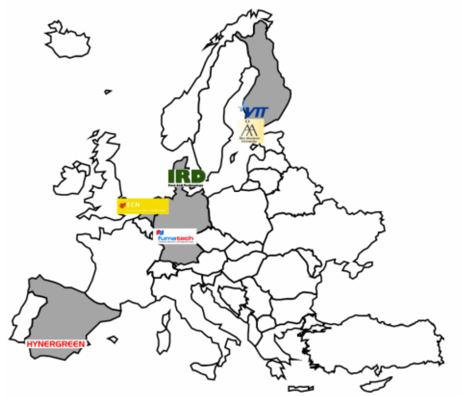


PrimoLyzer

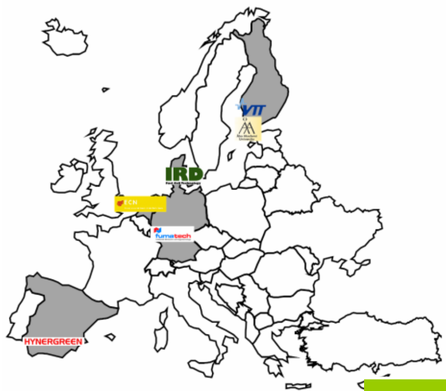
Pressurised PEM Electrolyzer stack

(FCH JU contract no. 245228)

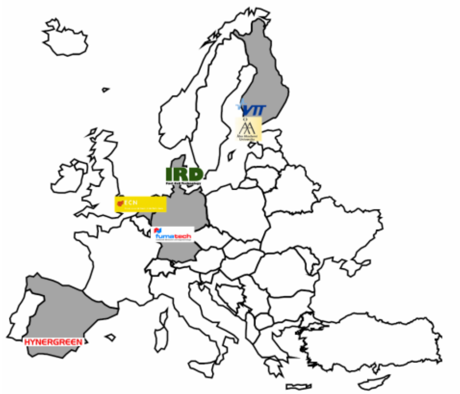
Laila Grahl-Madsen
IRD A/S

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)



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

Copy from pp.12-13 in the
"Multi - Annual Implementation Plan 2008 – 2013"

3.4.2 Hydrogen Production & Distribution

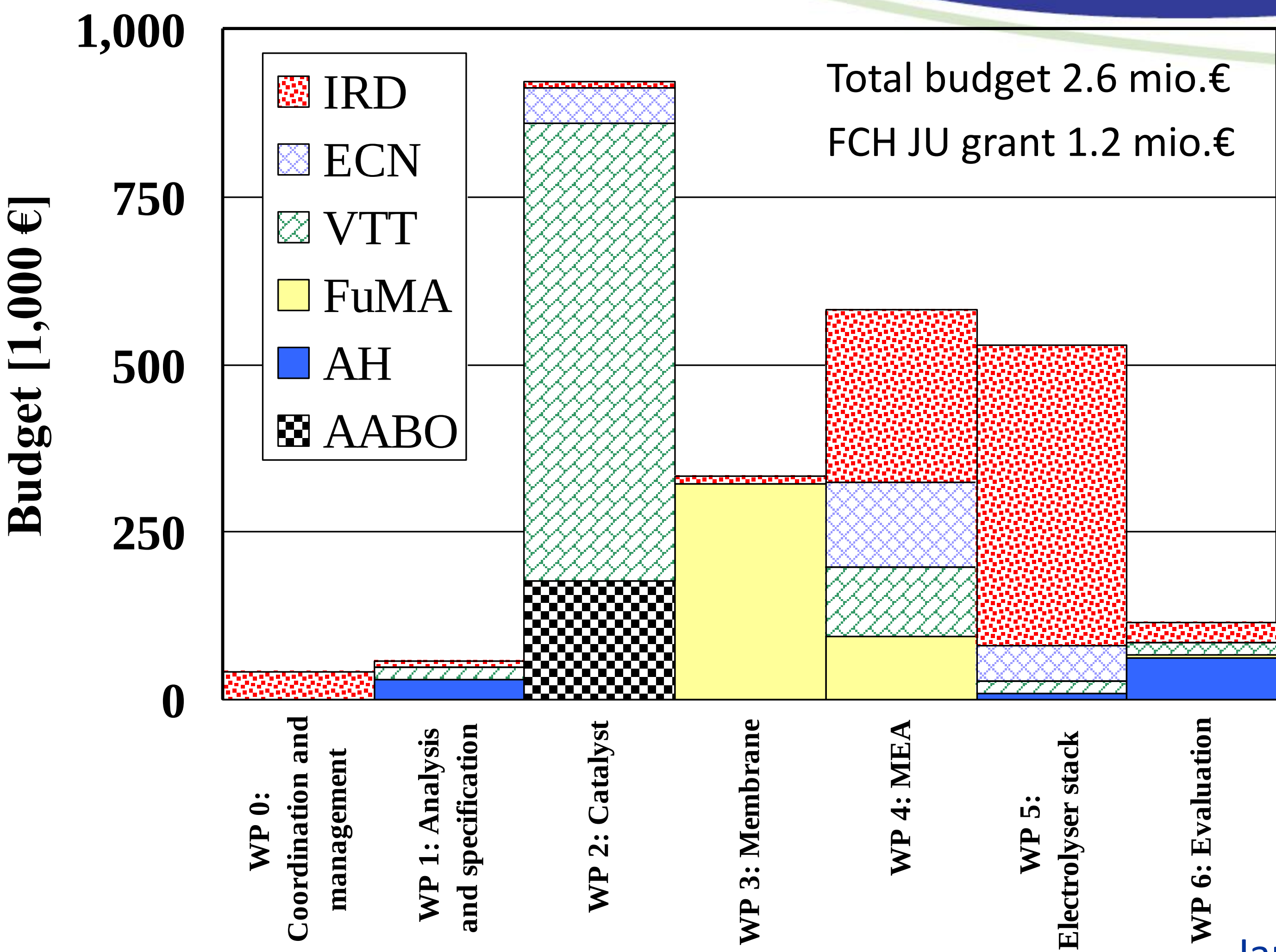
This application area aims to **develop a** portfolio of **cost-competitive, high energy efficient and sustainable hydrogen production**, storage and distribution processes and to test them under real market conditions as soon as possible. The mid-term target is to supply 10-20% of the anticipated hydrogen energy demand (expected to come mainly from transport and early market applications) with CO2 lean or CO2 free hydrogen by 2015. A second objective is to start preparatory work to enable the introduction of a widely spread hydrogen infrastructure beyond 2020-2030. Approximately 10-12% of the total budget will be devoted to this application area.

Several processes and feedstocks will be used to produce hydrogen either in a centralised (large scale) or **decentralised (small** scale) plants. These processes have different degrees of maturity, production capacity and sustainability. In the short and mid-term, the more mature technologies will have to meet the demand. In the longer term, **fully sustainable hydrogen production** and supply pathways need to be further developed and tested.

Accordingly, the main emphasis of this application area will be 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.

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 underground stores and liquefaction. 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. Although the latter is mainly suited for on-board storage of the next generation of hydrogen fuelled vehicles, other applications (e.g. stationary, portable) cannot be excluded.

Pre-normative research will be complementary to that foreseen in application area "*Transport and Refuelling Infrastructure*" and will include safety analysis and field test of hydrogen pipelines in order to ensure a safe and efficient high volume hydrogen distribution system.

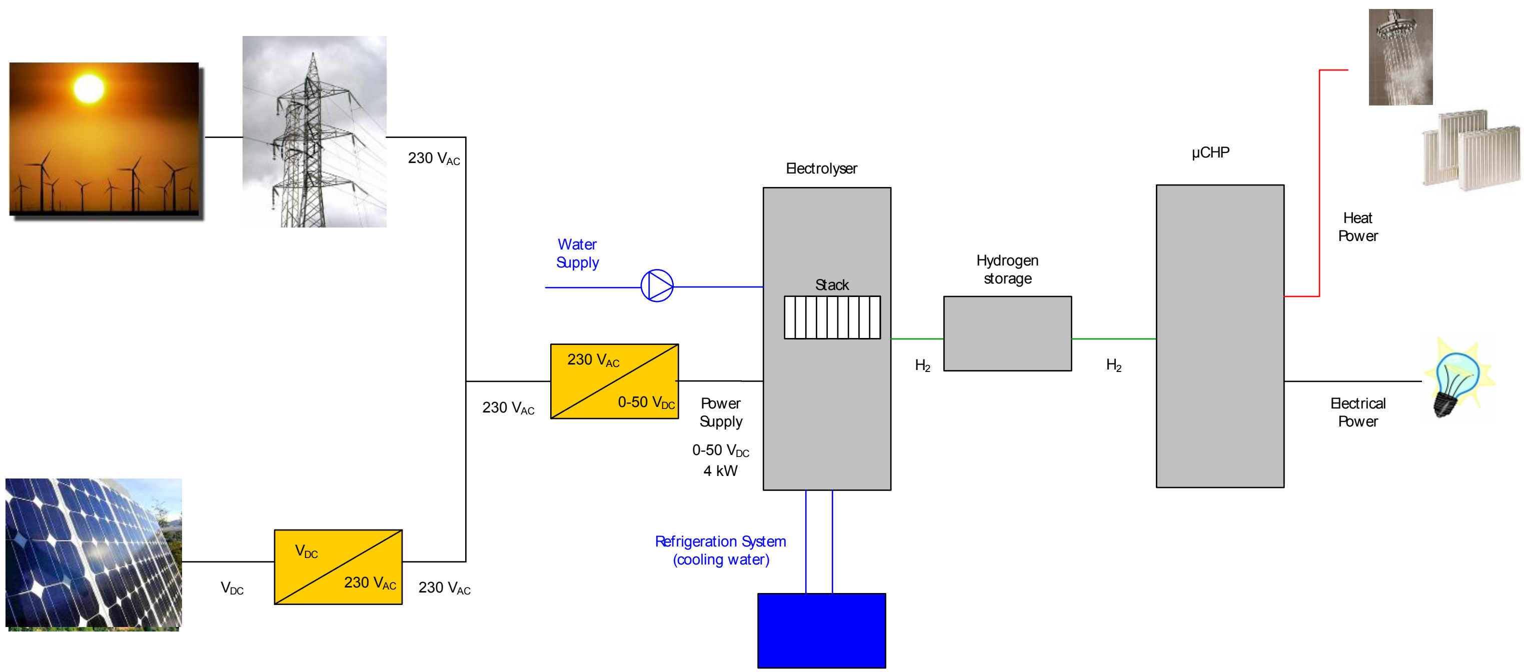


Jan-09 to Jun-12 (2½ year)

WP 1: Analysis and specification

- PEMEC stack
- PEMEC BoP
- PEMEC operation with RES

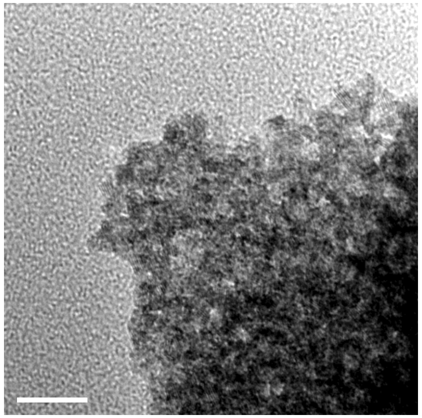
Renewable plant with electrolyser and µCHP



WP 2: Catalyst

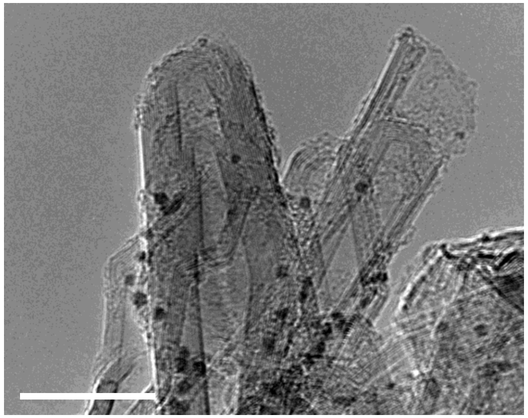
OER:

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



HER:

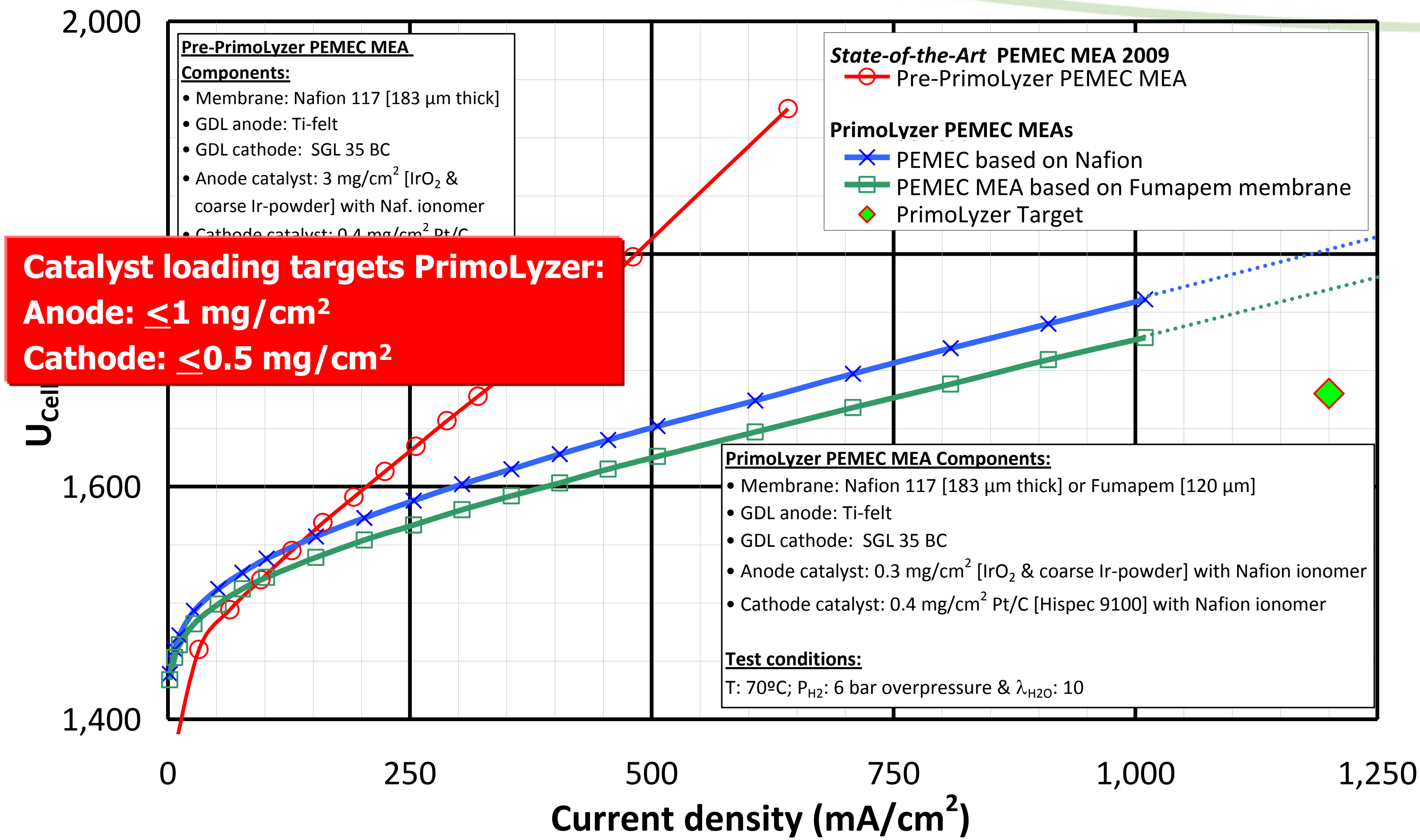
- Manufacture development & characterization of CNT supported Pt/Pd catalyst



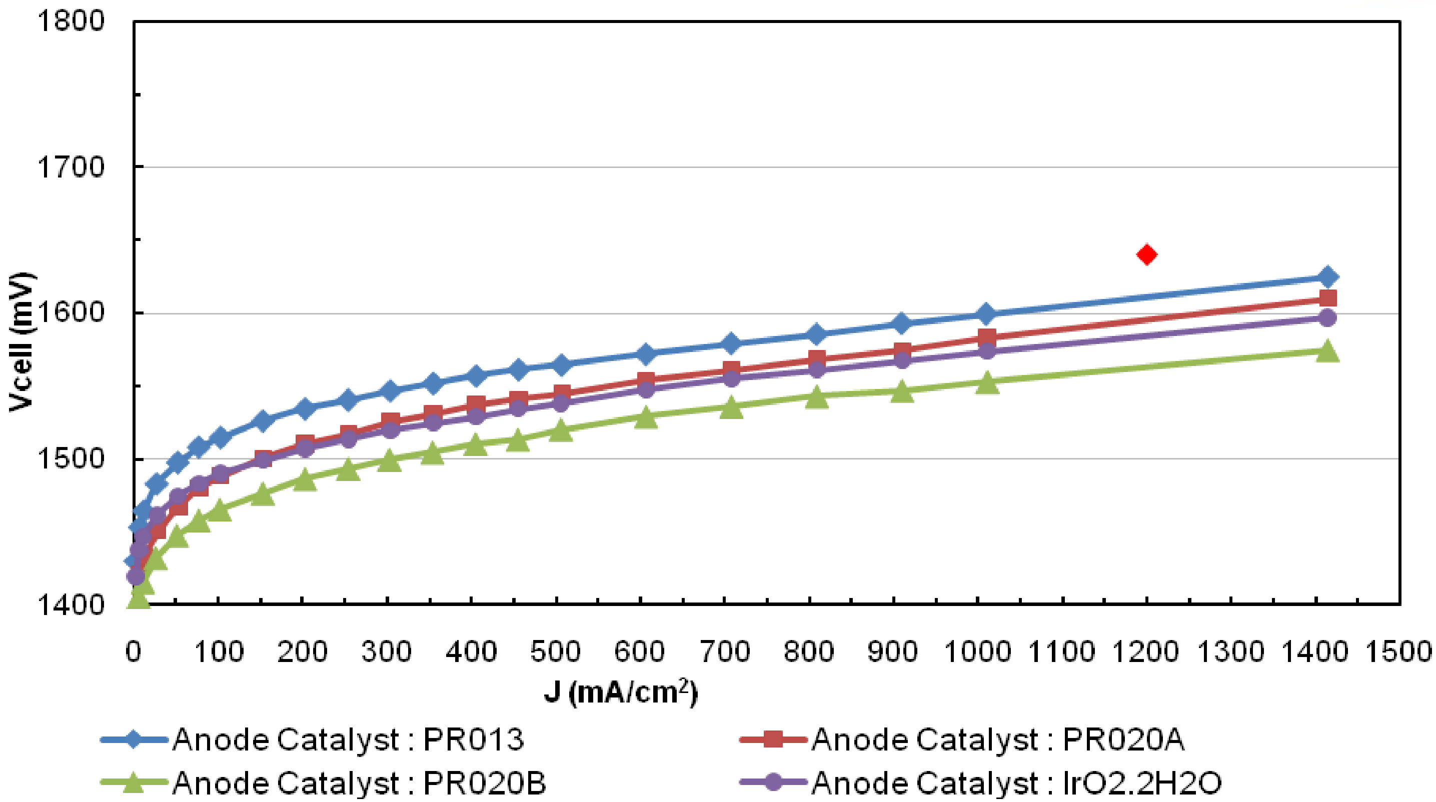
WP 3: Membrane

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

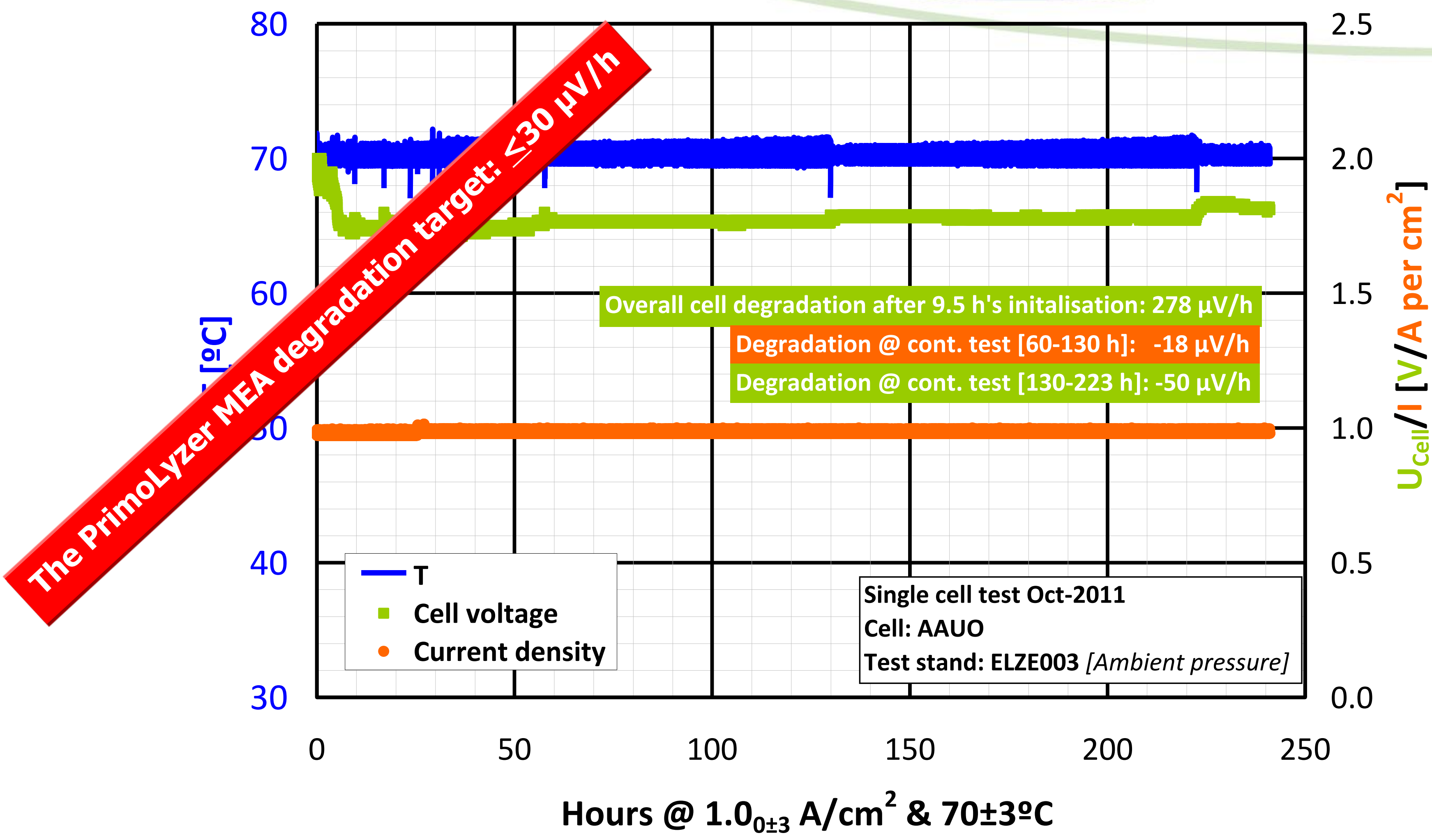

Pre-PrimoLyzer PEMEC MEA
Components:
• Membrane: Nafion 117 [183 µm thick]
• GDL anode: Ti-felt
• GDL cathode: SGL 35 BC
• Anode catalyst: 3 mg/cm2 [IrO2 & coarse Ir-powder] with Naf. ionomer
Catalyst loading targets PrimoLyzer:
Anode: ≤1 mg/cm2
Cathode: ≤0.5 mg/cm2
State-of-the-Art PEMEC MEA 2009
Pre-PrimoLyzer PEMEC MEA
PrimoLyzer PEMEC MEAs
PEMEC based on Nafion
PEMEC MEA based on Fumapem membrane
PrimoLyzer Target
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; PH2: 6 bar overpressure & λH2O: 10
2,000
1,600
1,400
0
250
500
750
1,000
1,250
Current density (mA/cm2)

WP 4: MEA



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

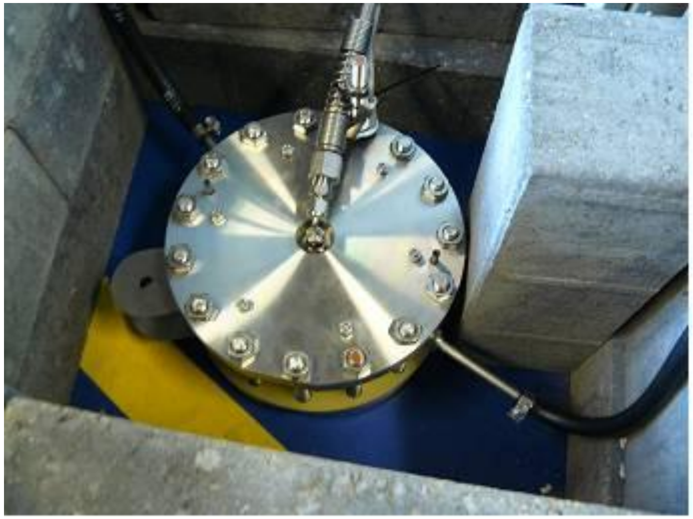
WP 4: MEA


The PrimoLyzer MEA degradation target: ≤30 µV/h
Overall cell degradation after 9.5 h's initalisation: 278 µV/h
Degradation @ cont. test [60-130 h]: -18 µV/h
Degradation @ cont. test [130-223 h]: -50 µV/h
T
Cell voltage
Current density
Single cell test Oct-2011
Cell: AAUO
Test stand: ELZE003 [Ambient pressure]
80
70
60
50
40
30
2.5
2.0
1.5
1.0
0.5
0.0
0
50
100
150
200
250
Hours @ 1.0 0±3 A/cm2 & 70±3ºC
UCell/I [V/A per cm2]

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:

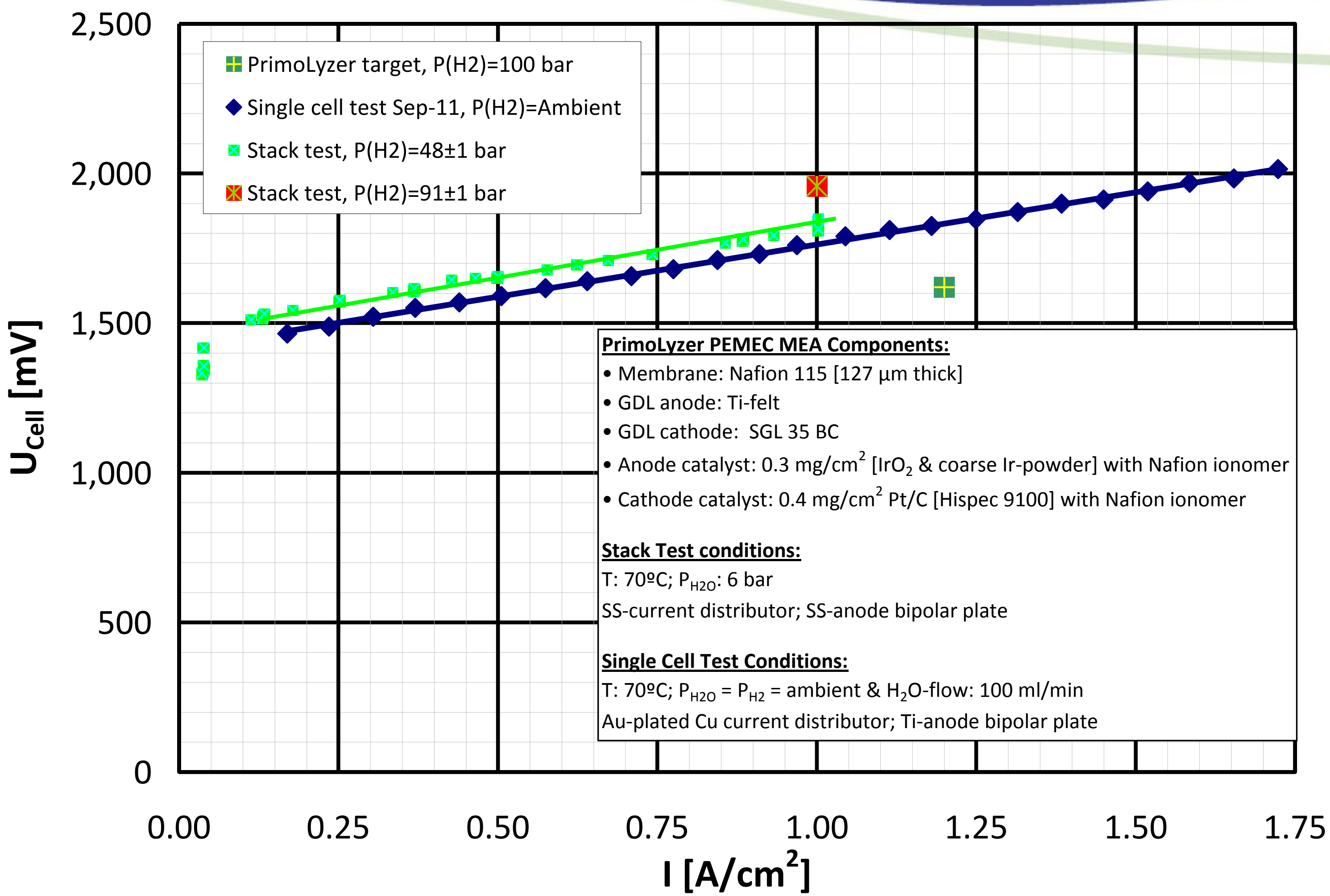
- Nominal operational pressure of 10 MPa (100 bars)
- Leakage rates that fulfil the requirements outlined in the IEC 62282-2 standard for fuel cell stacks even after 2,000 hours of continuous operation
- Water cooled to increase durability and offer the possibility of heat yield e.g. central heating
- $\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

The test of the of the PEM Electrolyzer stack will be done with a spread-out test setup with well defined operating conditions and commercial available BoP components e.g. different types and qualities of power supplies. Additionally the system will be tested as a hydrogen source for an IRD µCHP system for at least 2,000 hours.

The IRD γ-µCHP unit has the following key characteristics:

Nominal power:	1.5 kW_{AC}
Power range:	0.9-2.0 kW_{AC}
Nominal heat:	1.6 kW_{TH}
Heat range:	0.5-2.0 kW_{TH}

Efficiency (LHV) at nominal operation:

Electrical ($H_2 \rightarrow P_{DC}$)	47%
Electrical ($H_2 \rightarrow P_{AC}$)	44%
Combined efficiency	94%
Ready-mode power:	15 W_{AC}

WP 6: Evaluation

The objective of this WP is to analyse the results obtained in the previous WPs and to extrapolate and report the prototype results

Collaboration and dissemination:

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

- An international electrolysis workshop is being organized on May 10-11, 2012 in Copenhagen

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

  Organized by:

PRIMOLYSER
IRD Fuel Cell Technology
NEXPEL
SINTEF
WELTEMP Water Electrolysis at Elevated Temperatures
A project under the Seventh Framework Programme (FP7)

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

HYDROGEN AND FUEL CELLS
THE DANISH PARTNERSHIP

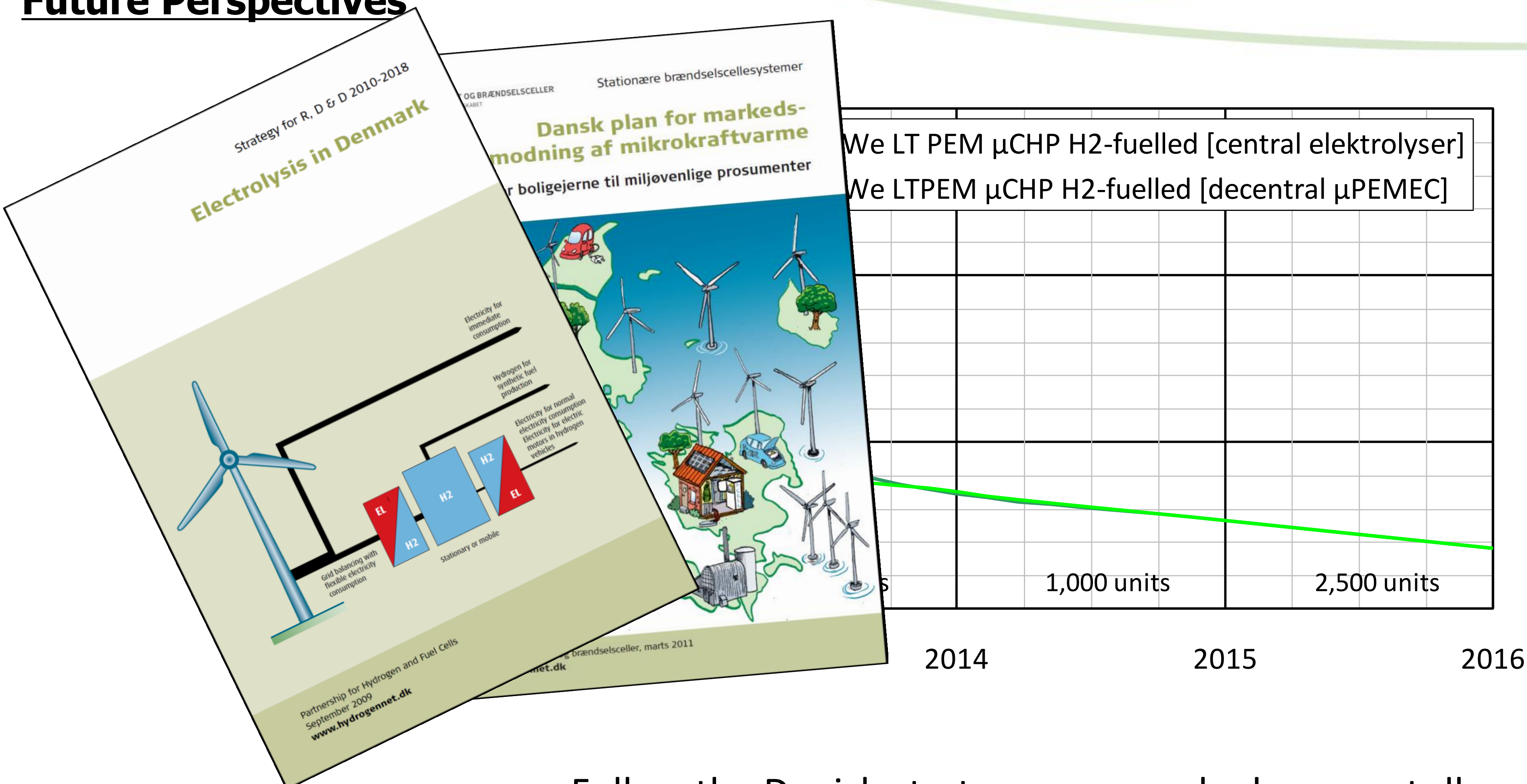
New Energy World JU
fuel cells & hydrogen for sustainability

Danish Agency for Science Technology and Innovation
Ministry of Science, Innovation and Higher Education
EUDP
Højteknologifonden

Future Perspectives for PrimoLyzer

- The on-going 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* in 2-3 years

Future Perspectives



Follow the Danish strategy on www.hydrogennet.dk

Future for Hydrogen

- Smart grid
- Efficient use of bio-mass
- Fuel for stationary applications
  and for transportation

http://www.hydrogennet.dk/fileadmin/user_upload/PDF-filer/Partnerskabet/Strategier/GreenSynFuels_report_final.pdf

Challenges for sustainable hydrogen production

- Basic material R&D necessary e.g. catalyst
- R&D on hydrogen storage needed
- International/EU legislation mandatory
  - Safety
  - Standards, Regulations, and Codes
- Modelling of economic benefits, needed
- Larger demonstration projects necessary
- Awareness of the “Valley of Death” particular for European SMEs