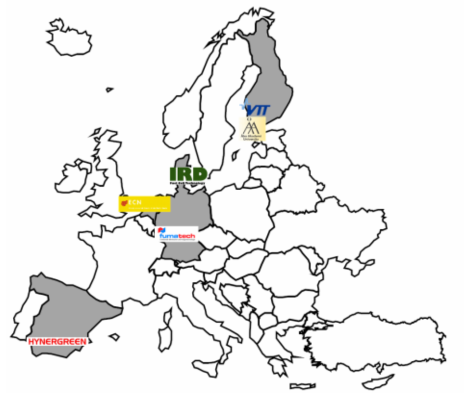


PrimoLyzer

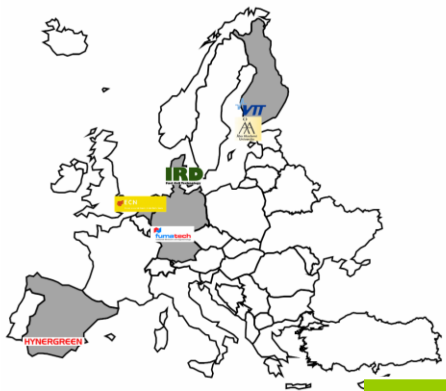
Pressurised PEM Electrolyzer stack

(FCH JU contract no. 245228)

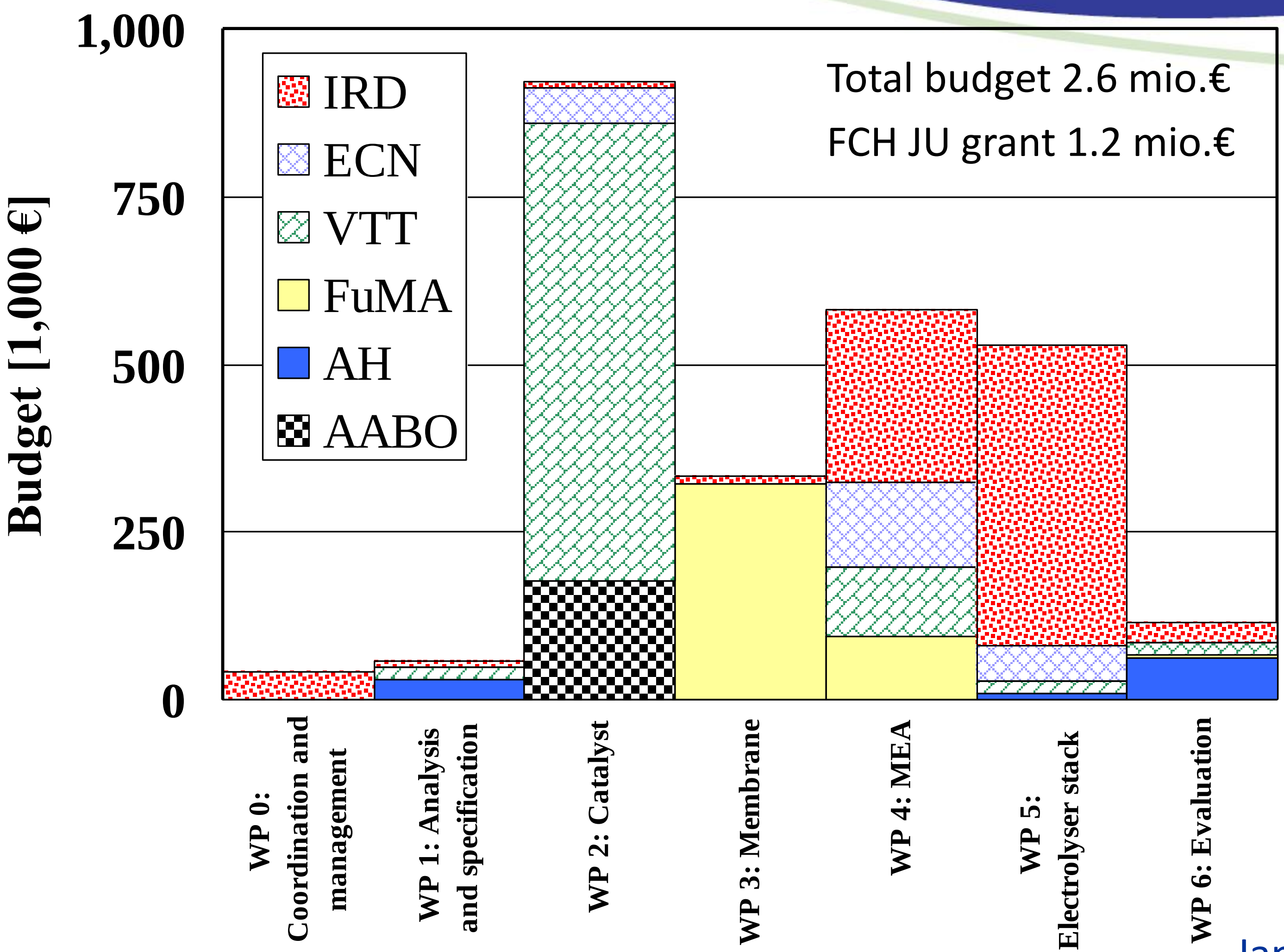
Laila Grahl-Madsen
IRD A/S

PrimoLyzer (245228)

www.primolyzer.ird.dk



Partner	Country	Main project Tasks
IRD Fuel Cells A/S	Denmark	• Project coordinator • Manufacture of MEAs • Design, construction and validation of Electrolyzer stack • Long-term testing of the Electrolyzer stack along with a PEM µCHP
Stichting Enerieonderzoek Centrum Nederland	Holland	• MEA development • Design, and validation of Electrolyzer stack
Valtion Teknillinen Tutkimuskeskus	Finland	• Catalyst development
Fuma-Tech Gesellschaft Fuer Funktionelle Membranen und Anlagentechnologie MBH	Germany	• Membrane development and supply
Hynergreen Technologies, S.A.	Spain	• Specification of the PEM Electrolyzer aimed for later integration with RES
Åbo Akademi	Finland	• Characterisation (catalyst & MEAs)

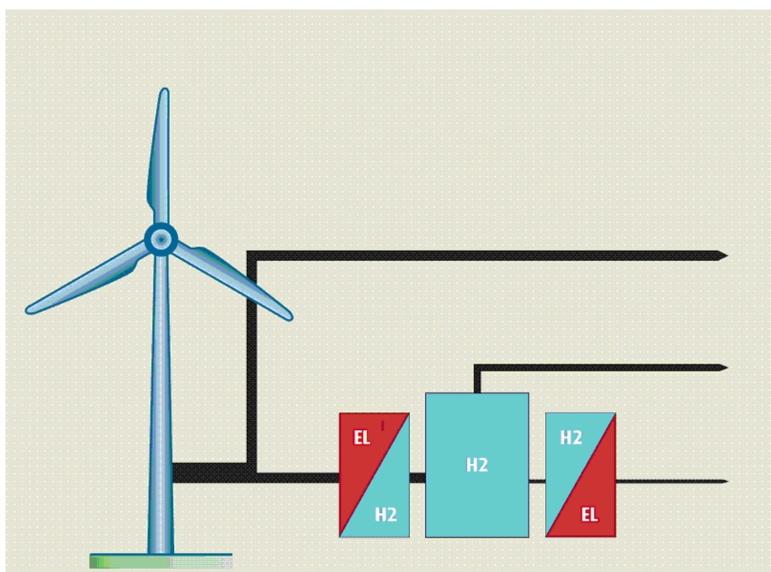


Jan-09 to Jun-12 (2½ year)

The primary objective of PrimoLyzer is to develop, construct, and test a cost-minimised highly efficient and durable PEM-Electrolyzer stack aimed for integration with domestic µCHPs. The key-targets for the stack are as follows:

- Hydrogen production capacity: 1 Nm^3/h
- Pressure: 10 MPa (100 bar)
- 1.68 V @ 1.2 A/cm^2 after 2,000 hours of continuous operation
- Cost: <5,000 € per Nm^3 H_2 production capacity per hour in series production
- Durability: >20,000 hours @ constant load
- Electrolyzer stack test together with a dead-end µCHP (1.5 kW_{AC}) for at least 2,000 hours

The primary objective of PrimoLyzer is to develop, construct, and test a cost-minimised highly efficient and durable PEM-Electrolyzer stack aimed for integration with domestic µCHPs.



Copy of selected sections from pp.13-14 in the MAIP 2008-13 revised in 2011
http://www.fch-ju.eu/sites/default/files/MAIP%20FCH-JU%20revision%202011%20final.pdf

3.4.2 Hydrogen Production & Distribution

This application area aims to develop and, where possible, fully implement a portfolio of cost-competitive, energy efficient and sustainable hydrogen production, storage and distribution processes enabling supply of the anticipated hydrogen energy demand while demonstrating the role that hydrogen can play as an energy carrier in reaching Europe's key long term and mid term energy objectives: …

Sections on the transport sector are excluded

Several processes and feedstocks will be used to produce hydrogen either in centralised (large scale) plants providing economies of scale or distributed (small scale) plants taking advantage of locally available primary energy sources and feedstocks with the benefit of generally improved sustainability and lower distribution infrastructure costs. These processes have different degrees of maturity, production capacity and sustainability. In the short and mid-term, the demand will need to be met by the more mature technologies. In the longer term, a wide variety of technologies could become available to exploit available primary renewable energy resources using hydrogen as an energy carrier. In this perspective, new hydrogen production and supply pathways need to be further developed and tested.

Accordingly, the main emphasis of this application area is on research and development of mature production and storage technologies and on breakthrough orientated research of longer term, fully sustainable hydrogen production and supply pathways. The mature production technologies include (i) reforming (and gas purification) based on bio-fuels as well as conventional fuels; (ii) cost-efficient low-temperature electrolysers adapted for the large-scale use of carbon free electricity and (iii) biomass to hydrogen (BTH) thermal conversion. Long-term and breakthrough orientated research will aim at improving efficiencies of technologies for water splitting using high temperature electrolysers as well as thermo-chemical processes based on solar, nuclear or waste heat, and at developing low-temperature, low-cost biological hydrogen (e.g. enzymes for fermentation) and photo-electrochemical processes for direct hydrogen production. A development objective for most decentralized production technologies is scale-up to cost effective capacity, as well more cost efficient, high performance materials (e.g. membranes) to meet the overall cost targets.

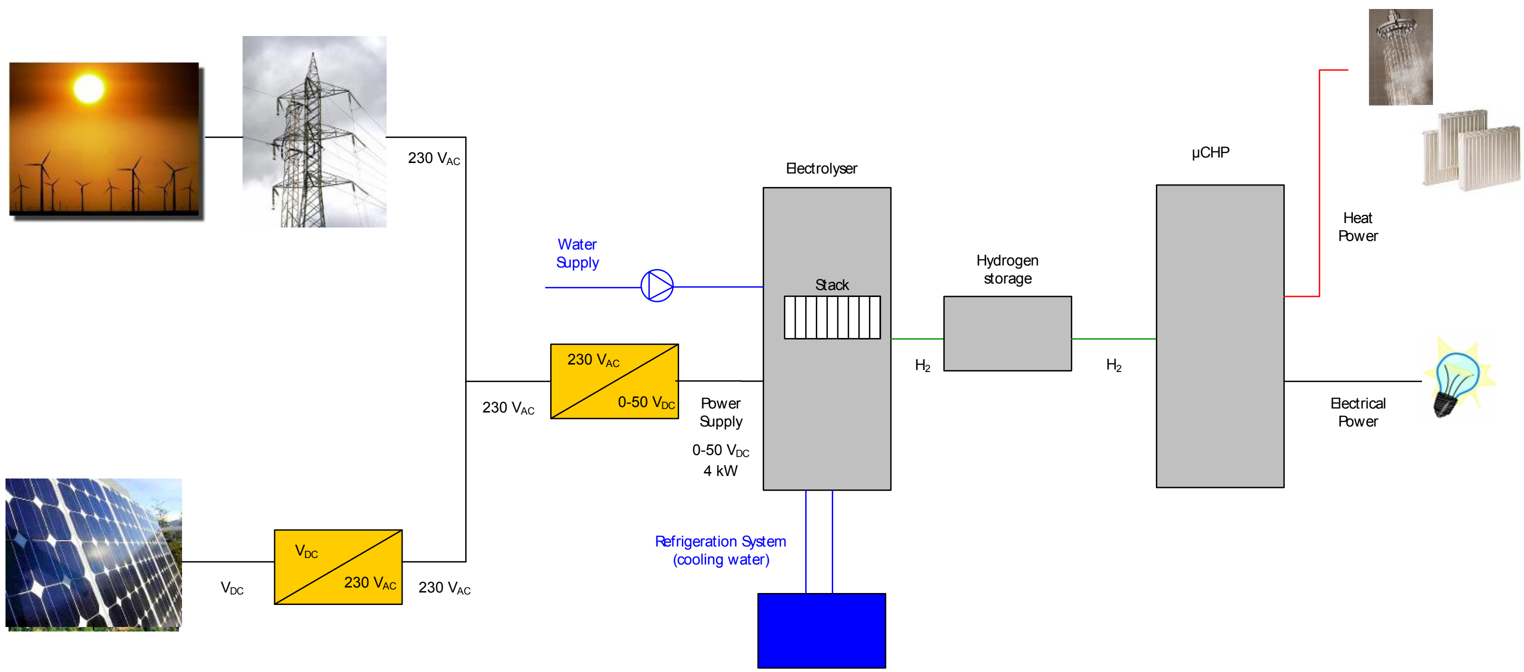
Section on CCS is excluded

Concerning the establishment of a safe, efficient and reliable hydrogen distribution and refuelling infrastructure the main focus will be on demonstration of technology options for high volume, safe hydrogen storage such as storage in underground caverns and decentralized storage, in synergy with the energy storage requirements resulting from the variability and intermittency of renewable energy sources connected to the electricity grid. This will be complemented by long-term and breakthrough orientated research on improved hydrogen storage based on solid and liquid materials for increased efficiency and storage capability. Some of these technologies are ready for implementation in small and medium scale stationary applications, e.g. in combination with high temperature fuel cells. Here, energy efficient integration and a significant reduction of cost of the storage systems will be the main development targets.

WP 1: Analysis and specification

- PEMEC stack
- PEMEC BoP
- PEMEC operation with RES

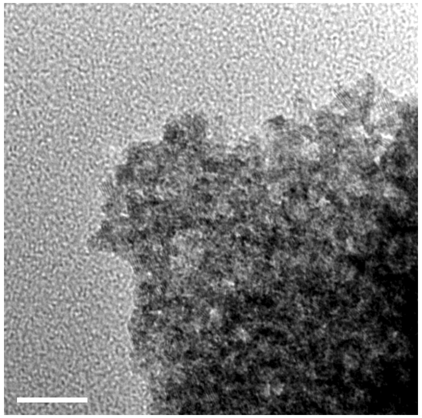
Renewable plant with electrolyser and µCHP



WP 2: Catalyst

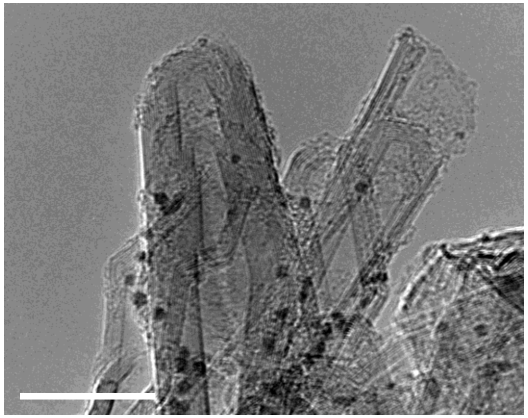
OER:

- Theoretical quantum mechanical surface modelling of MMO-crystals to predict interactions with H_2O & O_2
- Ternary (MMO) catalyst manufacture development & characterization



HER:

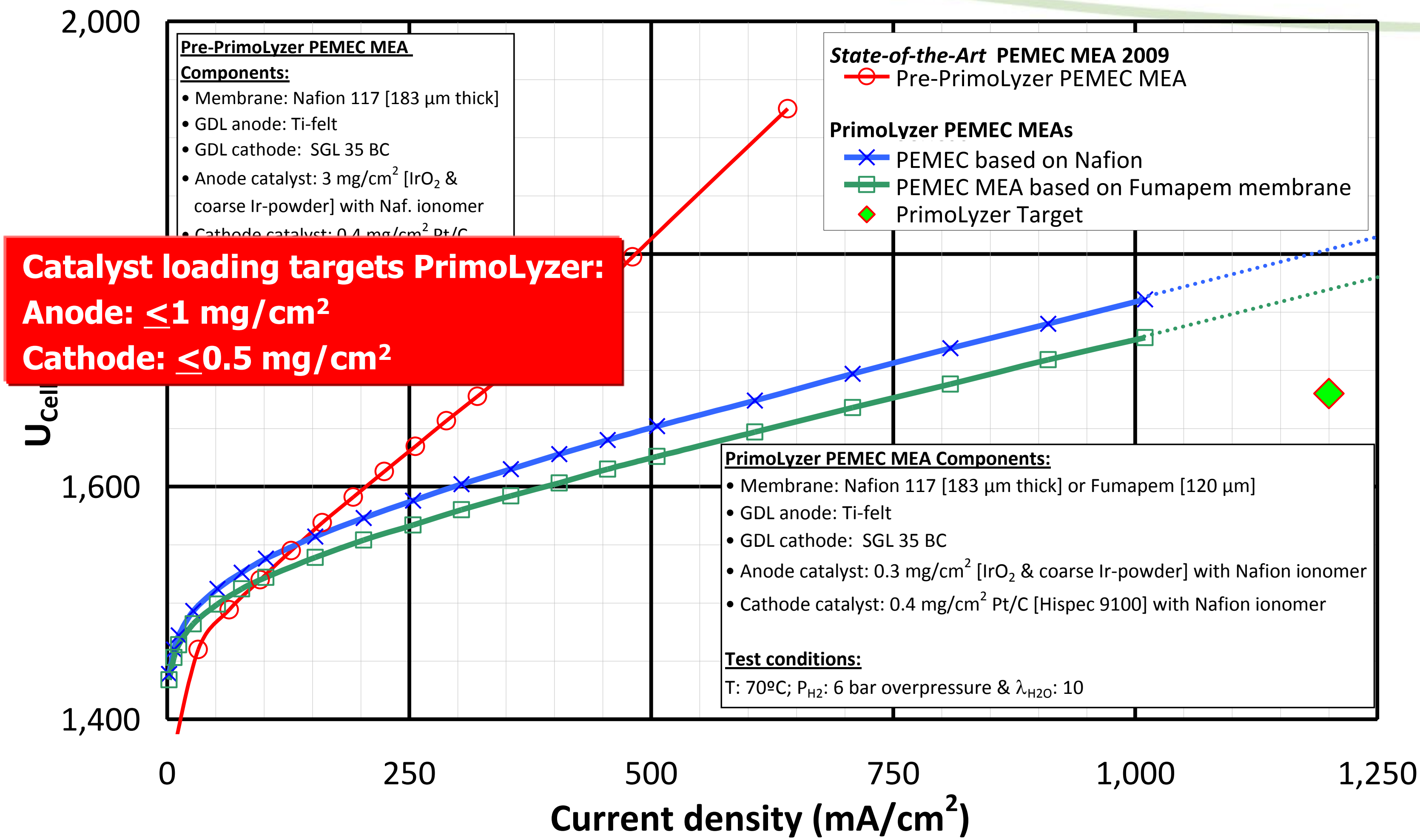
- Manufacture development & characterization of CNT supported Pt/Pd catalyst



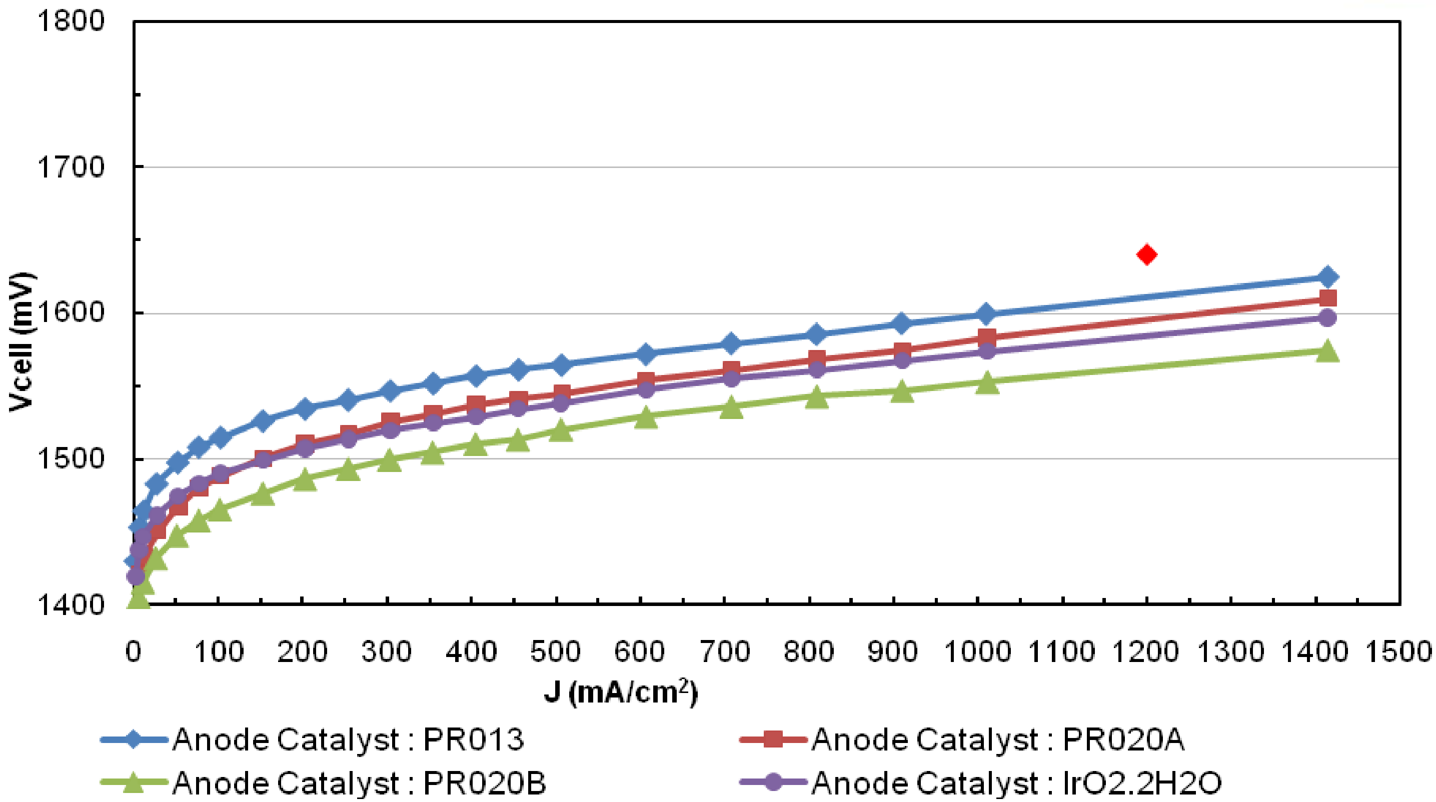
WP 3: Membrane

Focus on development of thinner and higher conductive membranes with equivalent or better mechanical properties than the benchmark membranes
[both sulfonated polysulfone (sPS) and reinforced PFSA membranes are developed]

WP 4: MEA

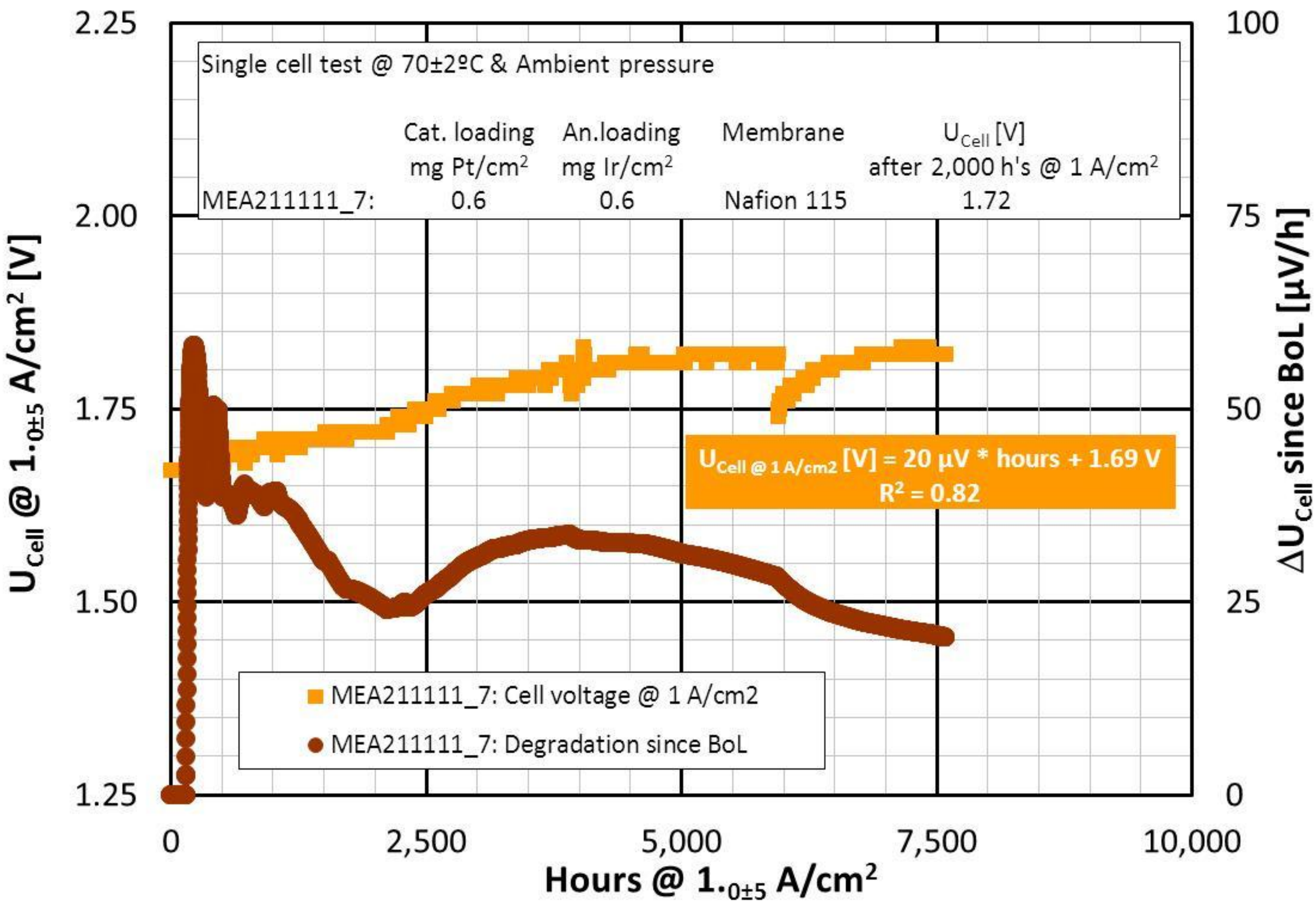

2,000
1,600
1,400
U_Cell
0
250
500
750
1,000
1,250
Current density (mA/cm²)
Pre-PrimoLyzer PEMEC MEA
Components:
• Membrane: Nafion 117 [183 µm thick]
• GDL anode: Ti-felt
• GDL cathode: SGL 35 BC
• Anode catalyst: 3 mg/cm² [IrO₂ & coarse Ir-powder] with Naf. ionomer
State-of-the-Art PEMEC MEA 2009
Pre-PrimoLyzer PEMEC MEA
PrimoLyzer PEMEC MEAs
PEMEC based on Nafion
PEMEC MEA based on Fumapem membrane
PrimoLyzer Target
Catalyst loading targets PrimoLyzer:
Anode: ≤1 mg/cm²
Cathode: ≤0.5 mg/cm²
PrimoLyzer PEMEC MEA Components:
• Membrane: Nafion 117 [183 µm thick] or Fumapem [120 µm]
• GDL anode: Ti-felt
• GDL cathode: SGL 35 BC
• Anode catalyst: 0.3 mg/cm² [IrO₂ & coarse Ir-powder] with Nafion ionomer
• Cathode catalyst: 0.4 mg/cm² Pt/C [Hispec 9100] with Nafion ionomer
Test conditions:
T: 70ºC; P_H2: 6 bar overpressure & λ_H2O: 10

WP 4: MEA

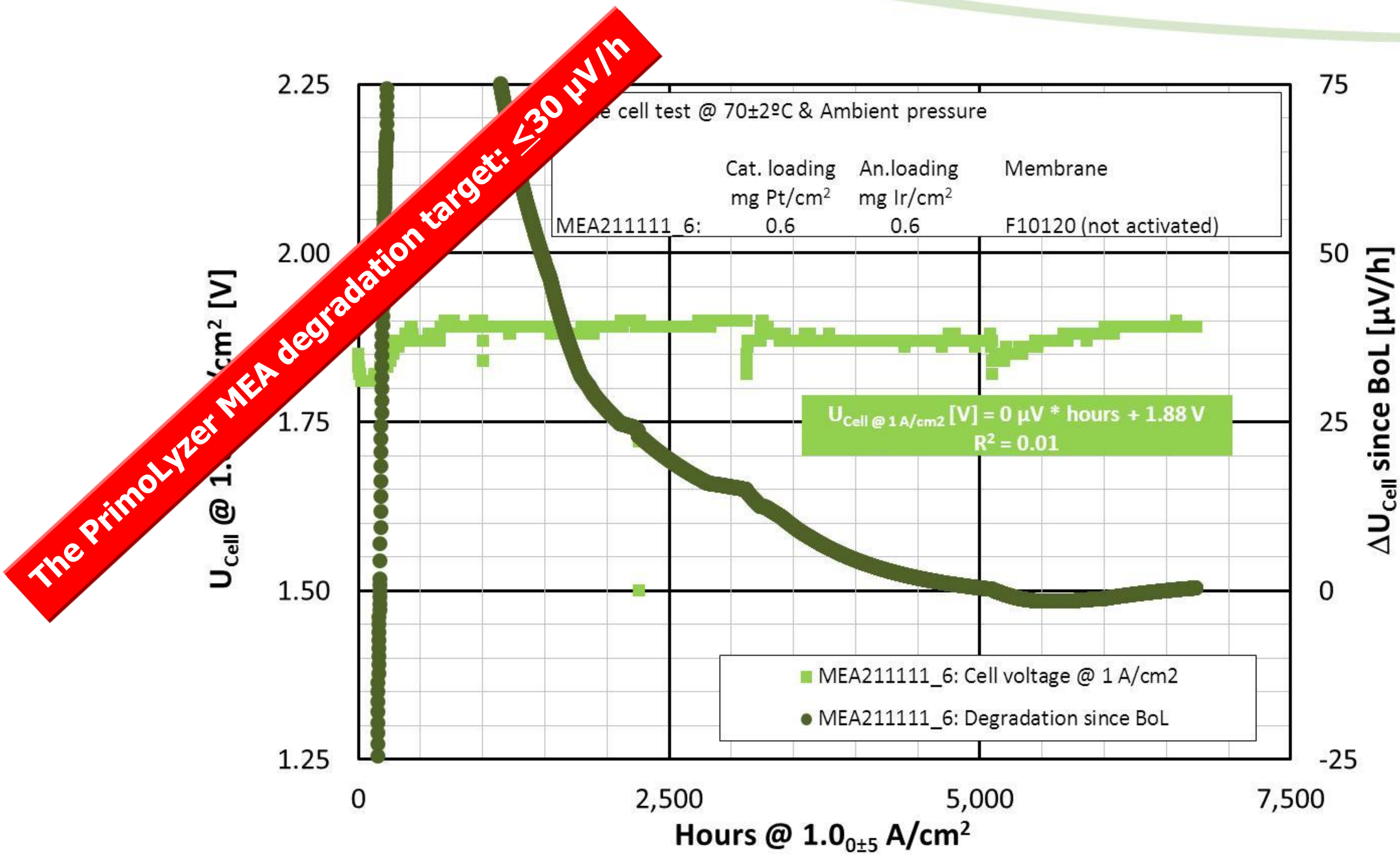


IR-corrected polarization curves @ 6 bar, 70ºC, λ=10

WP 4: MEA


Single cell test @ 70±2ºC & Ambient pressure
Cat. loading mg Pt/cm2
An.loading mg Ir/cm2
Membrane
UCell [V] after 2,000 h's @ 1 A/cm2
MEA211111_7: 0.6 0.6 Nafion 115 1.72
UCell @ 1 A/cm2 [V] = 20 µV * hours + 1.69 V
R2 = 0.82
MEA211111_7: Cell voltage @ 1 A/cm2
MEA211111_7: Degradation since BoL
UCell @ 1.0±5 A/cm2 [V]
ΔUCell since BoL [µV/h]
Hours @ 1.0±5 A/cm2
2.25
2.00
1.75
1.50
1.25
100
75
50
25
0
0
2,500
5,000
7,500
10,000

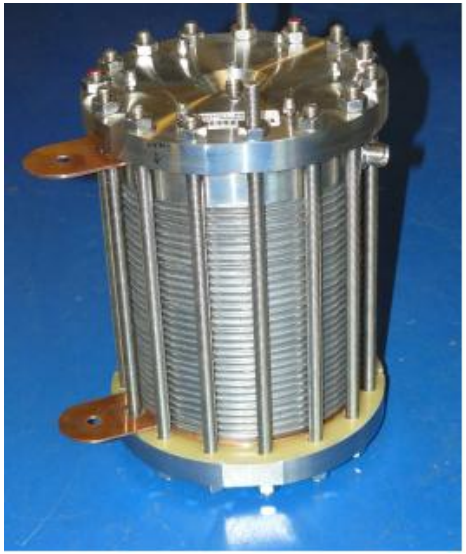
WP 4: MEA


The PrimoLyzer MEA degradation target: ≤30 µV/h
e cell test @ 70±2ºC & Ambient pressure
Cat. loading mg Pt/cm2
An.loading mg Ir/cm2
Membrane
MEA211111_6: 0.6 0.6 F10120 (not activated)
U_Cell @ 1 A/cm2 [V] = 0 µV * hours + 1.88 V
R² = 0.01
MEA211111_6: Cell voltage @ 1 A/cm2
MEA211111_6: Degradation since BoL
U_Cell @ 1.0 A/cm² [V]
ΔU_Cell since BoL [µV/h]
Hours @ 1.0_0±5 A/cm²
2.25
2.00
1.75
1.50
1.25
75
50
25
0
-25
0
2,500
5,000
7,500

WP 5: PEMEC stack

The objective of this WP is to design, and construct a c.4.5 kW PEM Electrolyzer stack that possess the following characteristics:

- Nominal operational pressure of 10 MPa (100 bars)
- Leakage rates that fulfil the requirements outlined in the IEC 62282-2 standard for fuel cell stacks even after 2,000 hours of continuous operation
- Water cooled to increase durability and offer the possibility of heat yield e.g. central heating
- $\geq$75% efficiency (LHV) @ 1.2 A/cm^2 & 1.68 V after 2,000 hours of cont. operation

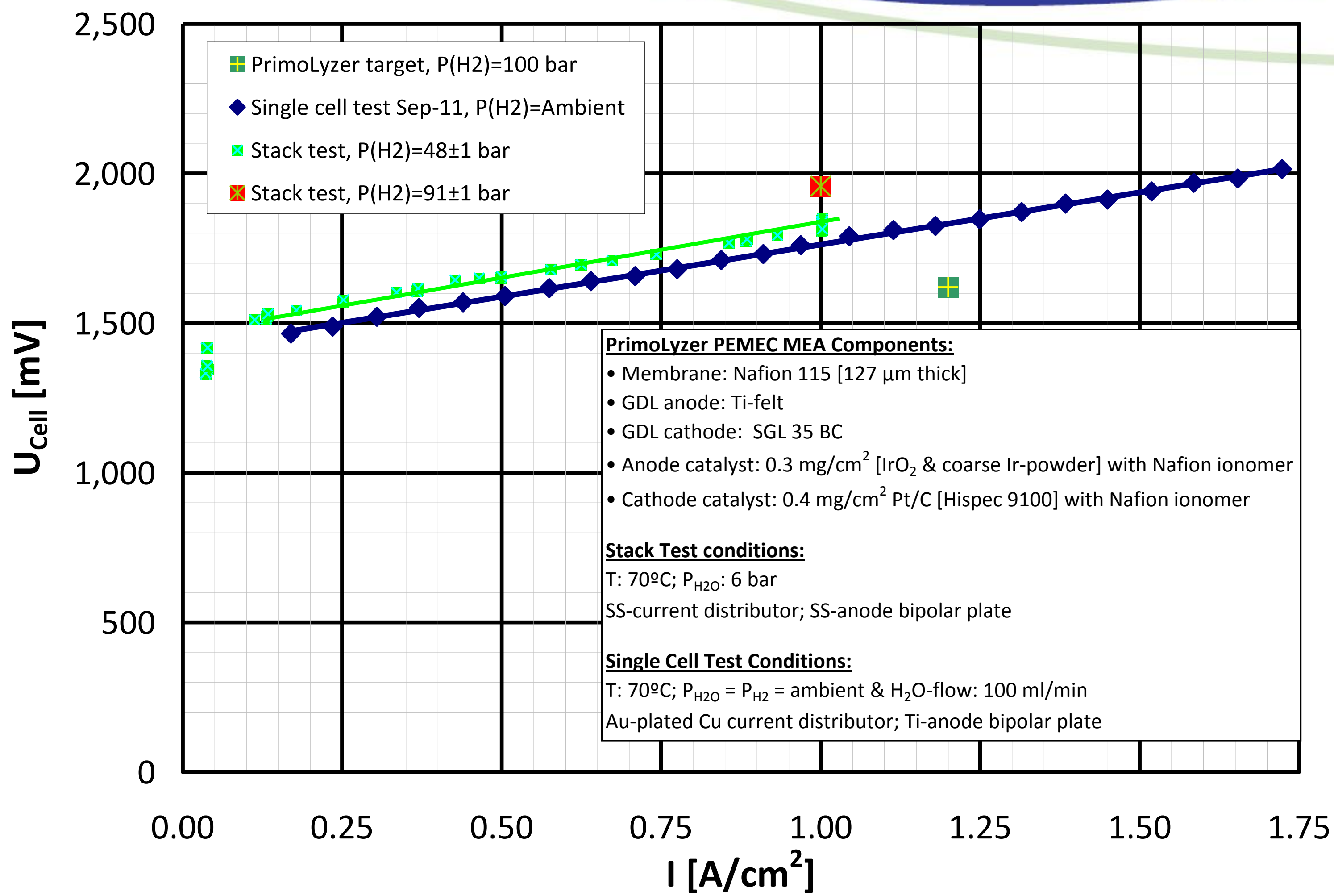


Results:

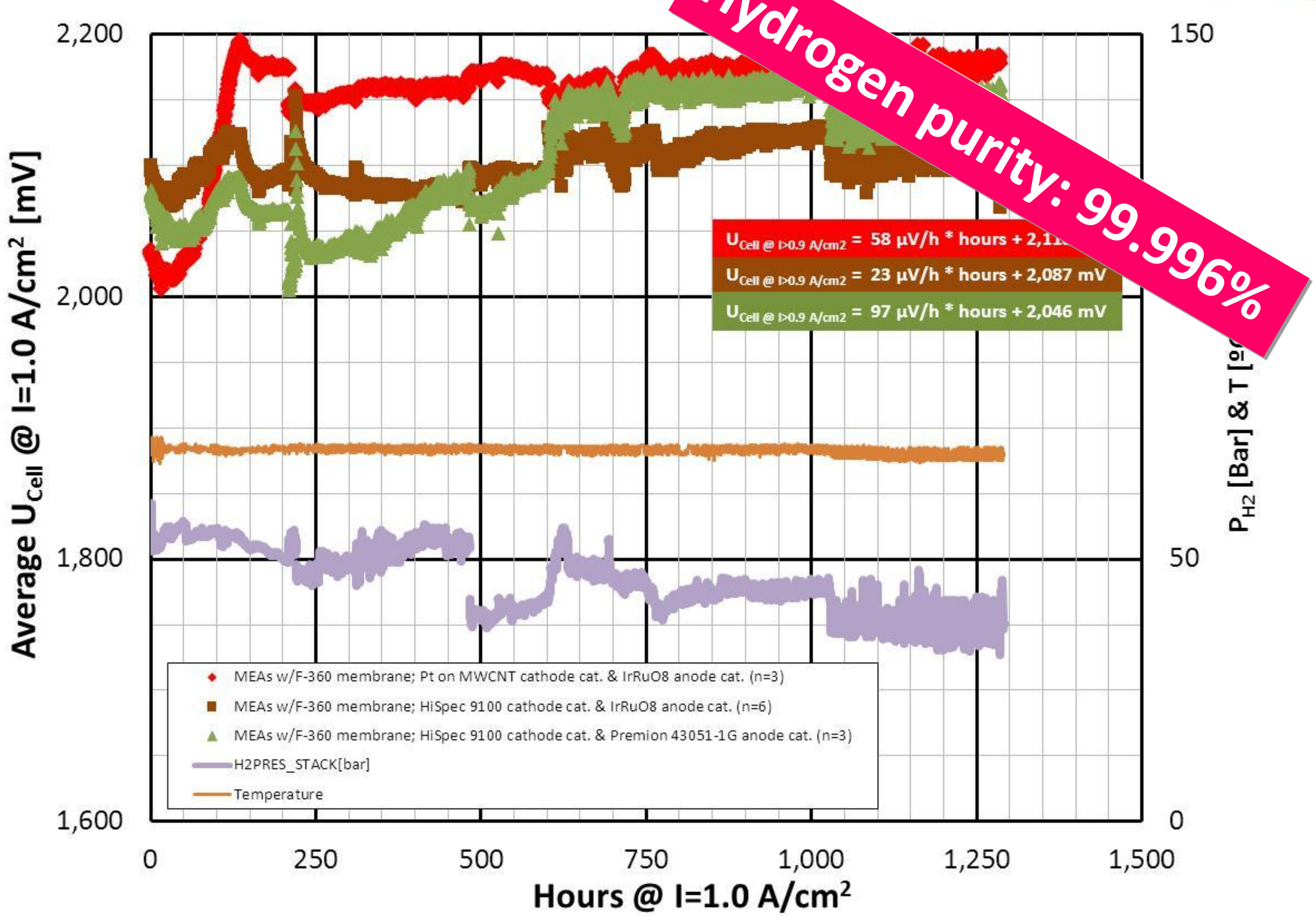
- A circular cell design
- Active electrode area: 69 cm^2
- 29 cells
- Nominal operating:
  Input voltage 48 V
  Input stack current of 83 A

WP 5: PEMEC stack

WP 5: PEMEC stack



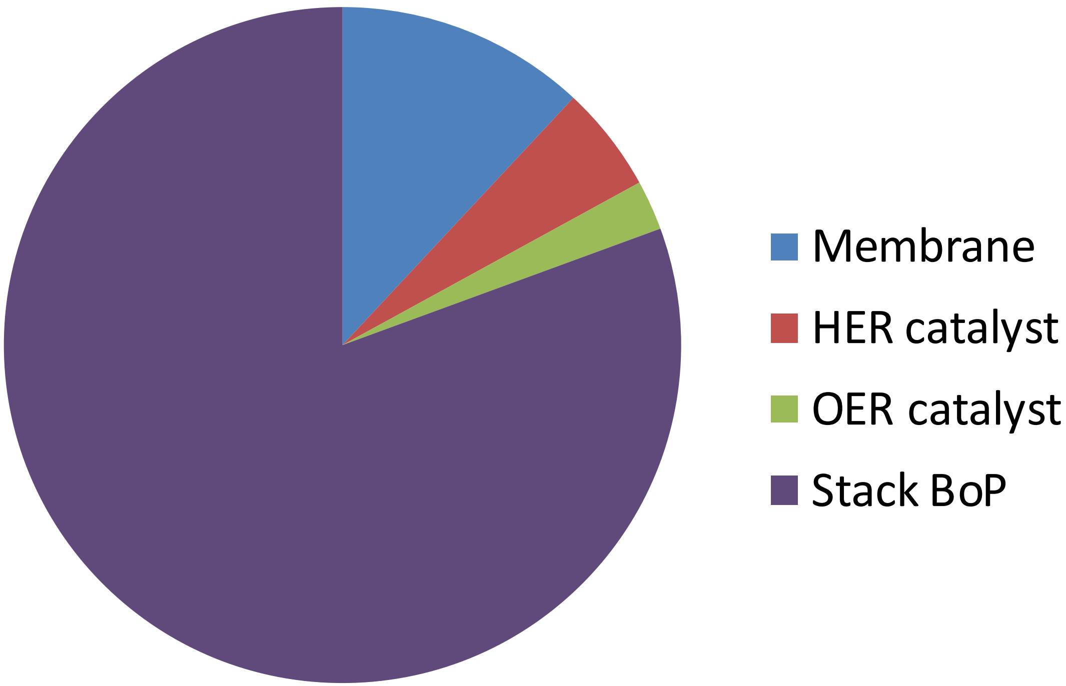
WP 5: PEMEC stack



WP 6: Evaluation

Stack cost in production of 100 units <5,000 € [1 Nm^3/h]

Stack cost analysis:



WP 6: Evaluation

The PEMEC electrolyser has been tested and the following efficiencies measured/calculated:

PEMEC stack: $P_{AC} \rightarrow H_2$: 60% efficient
PEMEC system: $P_{AC} \rightarrow H_2$: 53% efficient
PEMEC system: $P_{AC} \rightarrow H_2 + P_{TH}$: 96% efficient

Collaboration and dissemination:

- A Weltemp-PrimoLyzer workshop took place on 16th of Nov. 2010 in DK

- An international electrolysis workshop was being organized in May 10-11, 2012 in Copenhagen (http://H2carlsberg.com)

  Content:
  - Technical overview – International initiatives
  - The challenge: Stationary energy storage and energy for transportation
  - The solution: Hydrogen production by electrolysis
  - Technical presentations

  Organized by:

National Danish funded projects:
Medlys (FI 10-093906)
HyProvide the PEM track (EUDP)
Next Generation Alkaline Electrolysis (HT)

Targets/achievements:

☺ Stack hydrogen production capacity: 1 Nm^3/h

😐 Pressure: 10 MPa (100 bar) - *stack leak tested to 130 bar, perf… …ined at lower pressure*

☺ 1.68 V @ 1.2 A/cm^2 after 2,000 hours of continuo…
- *The PrimoLyzer electrodes are well performi…*
- *The PrimoLyzer membrane is well perfo… …y durable*
- *The final material selection is base… …is has lowered the MEA performance*

☺ Cost: <5,000 € per Nm^3 H_2 pr… …acity per hour in series production

☺ Durability: >20,000 ho… …nt load
Measured MEA de… …30 µV/h] predicts >20,000 hours of lifetime

😐 Electrolyser sta… …gether with a dead-end µCHP (1.5 kW_{AC}) for at least 2,000 hours
- *>500 test hours o… …tained in PrimoLyzer, the project is terminated but the test is on-going (>1,275 test hours has been achieved, so far)*

Material R&D on catalyst, membrane & stack components are still required to increase performance and lower cost

Future Perspectives for PrimoLyzer

- The recently terminated PrimoLyzer is a phase I of at least III phases

- The Partners aim to continue the work in a PrimoLyzer II project that will include system integration (PEMFC/PEMEC) and field test together with Solar power

- A larger scale demonstration [PrimoLyzer III] *tbd*

- IRD continues the PEMEC development in a national Danish project supported by EUDP [*HyProvide the LT PEM track J.Nº 64011-0107*]