CISTEM

Construction of Improved HT-PEM MEAs and Stacks for Long Term Stable Modular CHP Units

Long-term testing investigations in single HT-PEM fuel cells for CHP applications: The CISTEM approach

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08.04.2016

Prague (Czech Republic)

H_2-Days 2016

Overview

- Introduction to NEXT ENERGY
- EU-Project CISTEM:
  - Technical Targets & Challenges
- Long Term Tests:
  - Test Conditions
  - Electrochemical Evaluation
  - µ-CT-Investigations
- Summary

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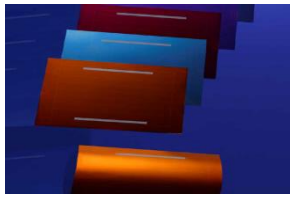
NEXT ENERGY · EWE Research Centre for Energy Technology

System Modelling and Analysis

Energy Systems

System Solutions for the Energy Transformation

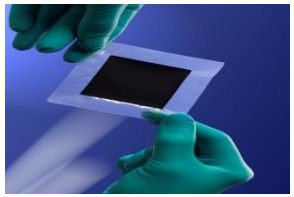


Photovoltaics

Integration of Thin-Film-Technology in Products

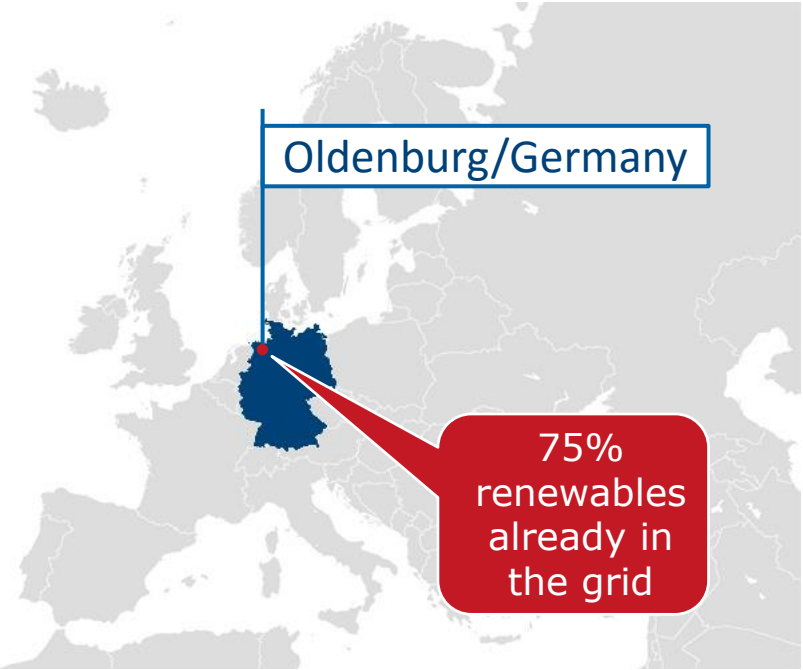
Energy Storage

Innovative Technologies for Stationary and Mobile Applications



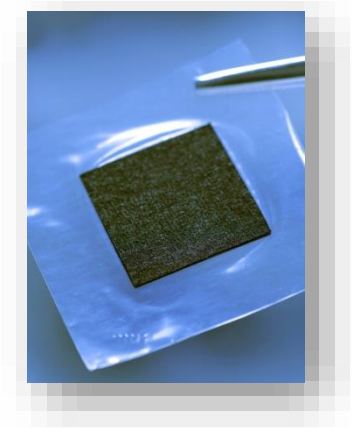
Fuel Cells

Efficient Supply of Power and Heat



www.next-energy.de

Fuel Cells Research Topics



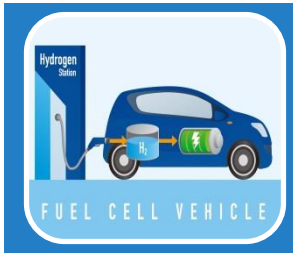
Fuel Cells
Efficient Supply of Power and Heat

Head of Division:
Dr. Alexander Dyck

Materials
Catalysts and Membranes for AEMFC, Electrochemistry

Characterisation
Analytics and Methods, Coatings, Degradation

CHP Systems
System Test and Integration, House Energy Management



Mobility
H_2 Infrastructure, Automotive Profiles and Hybrid Systems

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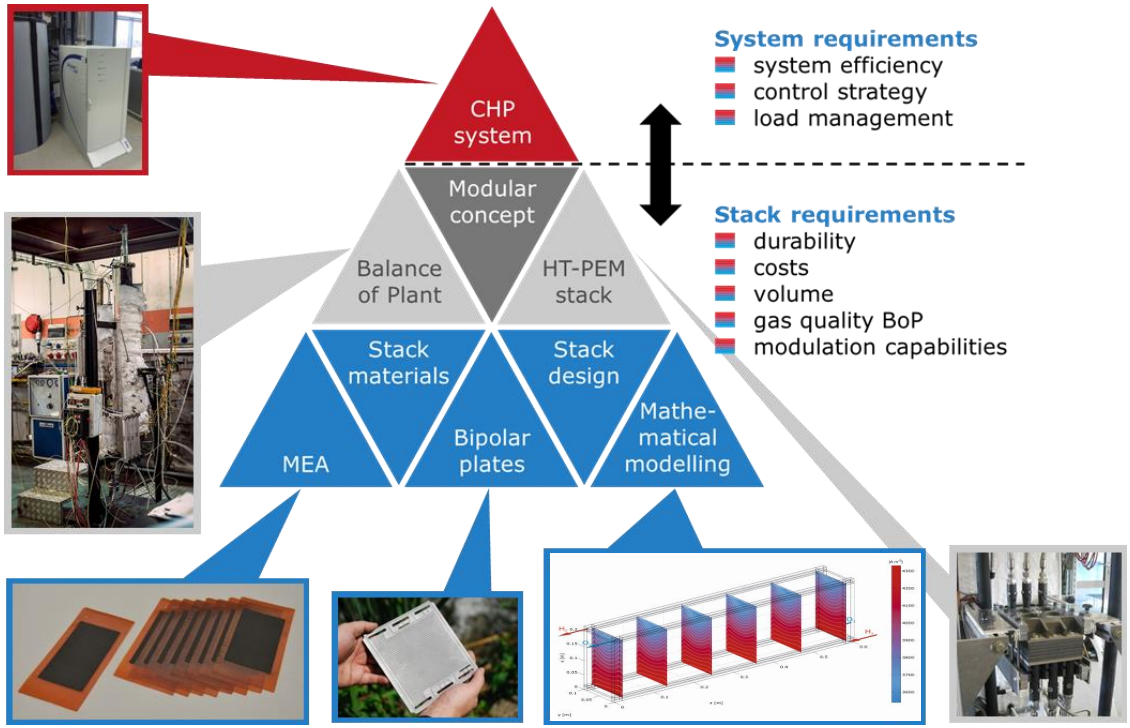
EU-Project CISTEM

- **CISTEM**: **C**onstruction of **I**mproved HT-PEM MEAs and **S**tacks for Long **Te**rm Stable **M**odular CHP Units
- **Vision**: Development of a new HT-PEMFC based CHP technology with high efficiency and long lifetime
- Proof viability of HT-PEM-FC technology for large CHP systems
- Degradation investigations: single components, MEAs, stacks, CHP units

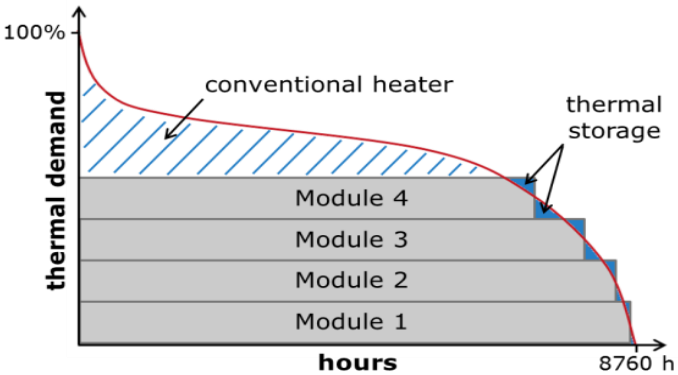


Development Overview

EU-Project CISTEM

Technical targets

- Modular setup with 4 kW_{el} stacks
- Electrical output:
  Up to 100 kW_{el}
- Electrical efficiency: > 40%
- Working temperature: 160°C
- Fuel flexible:
  pure H_2 / NG reformate
- GA No: 325262
- Duration: 1st June 2013 – 31st May 2016
- www.project-cistem.eu



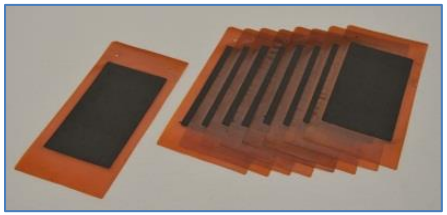
Annual load curve with modular CHP system

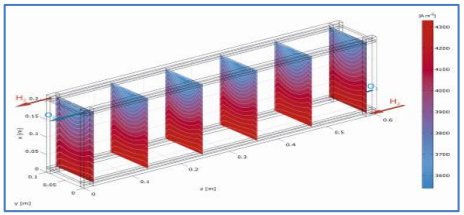
Modular Setup Approach Advantages:

- Suitability for mass production
- Higher system efficiency
- Maintenance "on the run"
- Stability and reliability

EU-Project CISTEM

Components → **Short Stacks Full Stacks** → **Balance of Plant** → **CHP Evaluation Unit** → **Operation**





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Request by FCH JU / Test Conditions

- MEAs from DPS with thermally cured membranes (3)
- 5*5 cm² cell
- Current density: 0.3 A/cm²
- Test duration: 2,000 h
- Temperature: 160 °C
- Reactant gases: H_2/air (λ=1.5/2)

- **Degradation rate: -<u>4 µV/h</u>**

Test Procedure

Start-up:
1) RT → 120°C
   N_2/N_2, 0 A/cm²
2) Reactant gases
3) Heat up: 160°C
   Load on (V< 800 mV)

Break-in:
100 h
@ 0.2 A/cm²

Test conditions:
Constant load: 0.3 A/cm²
H_2/Air

MEA Characterization:
BoL, every 1,000 h, EoT
IV

Shut-down:
1) Cool down:
   160°C → 120°C
2) Switch to N_2/N_2
   0 A/cm²,
   120°C → RT

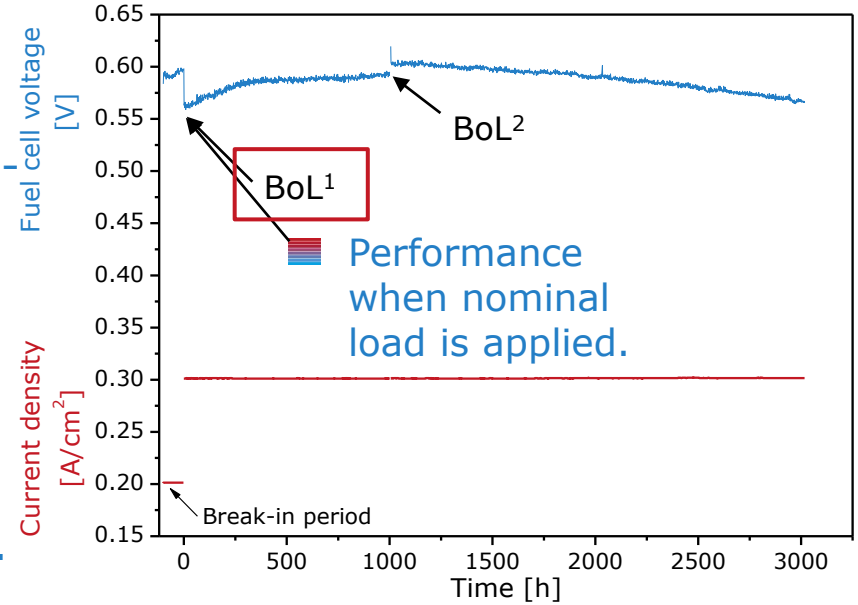
Definition of BoL

Beginning of life (BoL):

- BoL can be defined as the point in time of the first fuel cell performance at a given operational condition.

Scientific

- **BoL[1]:** First performance after break-in period.
- **BoL[2]:** Maximum performance.



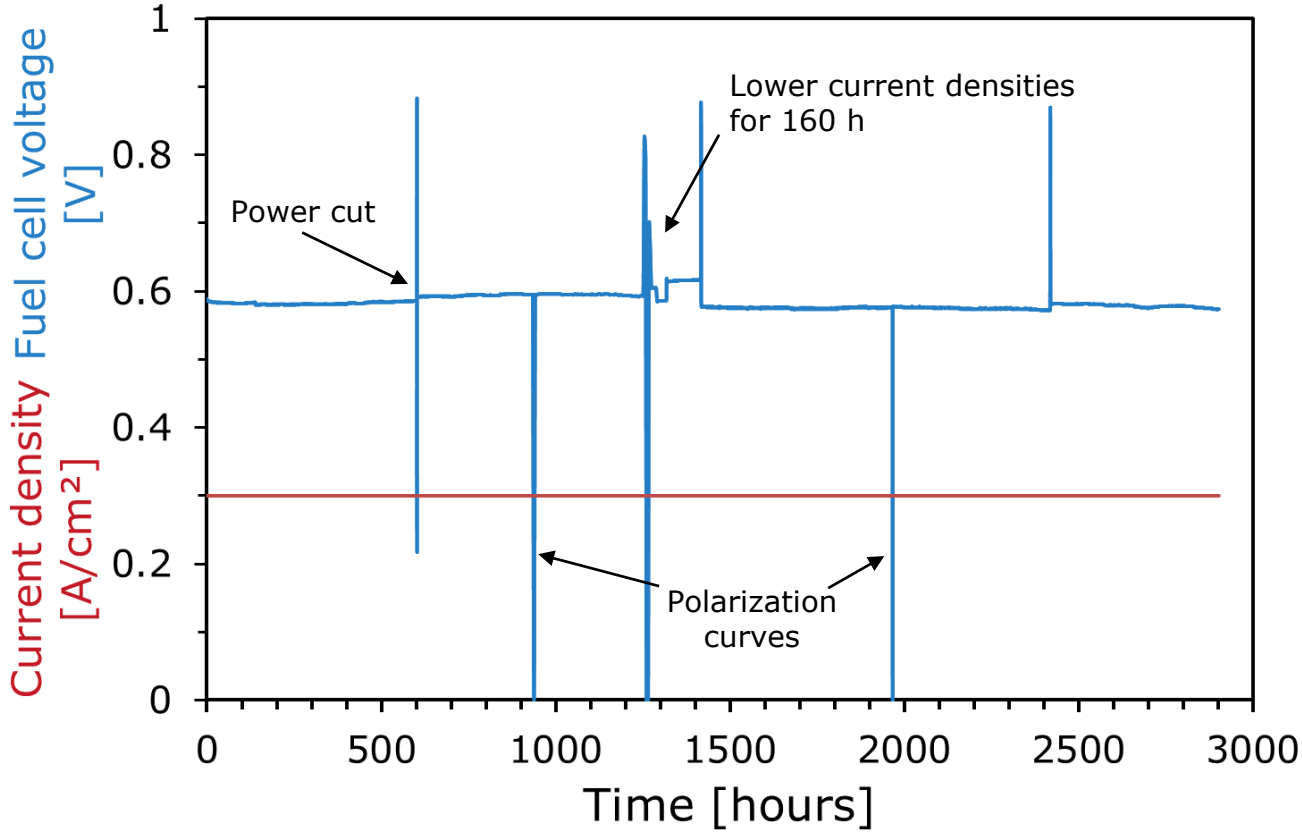
Long term test for the fuel cell operating with H_2/Air ($\lambda_{anode}/\lambda_{cathode}$ =1.5/2.0). T=160 °C, j=0.3 A/cm², p=0.1 MPa, SFF, P_c=0.75 MPa

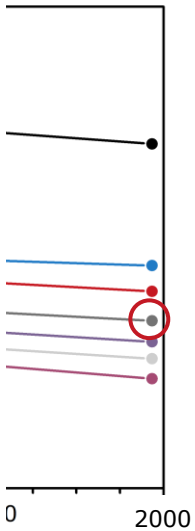
System Developer End User

- 1st performance after starting up the fuel cell for the first time.
- No customer will wait for several hundreds of hours to have a starting point.
- Break-in phase achieved in the factory after testing the CHP unit (BoL[1]).

Extended Long Term Test at DPS

- Volta points





- Degrac ation rate at 2,000 h: 3.5 µV/h = V_{loss} 0.12 % at 0.3 A/cm²
- Degradation rate at 3,000 h: -4.7 µV/h

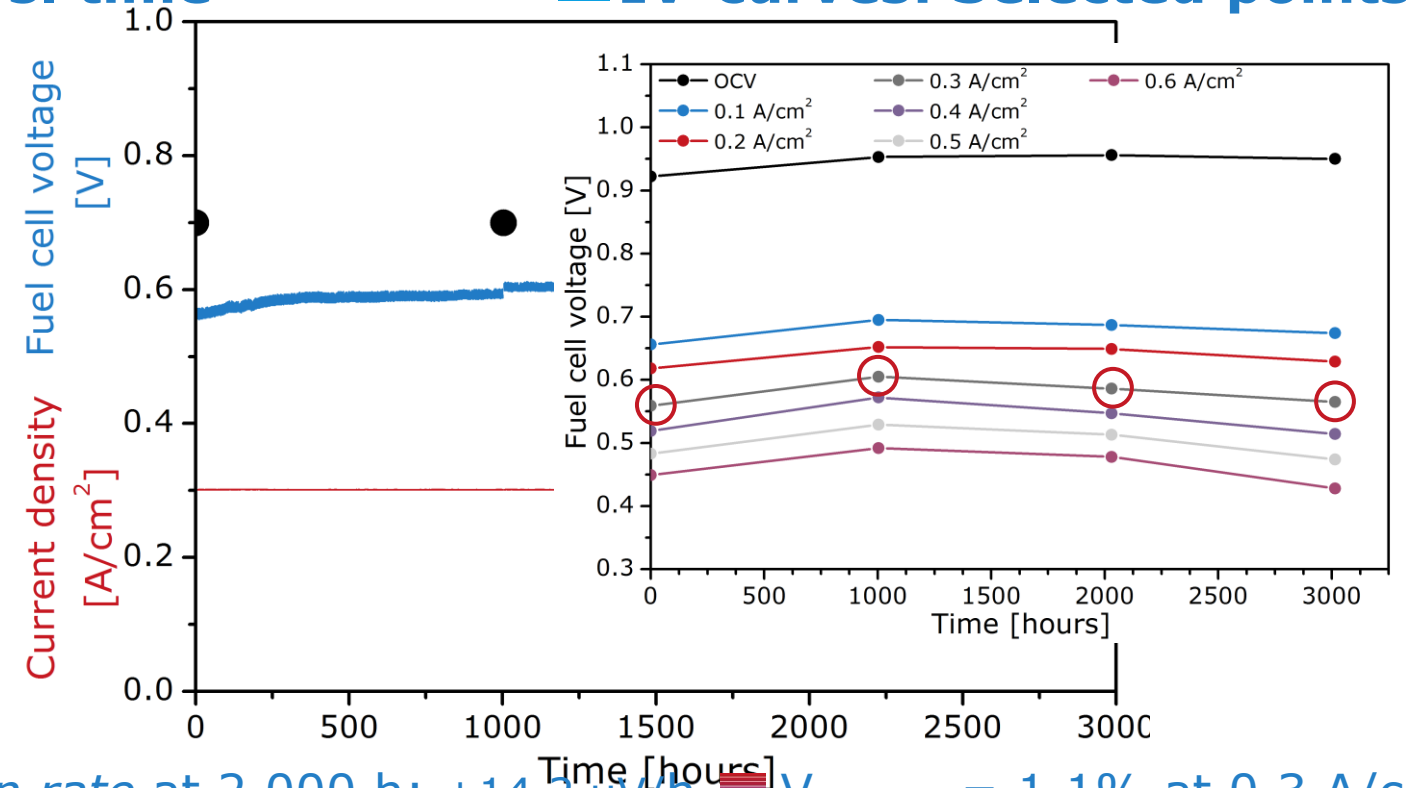
Ante Mortem Analysis: µ-CT of BoA[1]

Extended Long Term Test at DPS: µ-CT

Extended Long Term Test at NEXT - 1

Voltage vs. time

IV-curves: Selected points



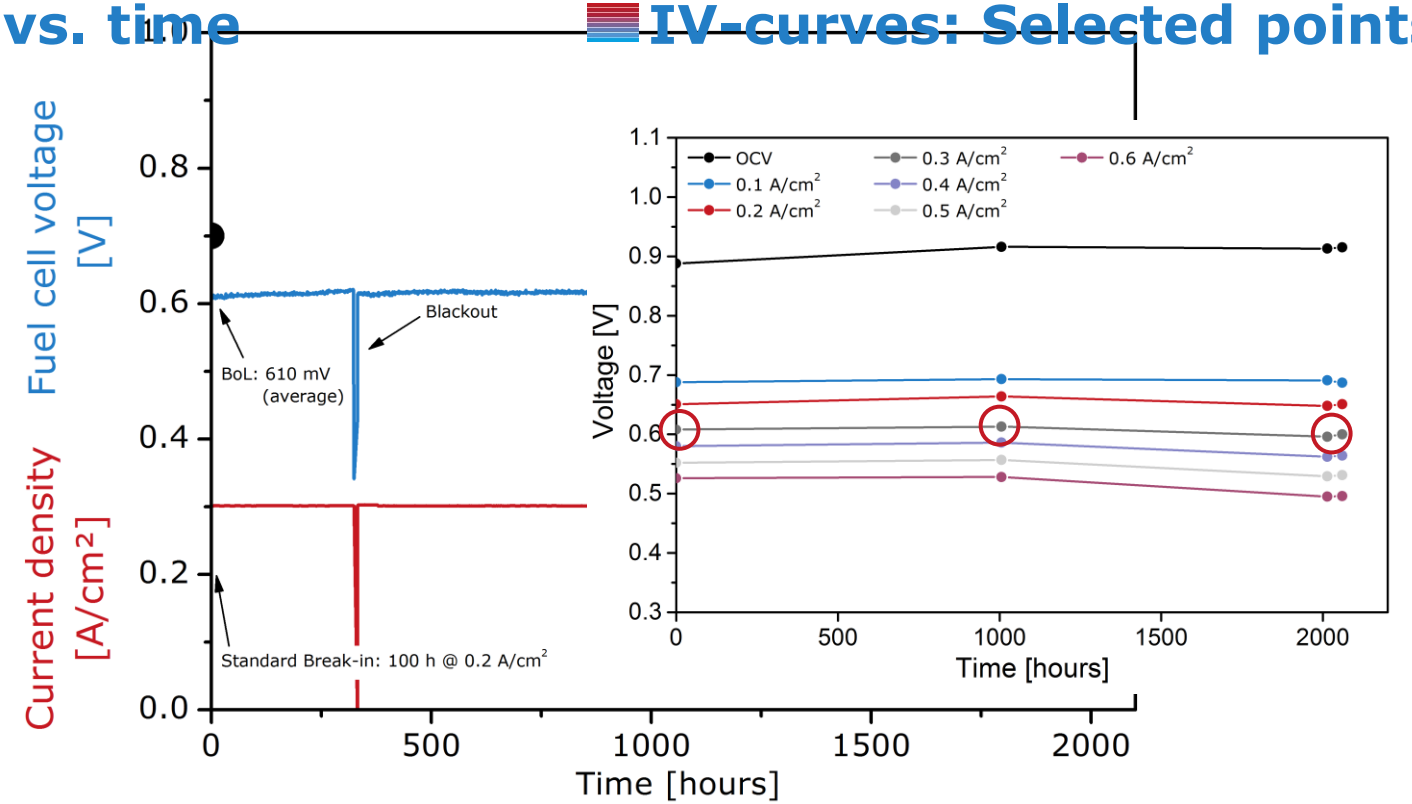
- *Degradation rate* at 2,000 h: +14.2 µV/h
- $V_{improve}$ = 1.1% at 0.3 A/cm²
- *Degradation rate* at 3,000 h: +2.0 µV/h

Extended Long Term Test at NEXT - 1

Extended Long Term Test at NEXT - 2

Voltage vs. time

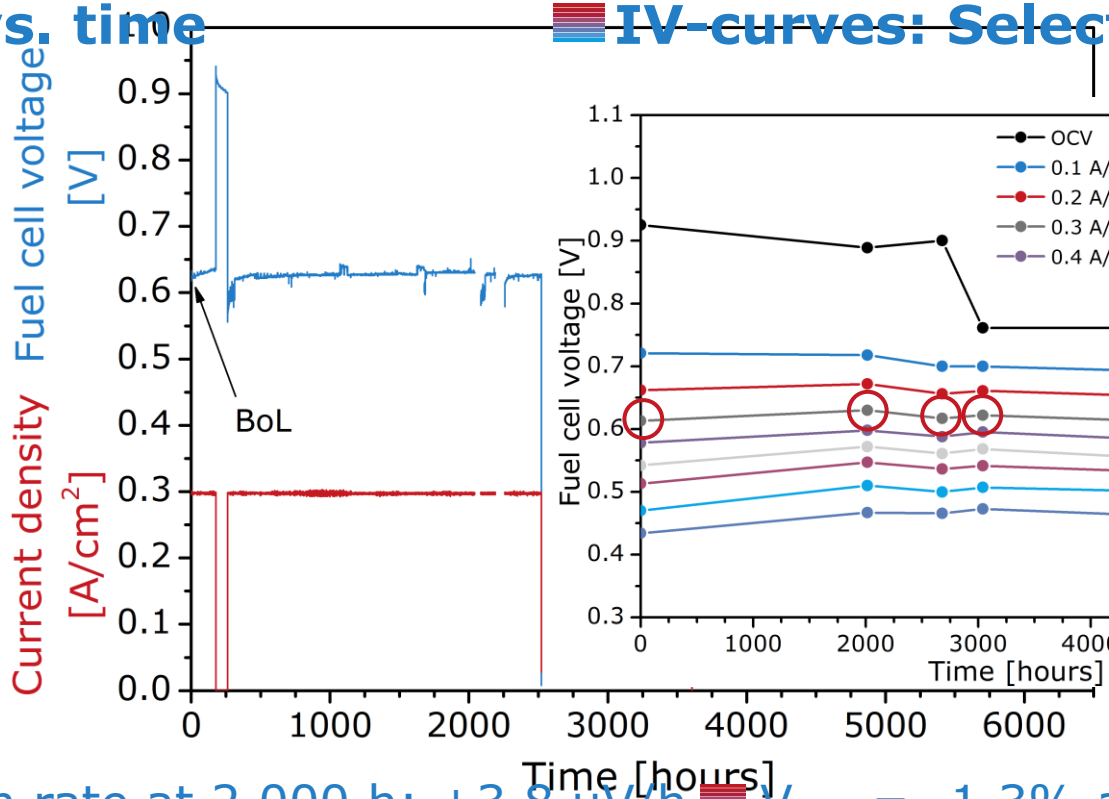
IV-curves: Selected points



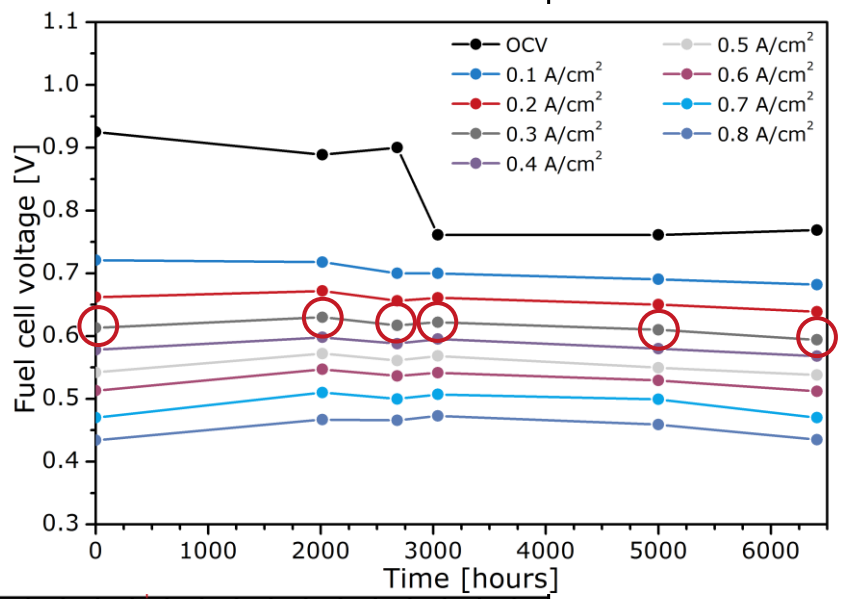
- Degradation rate at 2,000 h: -4.4 µV/h
- V_{loss} = -1.3% at 0.3 A/cm²

Extended Long Term Test at UCTP

Voltage vs. time



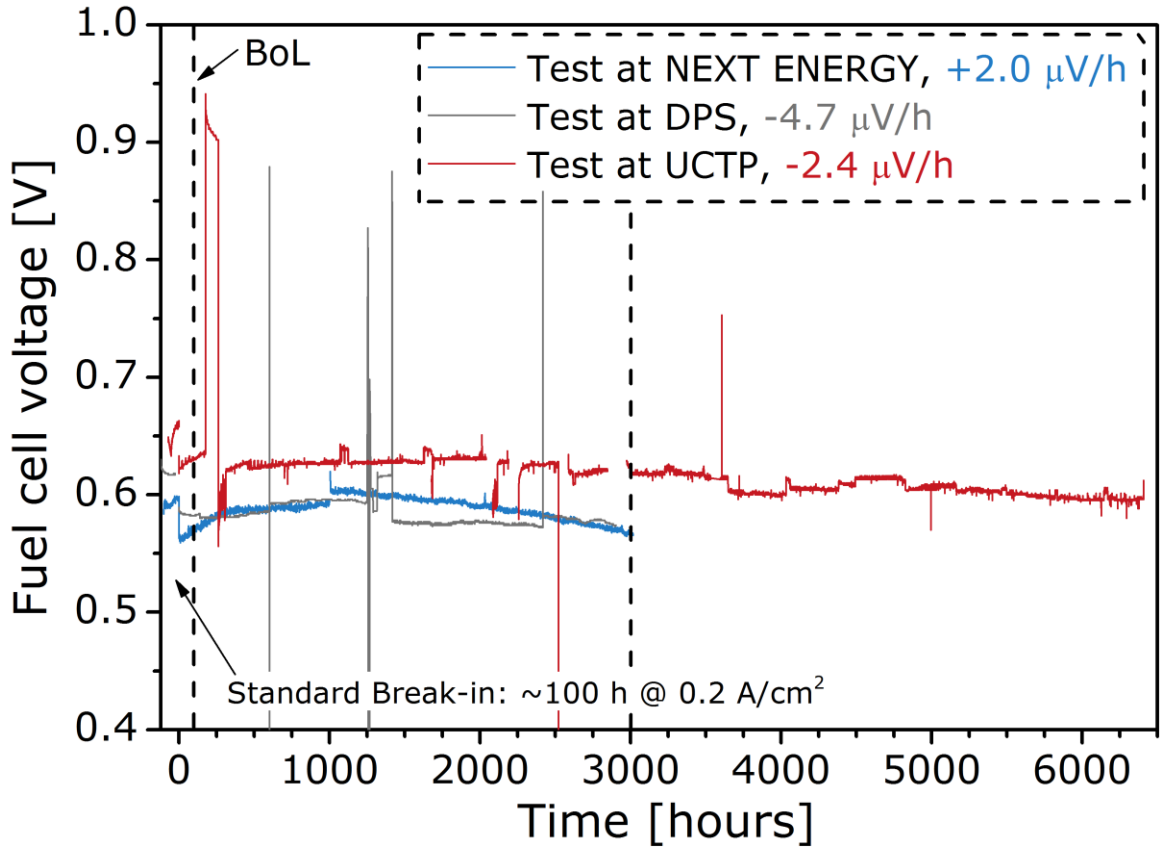
IV-curves: Selected points



- Degradation rate at 2,000 h: +3.8 µV/h
- V_{loss} = -1.3% at 0.3 A/cm²
- Degradation rate at 3,000 h: -2.4 µV/h
- Degradation rate at 6,400 h: -3.0 µV/h

Long-term Tests - Comparison

Voltage vs. time



Long term test for the fuel cell operating with H_2/Air ($\lambda_{anode}/\lambda_{cathode}$ =1.5/2.0). T=160 °C, j=0.3 A/cm² p=0.1 MPa, serpentine flow field, P_c=0.75 MPa

- MEAs tested in parallel:
  - DPS, UCTP, NE
- 3,000 h operation (DPS & NEXT)
- One test still running (UCTP): > 6,400 h
- Performance differences owing to different setup utilization.
- Blackouts and load off periods may cause FC degradation.

Long-term Tests - Comparison

Voltage rate over time / Degradation rate

MEA N°	2,000 h	3,000 h	6,400 h
MEA-14-707 (NE)	+14.2 µV/h	+2.0 µV/h	-
MEA-15-389 (UCTP)	+3.8 µV/h	-2.4 µV/h	**-3.0 µV/h**
MEA-15-396 (DPS)	-5.3 µV/h	-4.7 µV/h	-
MEA-15-529 (NE)	-4.3 µV/h	-	-

Voltage loss rate target: ≤ -4.0 µV/h (2,000 h test)

Voltage loss rate target: Ø -1.7 µV/h (3,000 h test)

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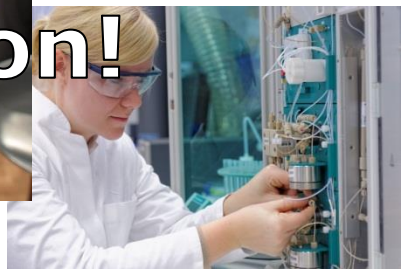
Summary

- Extended long term tests with BoA[1]-MEAs
  - Significantly improved degradation rates **< -4 µV/h** after 2,000h of operation under constant load (0.3 A/cm²) and hydrogen and air fuel supply
  - 3 differents facilities

- Further information can be found at our project webpage: www.project-cistem.eu

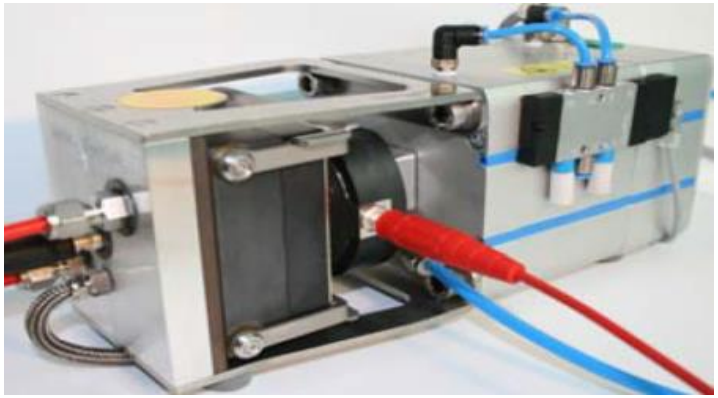
Thank you for your attention!



Construction of Improved HT-PEM MEAs and Stacks for Long Term Stable Modular CHP Units

Cell Compression Unit (CCU)

- Investigation of the role of compression on MEAs with different GDLs



- CCU: ↑ Pragma Industries ↑ Baltic Fuel Cells
  - Contact pressure range: 0.2 to 2.5 MPa
  - Operating temperature: 160°C