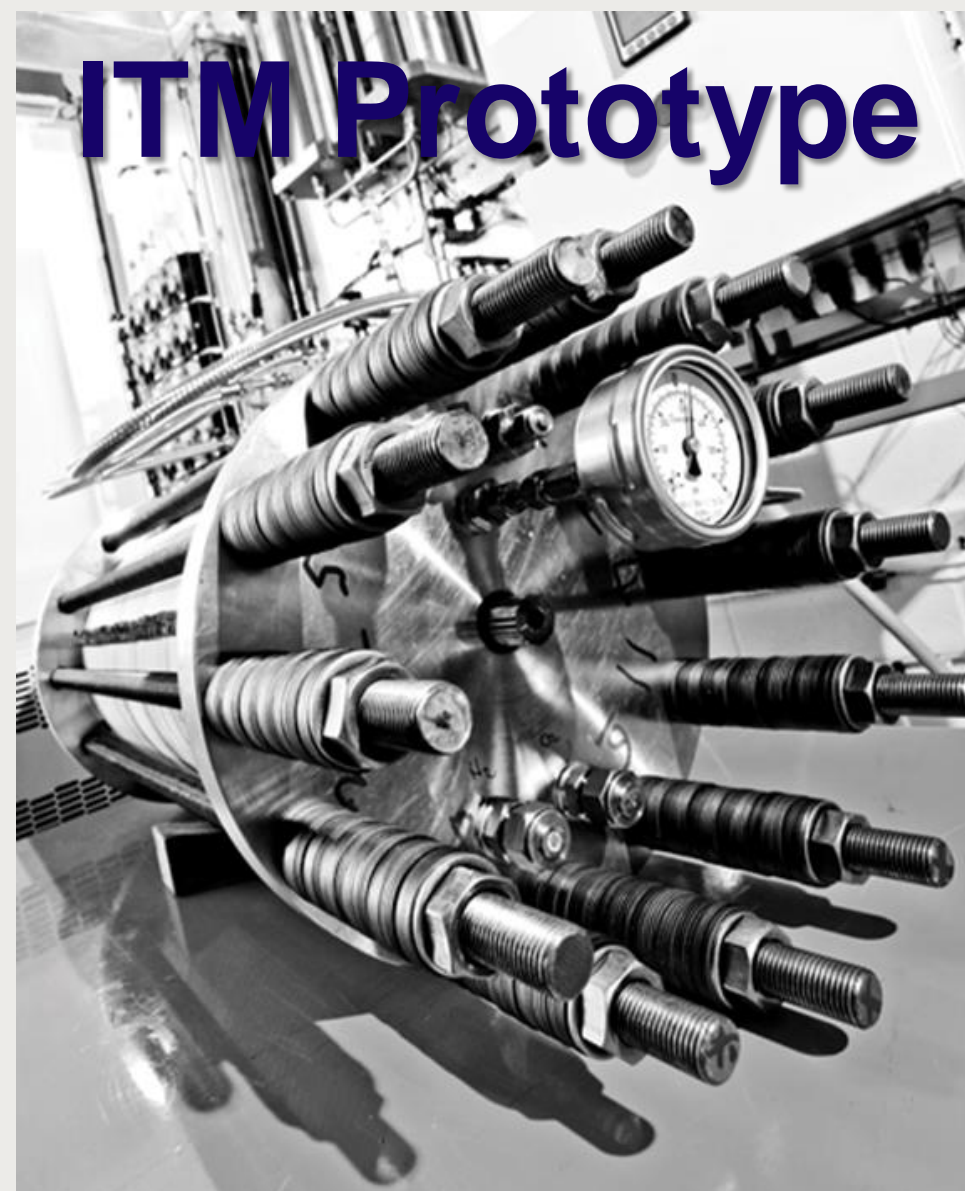


CONTEXT

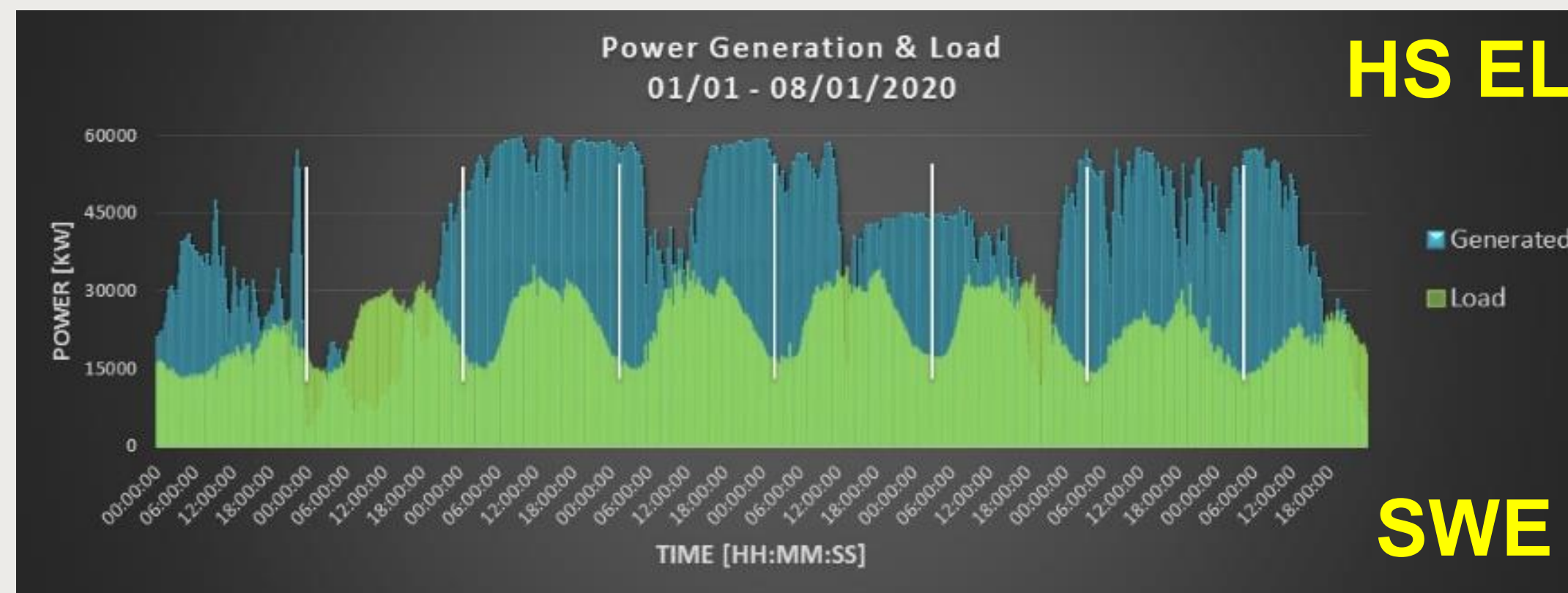


HPEM2GAS – High Performance PEM Electrolyzer for Cost-effective Grid Balancing Applications

- As more renewables are being integrated to the grid, there is a need to develop high performance electrolyzers to provide superior grid-balancing services and to produce “green” hydrogen for fuel cell vehicles and other applications.
- 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 H₂), 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 electrolyzers 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

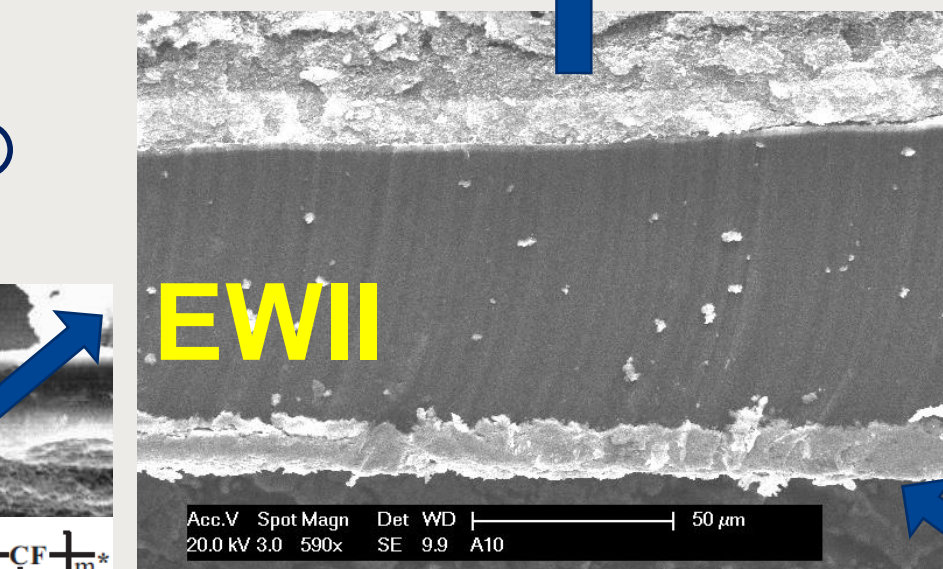
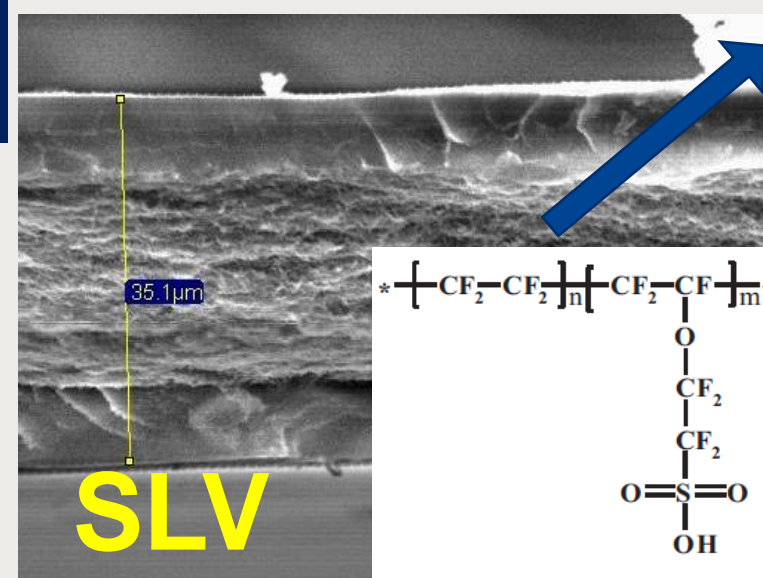
❑ Improved stack design



❑ Advanced BoP and safety integrated system

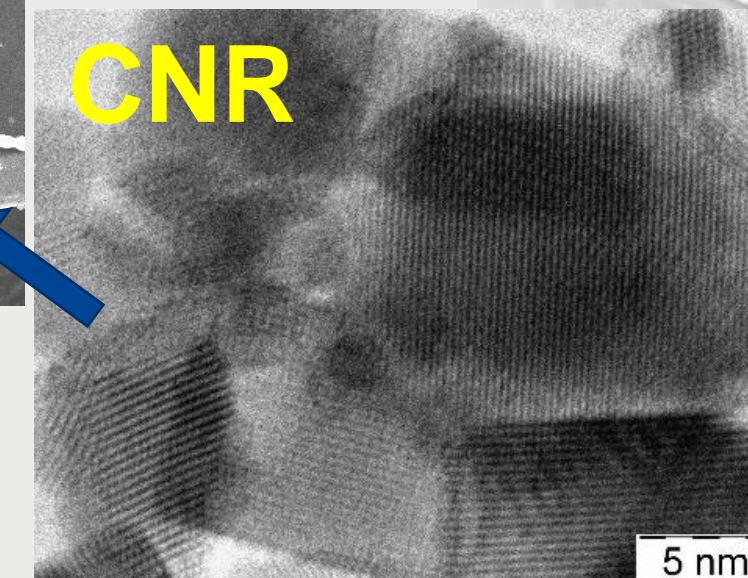


❑ SSC Aquivion® membranes



❑ Enhanced MEAs

TRL4



❑ 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.

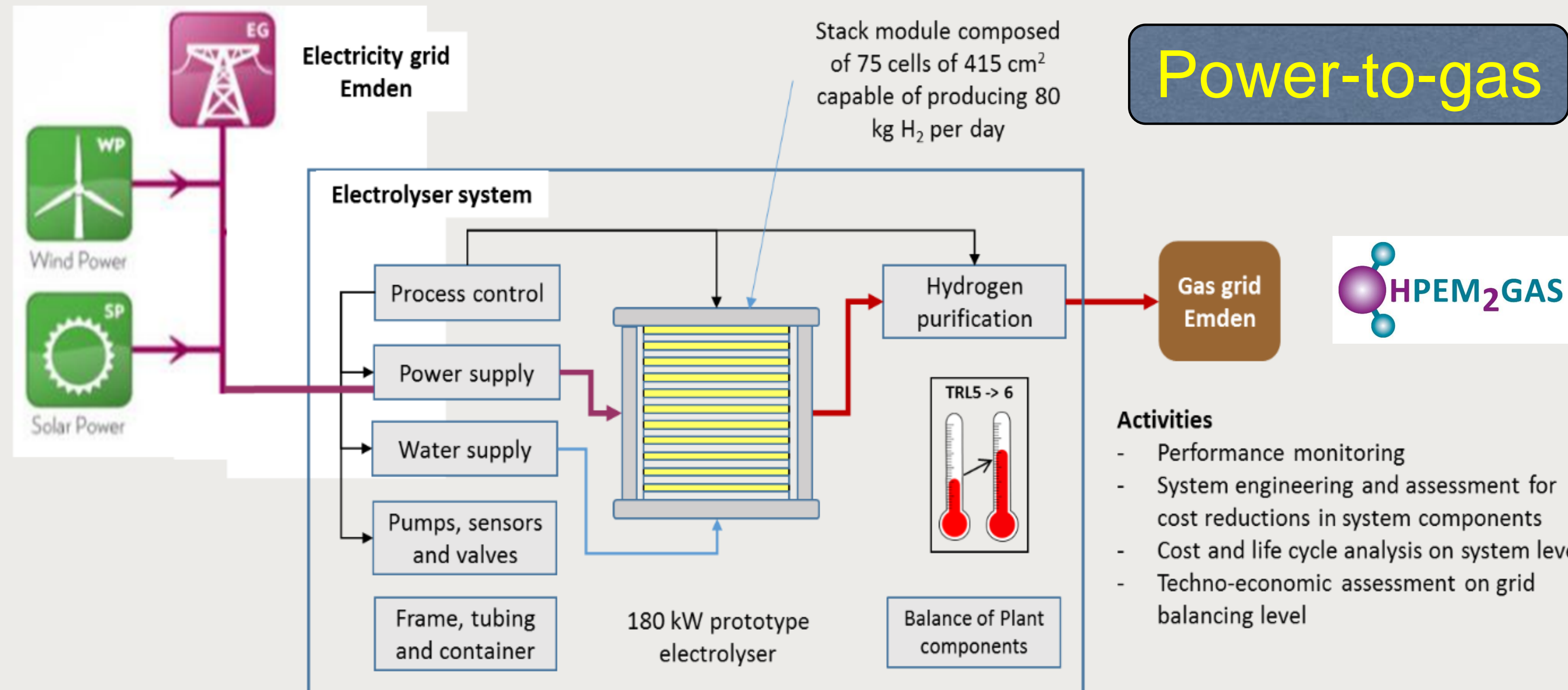
❑ Two wind farms have been built in the city of Emden which provides 117% (240 MWh/y) of the electric energy for homes

✓ Need for utilizing excess wind power;

✓ Need to address the congestion of transmission;

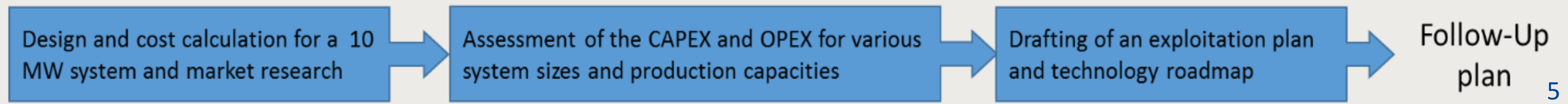
✓ Need to stabilize the electricity grid from frequent fluctuations;

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



Power-to-gas

- 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



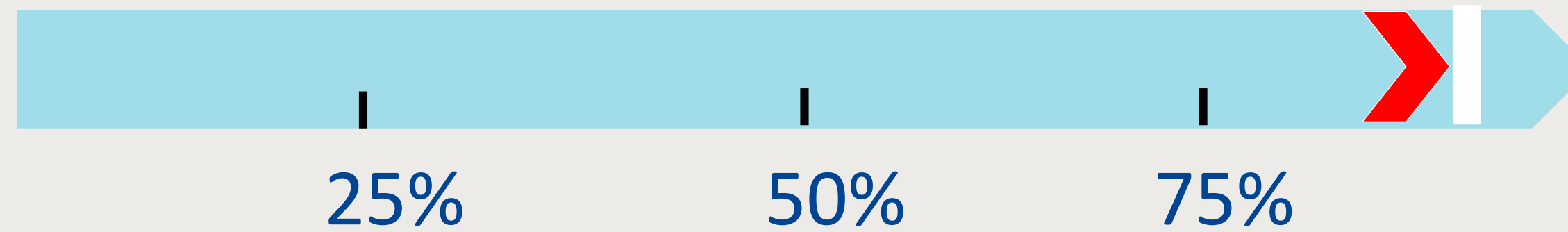
PROJECT PROGRESS/ACTIONS – Stack Efficiency



Achievement to-date
% stage of implement.

PROJECT START
VALUE
Eff. 77 %
@ 0.83 A cm⁻²

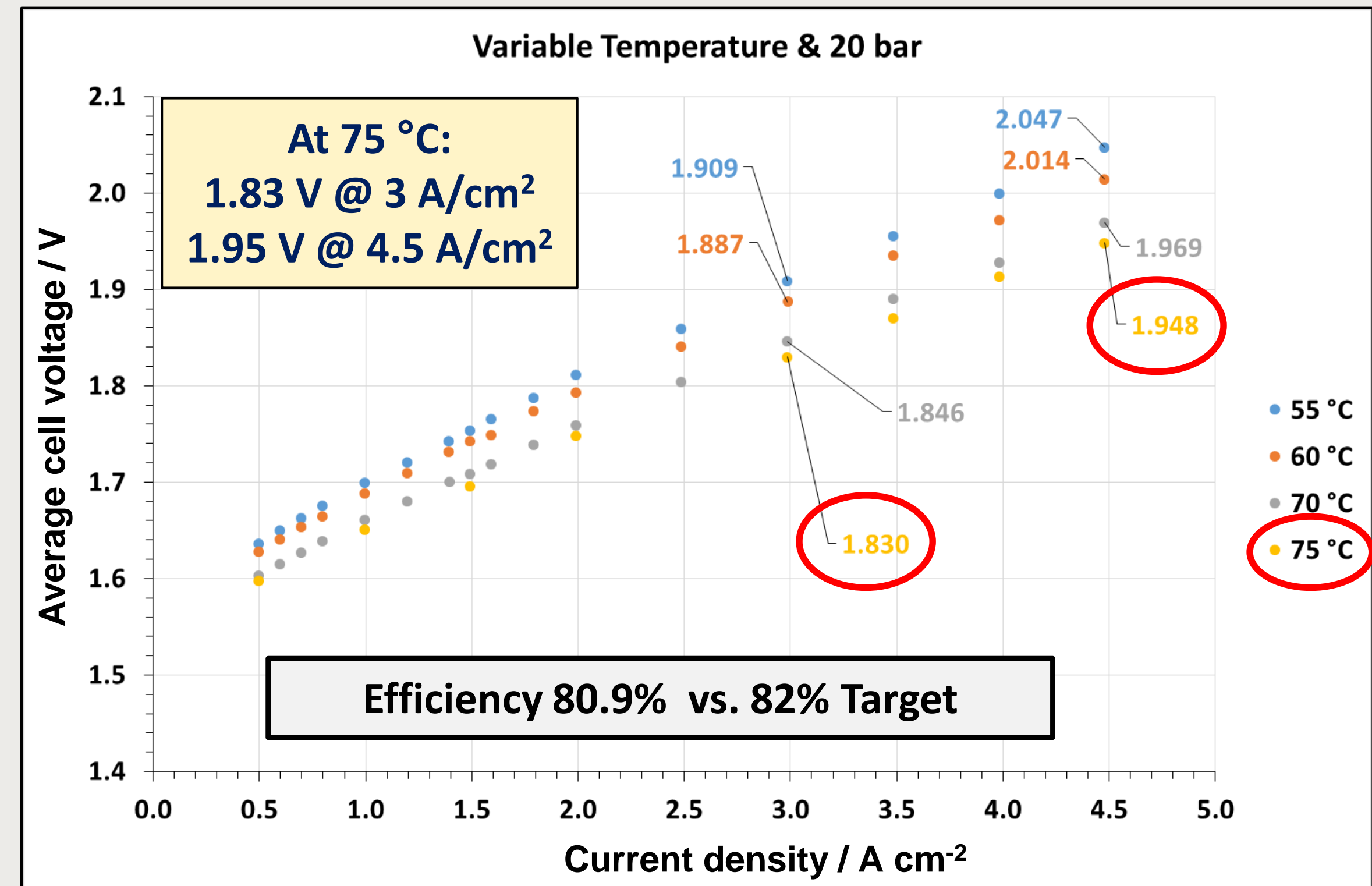
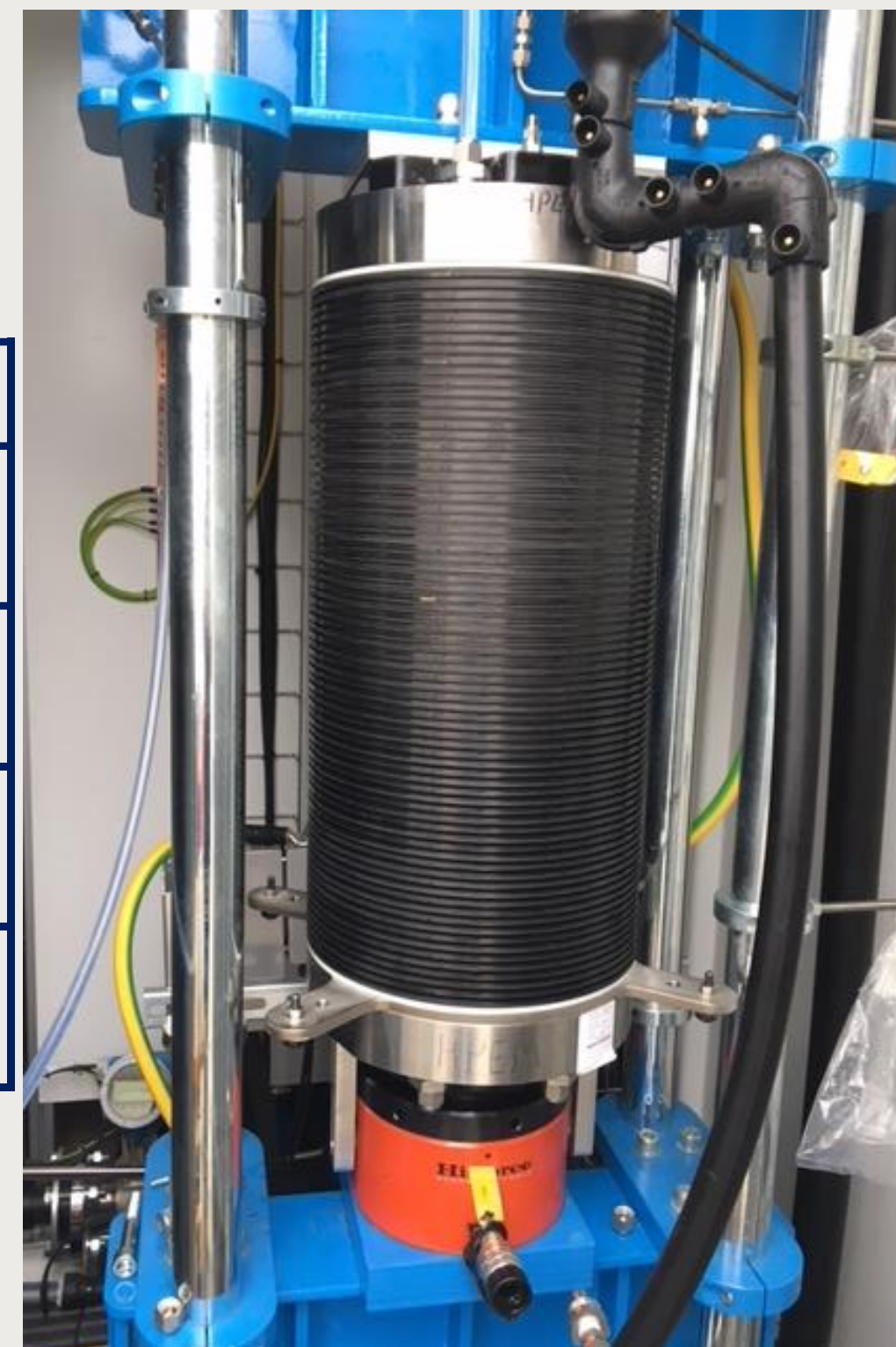
Efficiency: 81% at 3 A cm⁻² and 75 °C



**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	0.2	0.5
Temperature °C	75	-



PROJECT PROGRESS/ACTIONS – System Energy Consumption

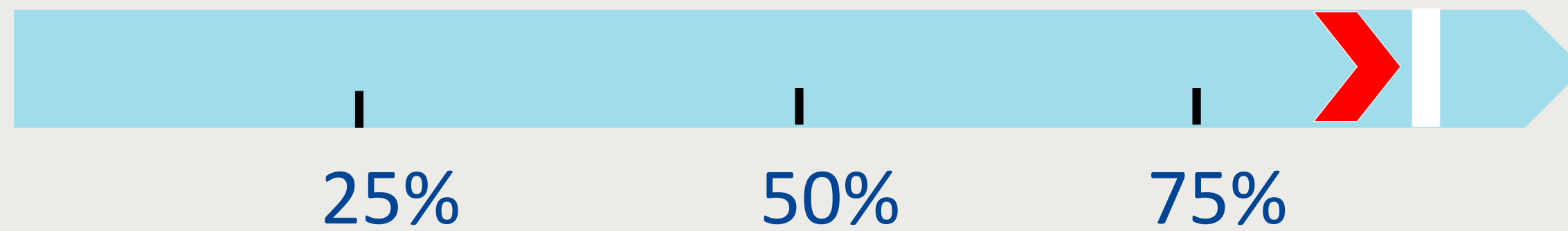


Energy consumption: 54.2 kWh/kg H₂ at 3 A cm⁻² and 55 °C

Achievement to-date
% stage of implement.

PEM electrolysis system

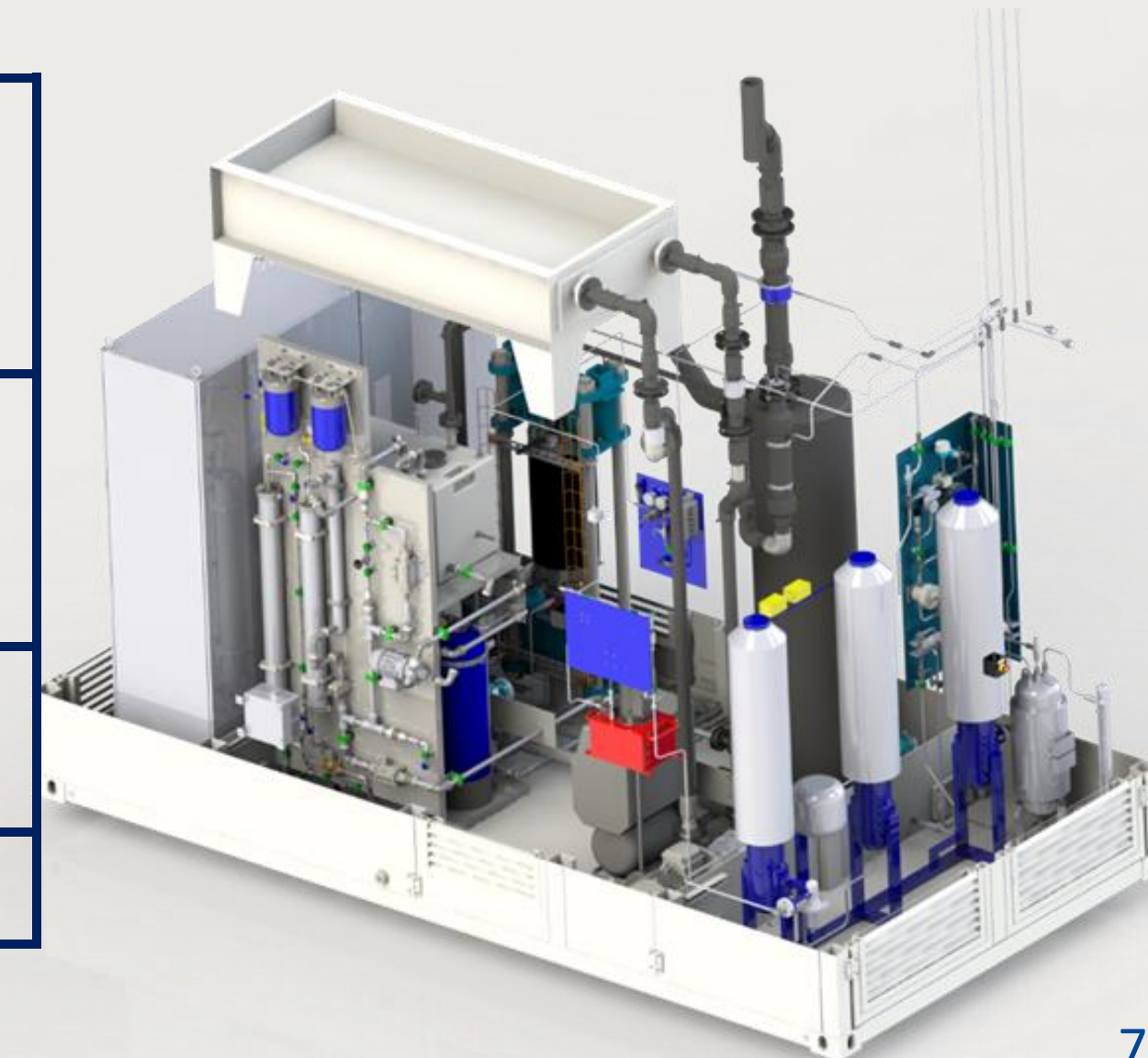
PROJECT START
VALUE
Energy
Consumption
53.2 kWh/kg H₂
@ 0.83 A cm⁻²



TARGET
SYSTEM ENERGY
CONSUMPTION
48 kWh/kg H₂



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	-	-	-

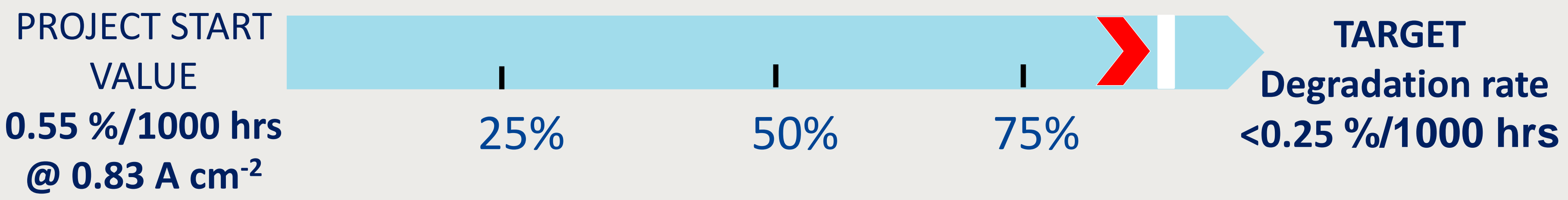


PROJECT PROGRESS/ACTIONS – Stack degradation rate



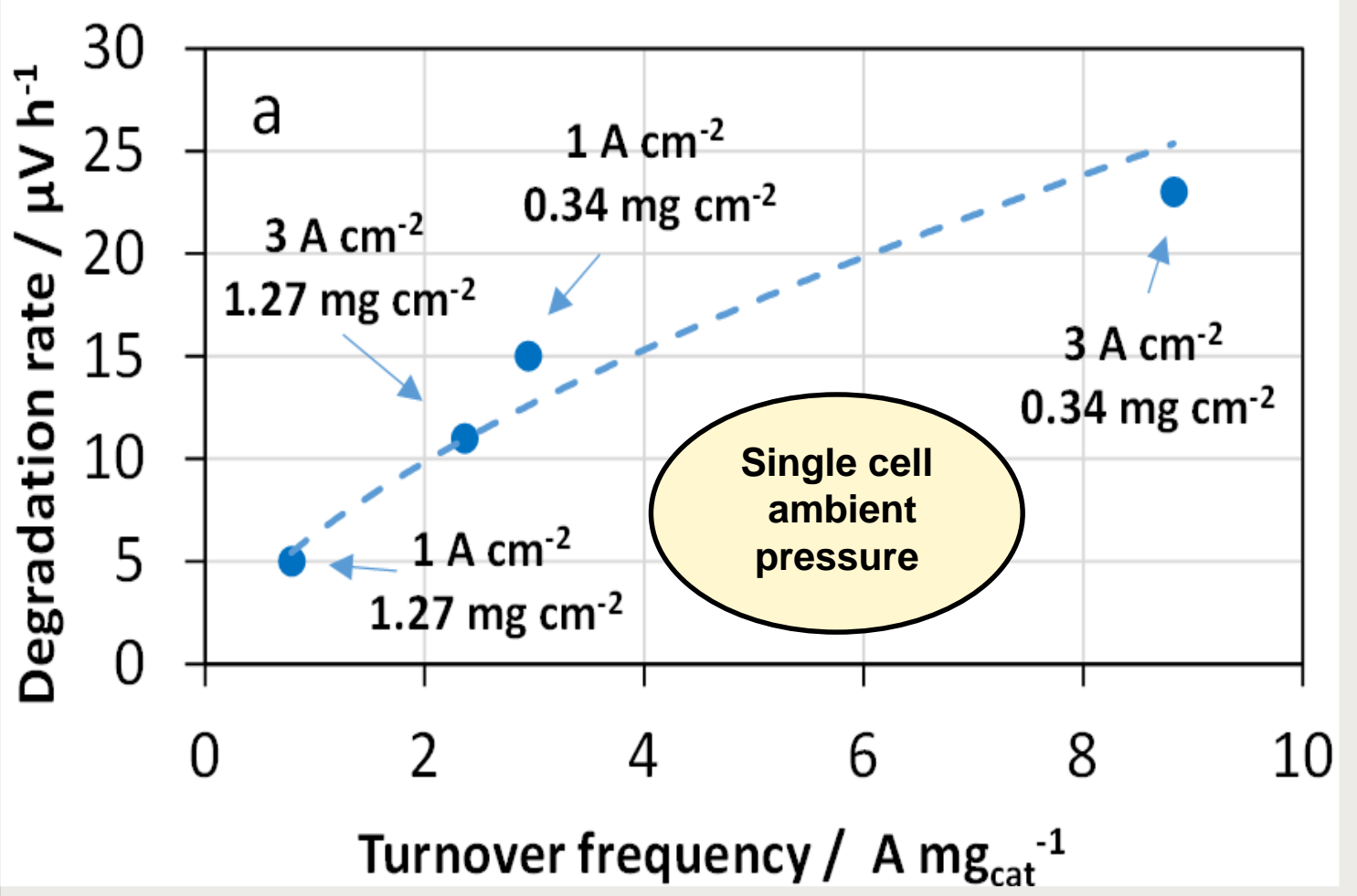
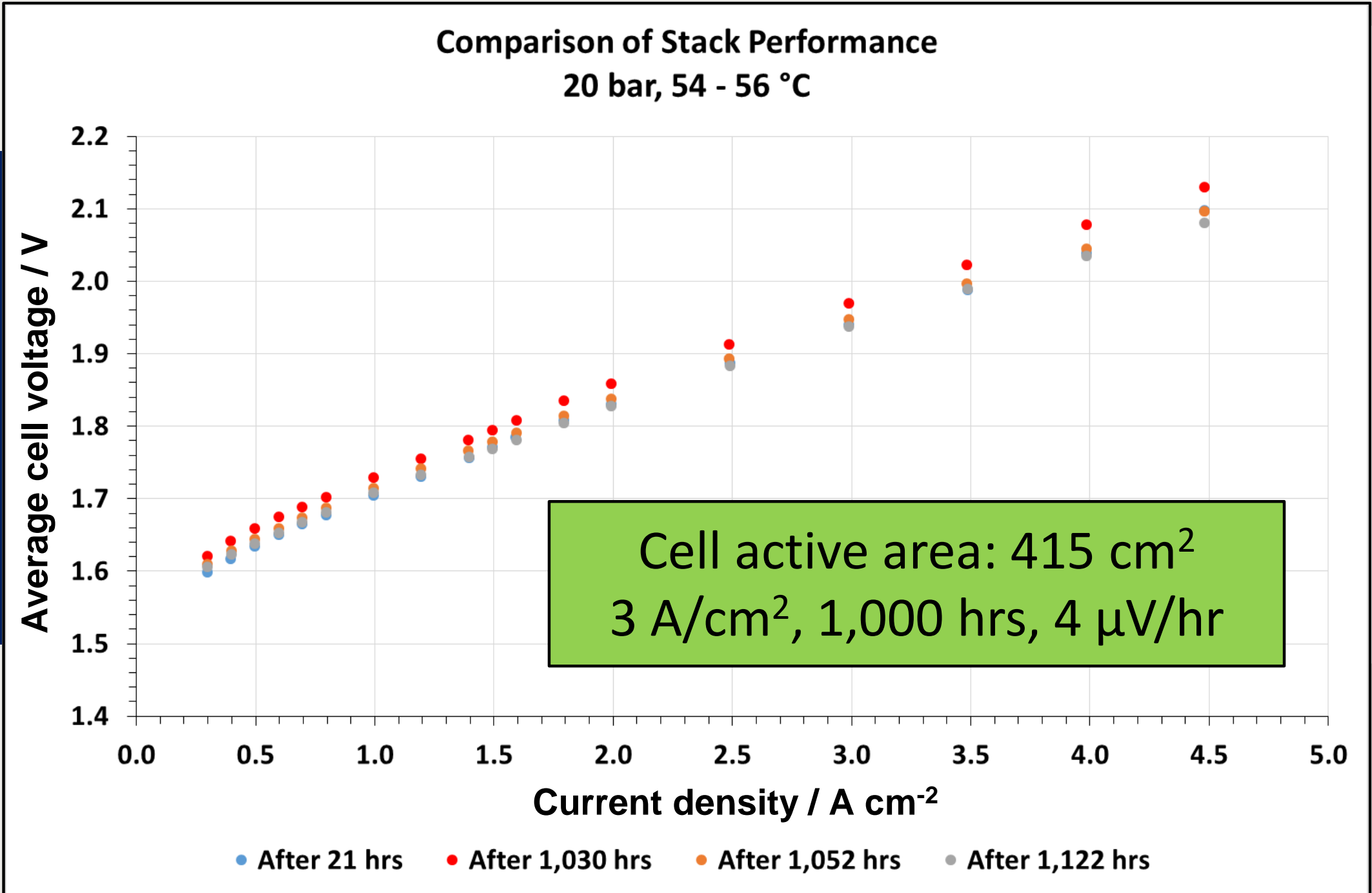
Degradation rate: 0.2 %/1000 hrs at 3 A cm⁻² and 55 °C

Achievement to-date
% stage of implement.



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

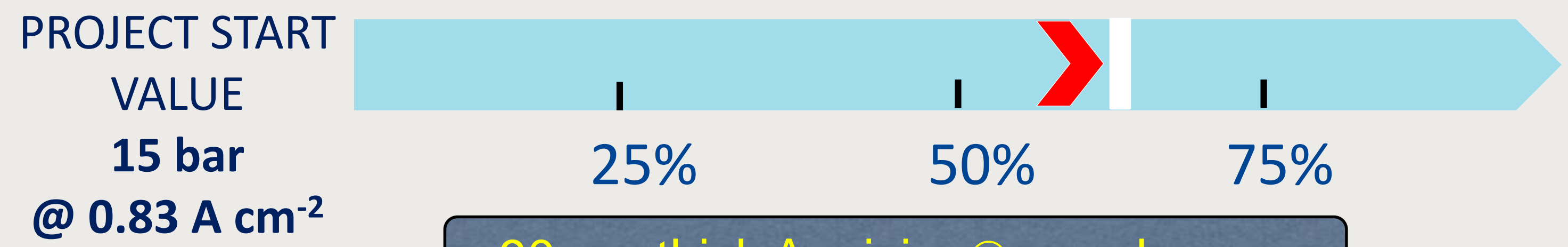


PROJECT PROGRESS/ACTIONS – Operating pressure



Max. operating pressure 50 bar at 3 A cm⁻² and 55 °C

Achievement to-date
% stage of implement.



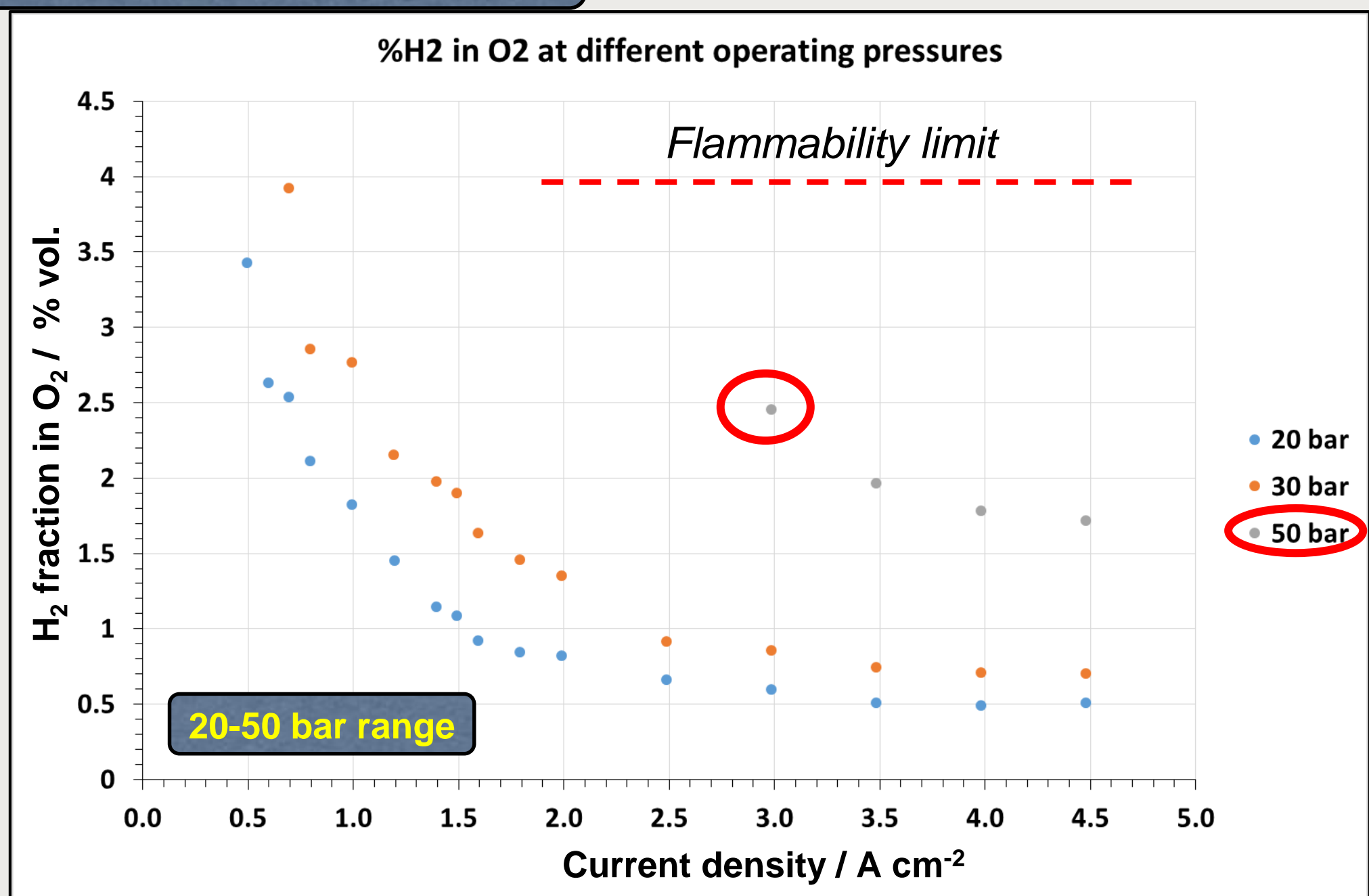
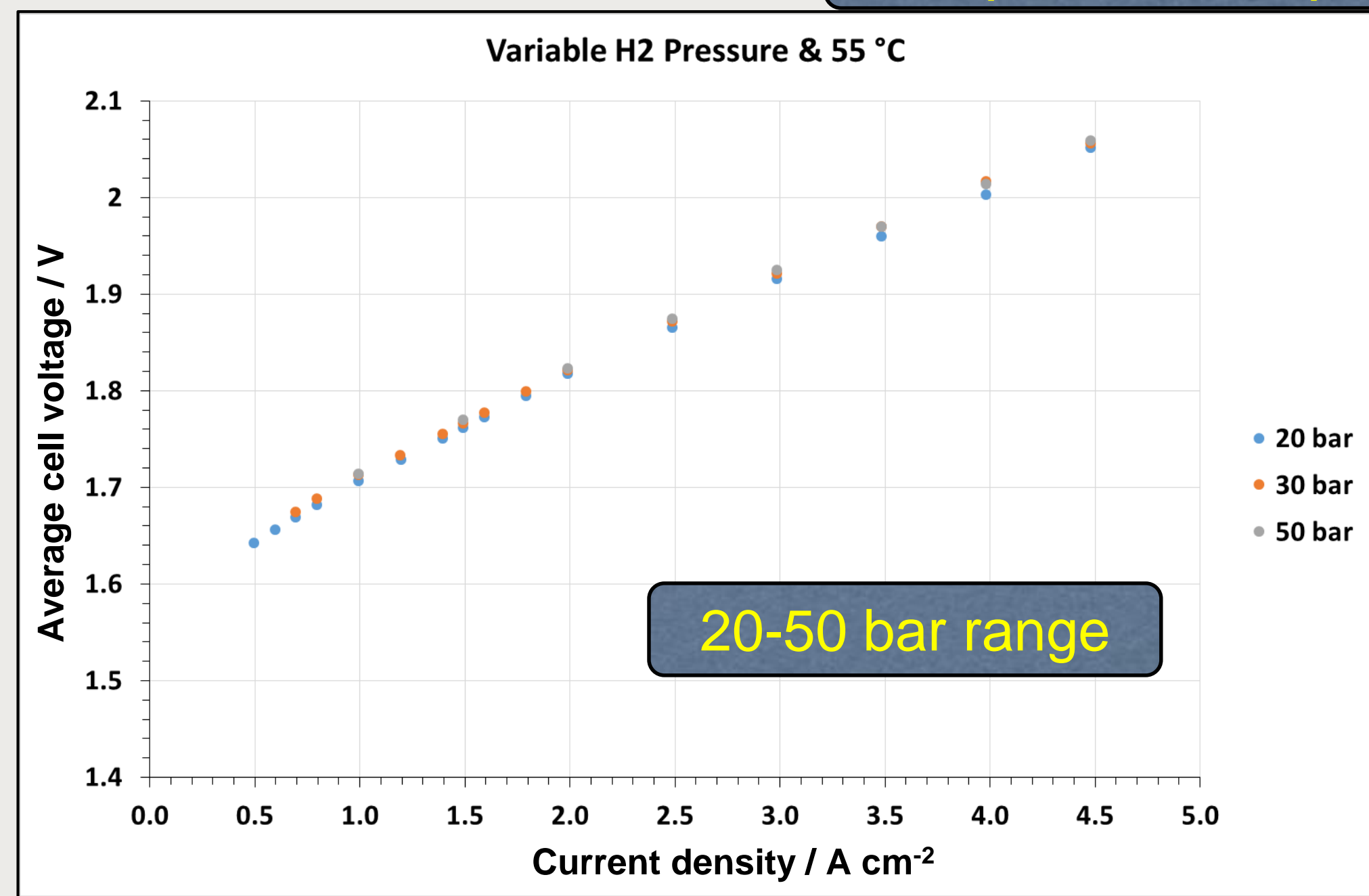
TARGET
Operating pressure up to 80 bar

90 μm thick Aquivion® membranes

PEM electrolysis short stack

Gas cross-over
2.5% H₂ in O₂ @ 3 A/cm² observed at 50 bar

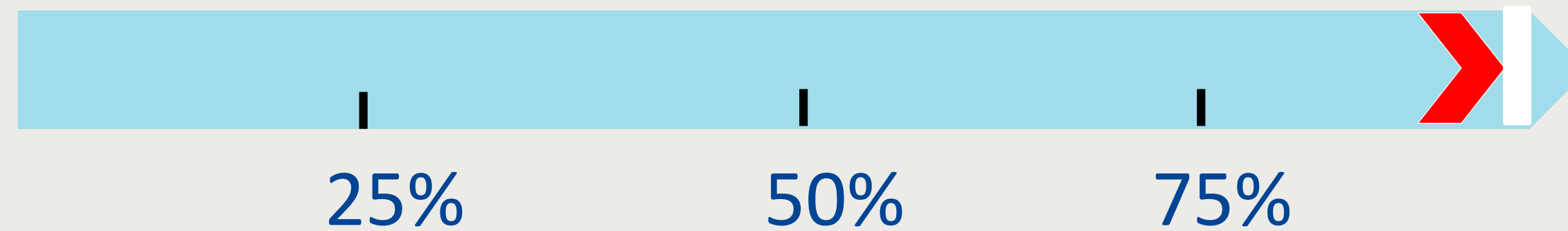
New strategies:
Recombination catalyst
(not yet implemented at stack level)



PROJECT PROGRESS/ACTIONS – Dynamic behaviour



7500 cycles with variable load (from 0.15 to 4.5 A cm⁻²)

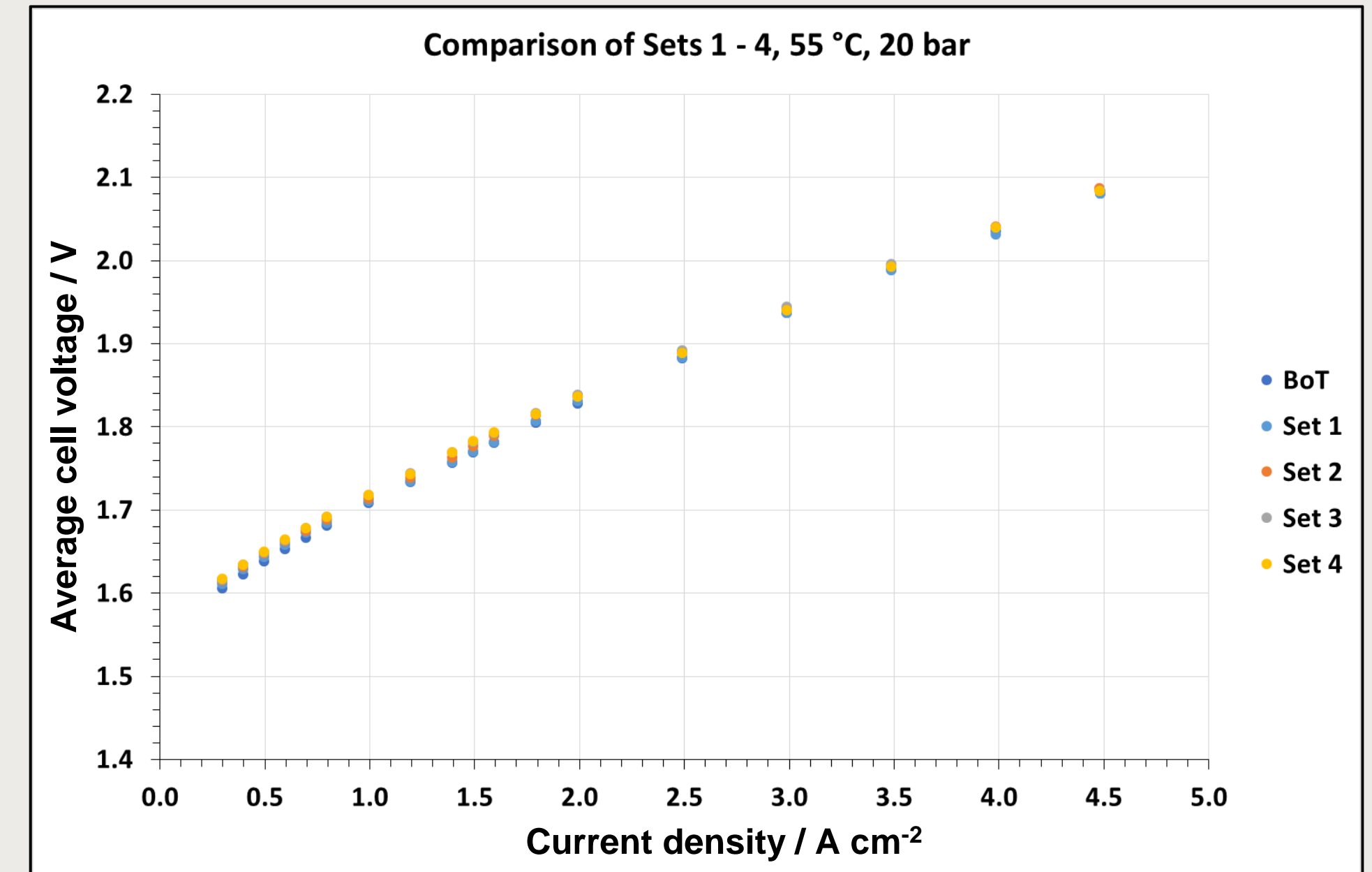
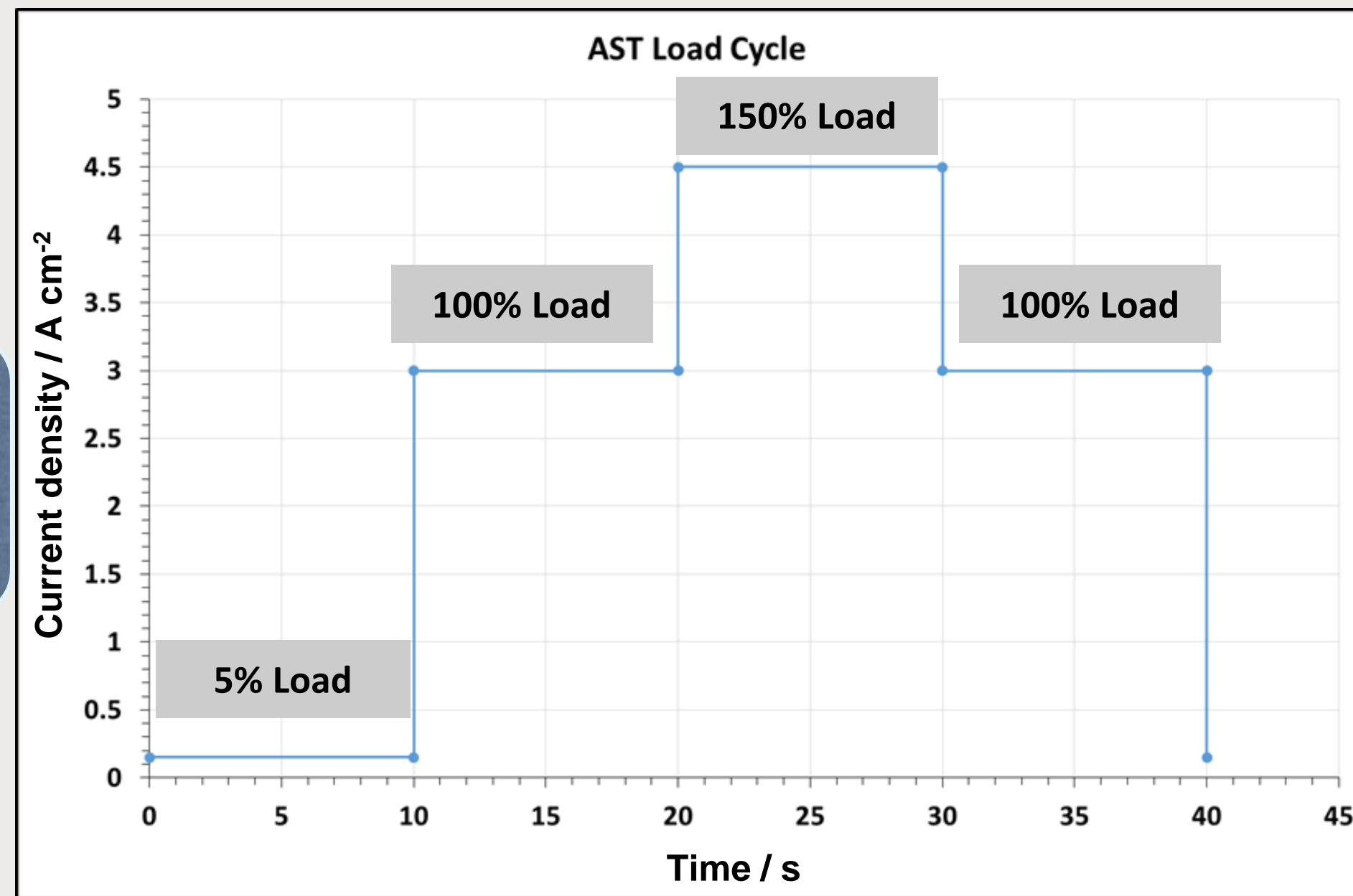


TARGET

Ramp rates of up to 100% of nominal load per second and a load range 5%-160%

Achievement to-date
% stage of implement.

No relevant performance degradation during cycled operation

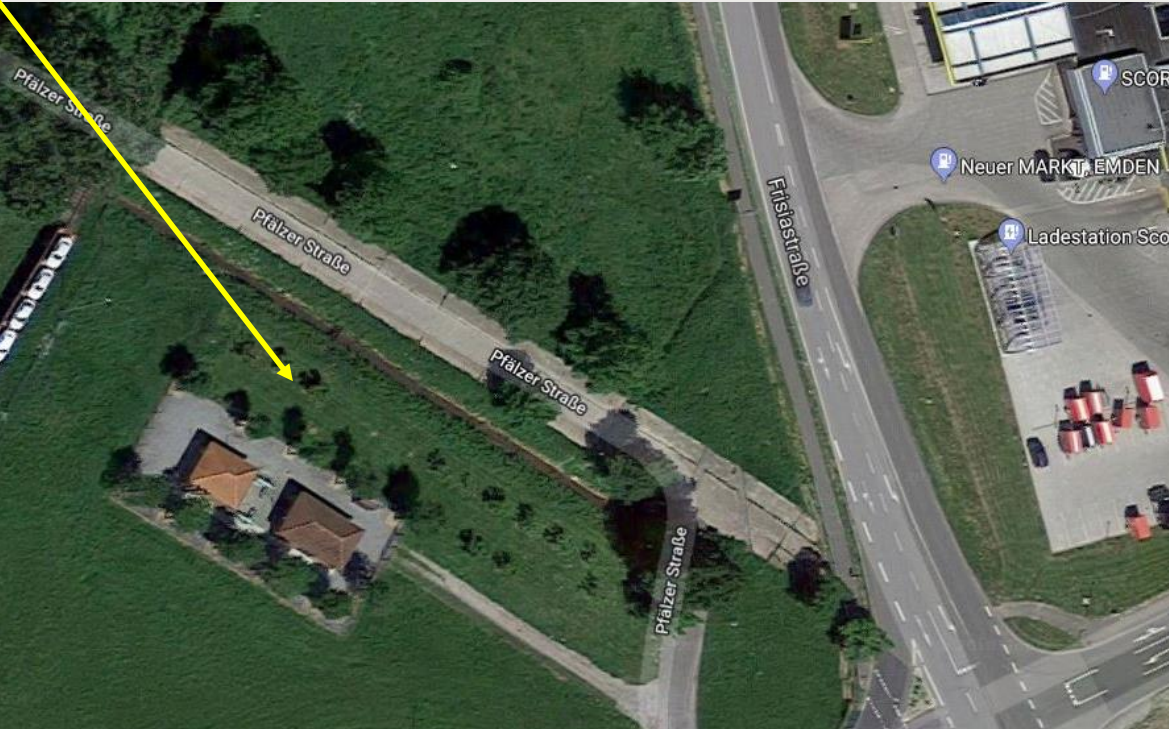


Dynamic response: Short Stack Testing at Full-scale (415 cm² active area)
20 bar, ~55 °C, 4 sets of cycles, total of 7500 cycles; Sets 1 & 2: 1530 cycles, Sets 3 & 4: 2220 cycles

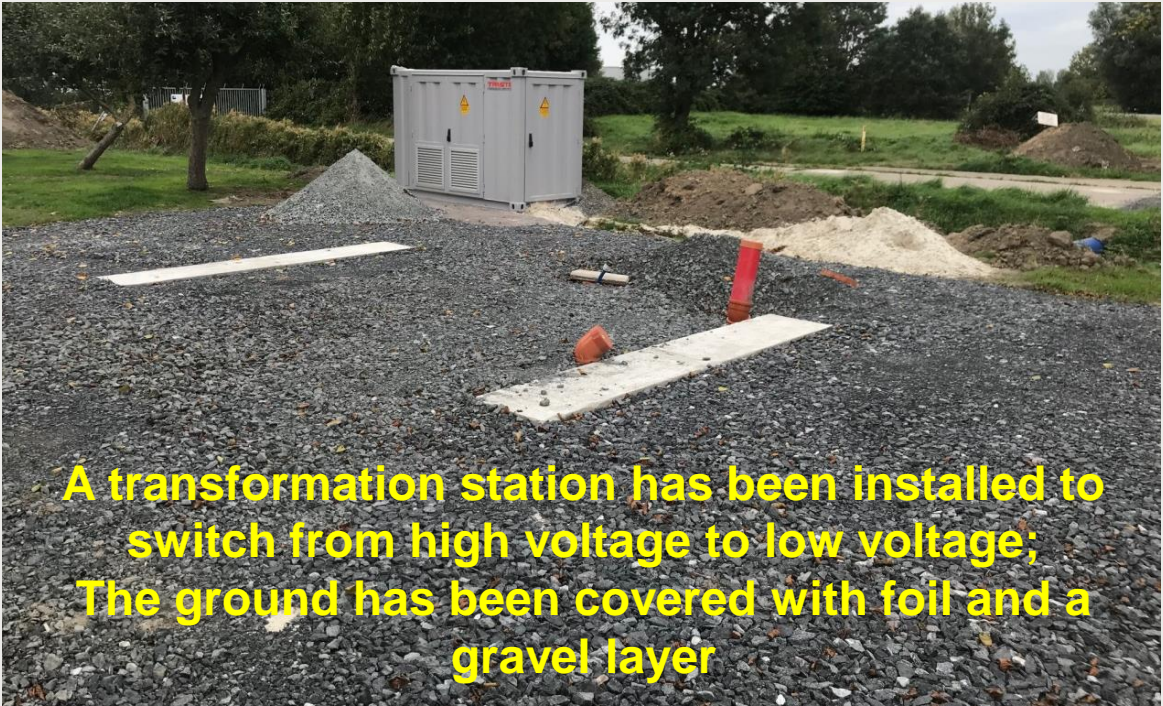
PROJECT PROGRESS/ACTIONS – Setting-up field testing site



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



Gas transfer station

Control station



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

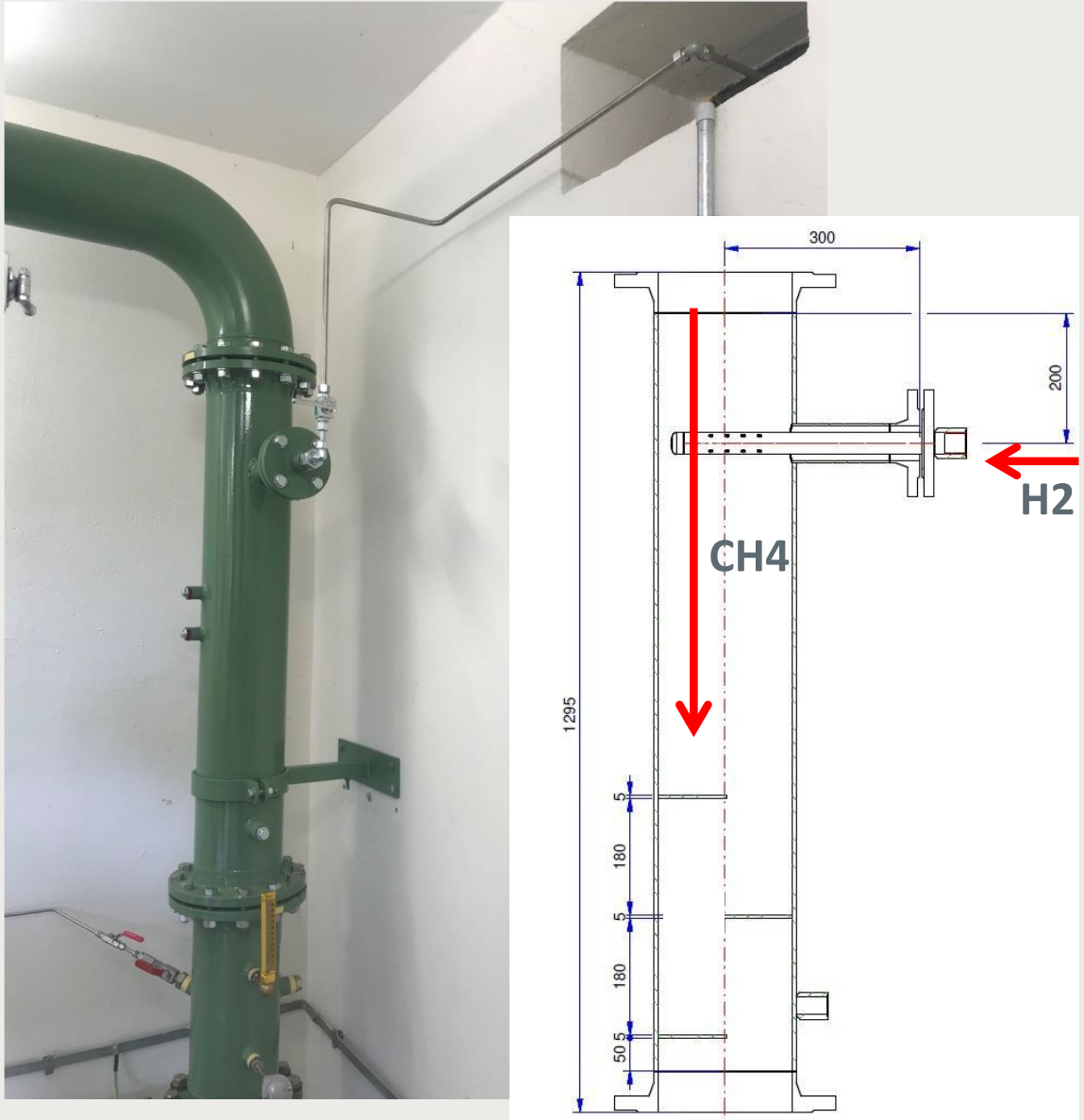


- ✓ After the check, the hydrogen leaves the control station and enters the gas transfer station
- ✓ Above-ground pipeline with a DN12 pipe

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



Risks and Challenges



- ✓ Factory acceptance test was completed for the electrolysis system at ITM POWER in Sheffield (UK)
- ✓ The system is 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 2.5 months in the overall planning that may reduce the period of field testing
- ✓ 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



Communications Activities



Web-site: <http://hpem2gas.eu/>

Workshop in Emden (Germany)
12th February 2019

Newsletters

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

Hydrogen is an alternative energy carrier mediating between energy distribution and renewables.

The HPEM2GAS project will develop a low cost PEM electrolyser optimised for grid management through both stack and balance of plant innovations, culminating in a six month field test of an advanced 180 – 300 kW PEM electrolyser. The electrolyser developed will implement an advanced BoP and improved stack design and components. Several strategies are applied to lower the overall cost, thus enabling widespread utilization of the technology. These primarily concern a three-fold increase in current density (resulting in the proportional decrease in capital costs) whilst maintaining cutting edge efficiency, a material use minimisation approach in terms of reduced membrane thickness whilst keeping the gas cross-over low, and reducing the precious metal loading.

Latest news

- HPEM2GAS – General Assembly 06, in Taormina, Sicily IT
- HPEM2GAS | Final Event | Save the date
- HPEM2GAS – Radio Interview by the Coordinator

HPEM2GAS | Final Event | Save the date

The HPEM2GAS consortium is pleased to invite you to the Final Event of the HPEM2GAS project. The event will take place on Tuesday, 12 February 2019 in Emden, Germany at the Hochschule Emden-Leer.

The registration for the final event will be opened in October 2018.

Please click here below for more information

12 February 2019 in Emden, Germany

HPEM2GAS FINAL EVENT

SAVE THE DATE

HPEM2GAS - Newsletter 2 - September 2017

HPEM2GAS

Dear reader, HPEM2GAS is a Horizon 2020 / Fuel Cells and Hydrogen Joint Undertaking (FCH2 JU) funded project which focuses on the development of a low costs PEM electrolyser for grid management and its related key technologies. You are receiving this newsletter because the project partners indicated that you might be interested in our results. If you do not want to receive the newsletter anymore you can unsubscribe using the link below and you will be automatically be removed from the mailinglist.

Facts & Figures

Full name: High Performance PEM Electrolyzer for Cost-effective Grid Balancing Applications
Acronym: HPEM2GAS
Duration: 36 months
Start date: April 2016
Total budget: 2,65 ME
EC Funding: 2,5 ME

Introduction from the coordinator

Sustainable hydrogen generation by water electrolysis using renewable electrical energy is a very promising technology for the next energy system. Polymer electrolyte water electrolysis is characterized by excellent efficiency and appropriate dynamic characteristics for storing renewable energy in hydrogen. This can efficiently address the gap between intermittent renewable power production and grid demand while hydrogen can become the future energy vector.

Increase in hydrogen production rate - by ITM Power

ITM Power increases hydrogen production rate of its PEM Water Electrolyser three-fold observing negligible impact on degradation during laboratory stack testing

The large-scale deployment of wind power and solar energy sources will strongly contribute to the implementation of Europe's energy policies objectives i.e. to produce 65% of electricity from renewable energy sources by 2050 and to reduce CO₂ emissions linked to energy production by 50%. [Read more..](#)

HPEM2GAS - Dissemination

Flyer Newsletter 1

HPEM2GAS - Consortium

The HPEM2GAS - consortium consists of 7 partners from 5 different European countries.

PGM (precious group metal) amount in PEM catalyst layers - by EWII

One of the ambitious targets in HPEM2Gas is to lower the amount of precious group metal (PGM) in the catalyst layers without jeopardizing good performance or durability. The specific target is to reduce the total PGM loadings down to 0.5 mg_{PGM}/cm² or below. Good results are obtained e.g. the cathode PGM loading has been reduced by a factor of five without significant loss of performance nor durability (Figure below). Furthermore, prolonged single cell test show encouraging low degradation rates in steady state test.

The HPEM2GAS - consortium consists of 7 partners from 5 different European countries.

- 1 - CNR-itae
- 2 - ITM
- 3 - SLV
- 4 - EWII
- 5 - SWE
- 6 - HSE
- 7 - UNR

Calculated U_{act} @ 1 A/cm² [V]

After 4700 operational hours at nominal conditions
Single cell test @ ambient pressure & 25,5°C

Radio interview to a network with national audience

Brochure

PROJECT PARTNERS

- Consiglio Nazionale delle Ricerche - CNR (coordinator) www.itae.cnr.it
- ITM POWER www.itm-power.com
- Solvay Specialty polymers Italy S.p.A. www.solvayplastics.com
- EWII Fuel Cells A/S www.ewiifuelcells.com
- Stadtwerke Emden GmbH www.stadtwerke-emden.de
- Hochschule Emden/Leer www.hs-emden-leer.de
- Uniresearch B.V. www.uniresearch.com

FACTS and FIGURES

Full name: High Performance PEM Electrolyzer for Cost-effective Grid Balancing Applications
Acronym: HPEM2GAS
Grant Agreement: 700008
Start date / Duration: 1 April 2016 / 36 months
Total budget / funding: 2,5 ME

The consortium consists of 7 partners from 5 different European Countries.

CONTACTS

Project Coordinator: Dr. Antonino Salvatore Arico - CNR - ITAE
Project Manager: Dr. Anna Molinari - Uniresearch
Exploitation Manager: Dr. Nick Van Dijk - ITM Power plc

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No700008. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme and Hydrogen Europe and N.EEMEN

High Performance PEM Electrolyzer for Cost-effective Grid Balancing Applications

HPEM2GAS

HPEM2GAS is a 3-years FCH JU Horizon 2020 project addressing the topic 'Improved electrolysis for Distributed Hydrogen production'

www.hpem2gas.eu

Publication on a divulgative journal (planned)



EXPLOITATION PLAN/EXPECTED IMPACT

Exploitation plans of industrial partners (highlights):

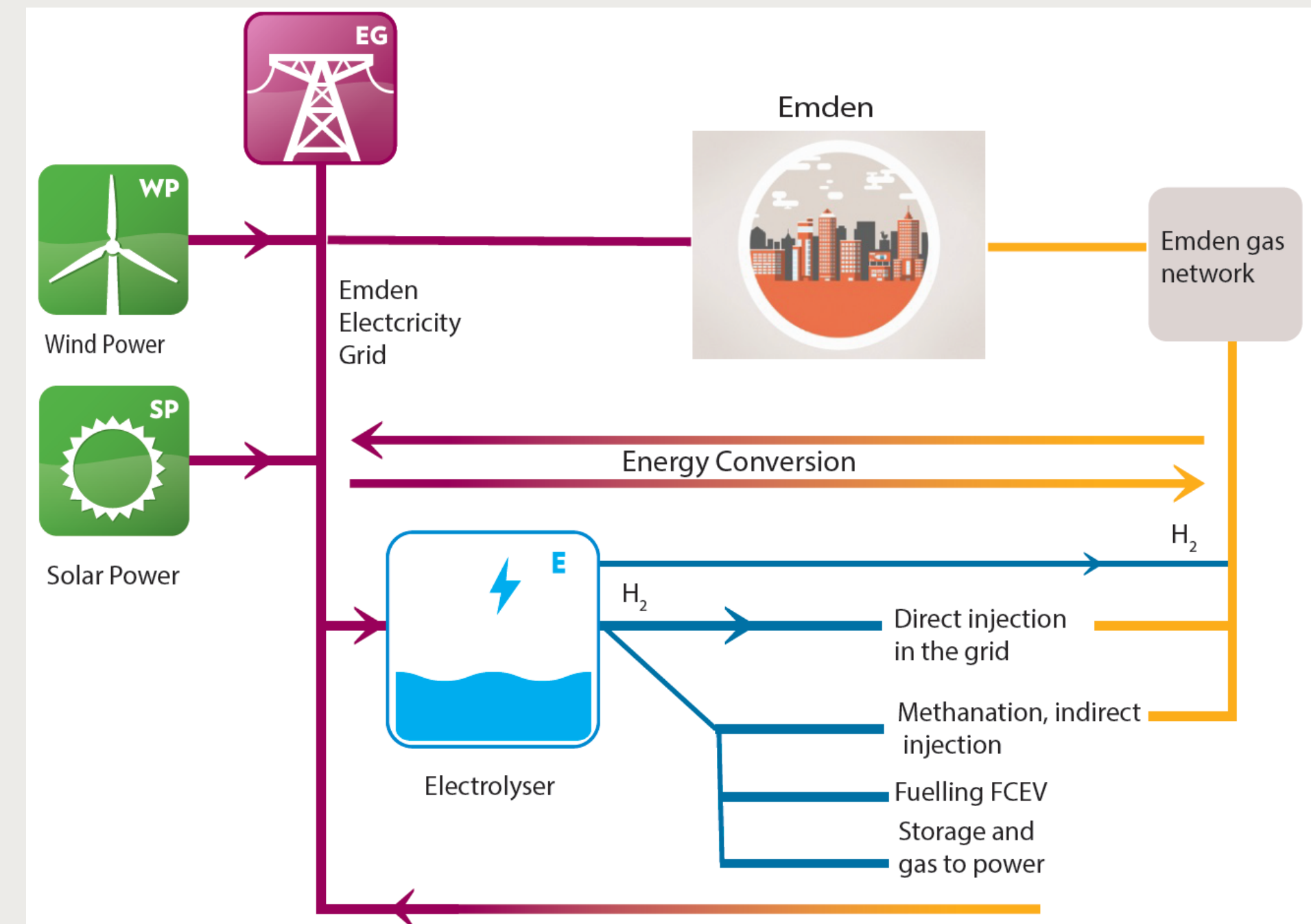
- ITM → new electrolyser system with increased operating current density (3 A cm^{-2}) and lower cost.
 - Solvay → commercialisation of ionomer membranes for PEM water electrolysis application
 - EWII → extending the portfolio of products for electrochemical systems and the development of components 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 be 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.



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 <u>perfluorosulfonic ionomer</u>	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



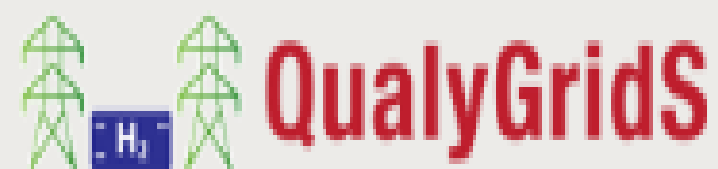
SYNERGIES WITH OTHER PROJECTS AND PROGRAMMES



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



High Performance PEM Electrolyzer for Cost-effective Grid Balancing Applications

Thank You !

HPEM2GAS | Final Event | Save the date

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Emden 12th February 2019

