KeePEMalive
(GA no.: 245113)

Programme Review Day 2012
Brussels, 28th/29th November

Steffen Møller-Holst
SINTEF Materials & Chemistry

Project & Partnership description

Knowledge to **E**nhance the **E**ndurance of **PEM** fuel cells by **A**ccelerated **LI**fetime **V**erification **E**xperiments

Partner	Country	Category
ECN	NL	Research
SINTEF	**NO**	**Research**
CNRS	FR	Research
EIfER	DE	Research
SEAS NVE	DK	Industry
IRD	DK	Industry/SME
FumaTech	DE	Industry
Tech. Univ. Graz	AU	University
JRC, Petten	NL	Research

Coordinator until 28th February 2011

Coordinator as of 1st of March 2011

SP1-JTI-FCH.2008.3.3: Degradation and lifetime fundamentals

Start date: 1 January 2010
Duration: 36/42* months
Cost: €2.9 million
FCH JU funding: €1.3 million
* *Prolongation accepted*

Goals, Targets and Milestones

Part 1, slide 1 of 7

KeePEMalive's overall objectives include establishment of:

- *improved understanding of degradation and failure mechanisms for stationary PEM fuel cells, with special focus* on µ-CHP applications
- *accelerated stress test (AST) protocols, sensitivity matrix and a lifetime prediction model for stationary* µ-CHP applications

Targets for µ-CHP systems based on Low Temperature PEMFCs:

- *Lifetime of 40 000 h under real operation conditions*

Milestones

- *M1: First set of AST protocols defined using input from real life operation*
- *M2: Identification of key degradation issues*
- *M3: Definition of improved AST protocols focussing on key issues*
- *M4: Mid-Term Review, "project is progressing very well" (ext. experts)*
- *M5: Materials improved with respect to key issues identified*
- *M6: Availability of assessed AST protocols & lifetime prediction model*

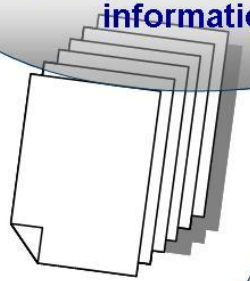
Activities & Approach

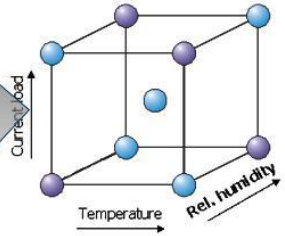
Part 1, slide 2 of 7

WP1/WP5

Systemize & synthesize all available information

Design experiments & accelerated stress test protocols



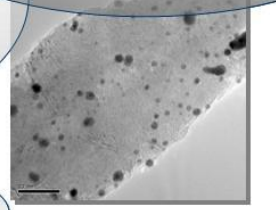


WP2

Advanced cell & stack degradation studies *in-situ-techniques*

WP3

Comprehensive materials characterization *Ex-situ- techniques*

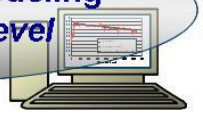


WP4

MEA manufacturing and improvements

WP5

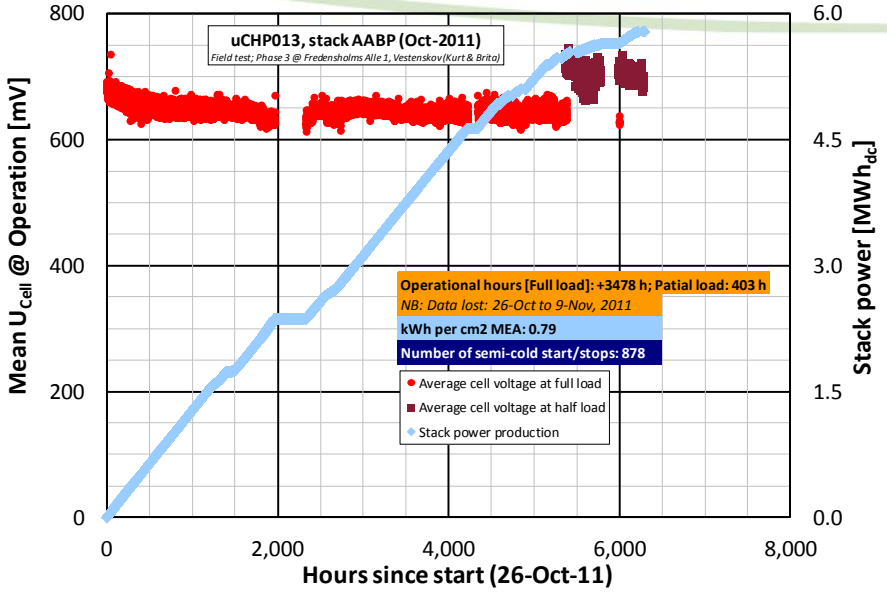
Statistical analysis & Modeling *@ Micro and Macro-level*



WP 1: From real-life operation to experimental program

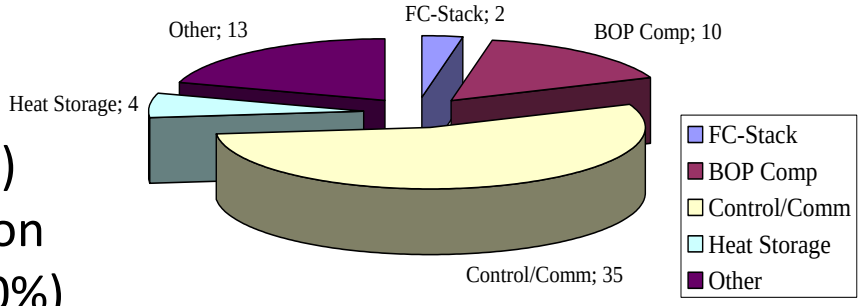
Main objective: To provide guidance for the experimental program and to define AST protocols. This will be achieved by:

- *Identification of relevant operational conditions for µ-CHP applications*
- *Definition of the experimental program and establishment of AST protocols*



Main achievement:

- ✓ Initial and revised sets of AST protocols defined based on µ-CHP field tests and results from phase I of ASTs (+ AST Stacks)
- ✓ Reduced PEMFC µ-CHP system degradation (20 ➔ 4µV/h), ➔ Lifetime ~ 17 000 h (10%)

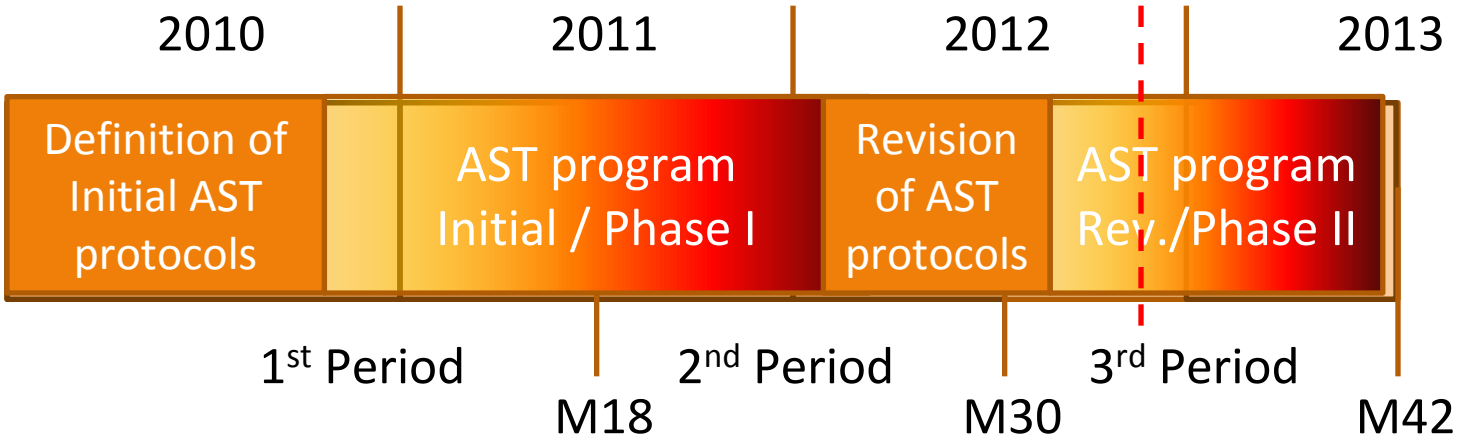


WP 2: Accelerated Stress Tests on stacks and single cells

Main objective: To obtain quantitative data on the impact of stressing conditions by application of AST protocols to single cells and stacks

Main achievement:

- ✓ Phase I of AST program completed, > 10 000 test hours, input to WP5 (challenges for ASTs on single cells encountered ➔ stack tests postponed)
- ✓ Phase II of AST program initiated, single cells (based on Revision (WP1))
- ✓ AST program for Stacks defined, tests in progress



Technical Accomplishments & Progress

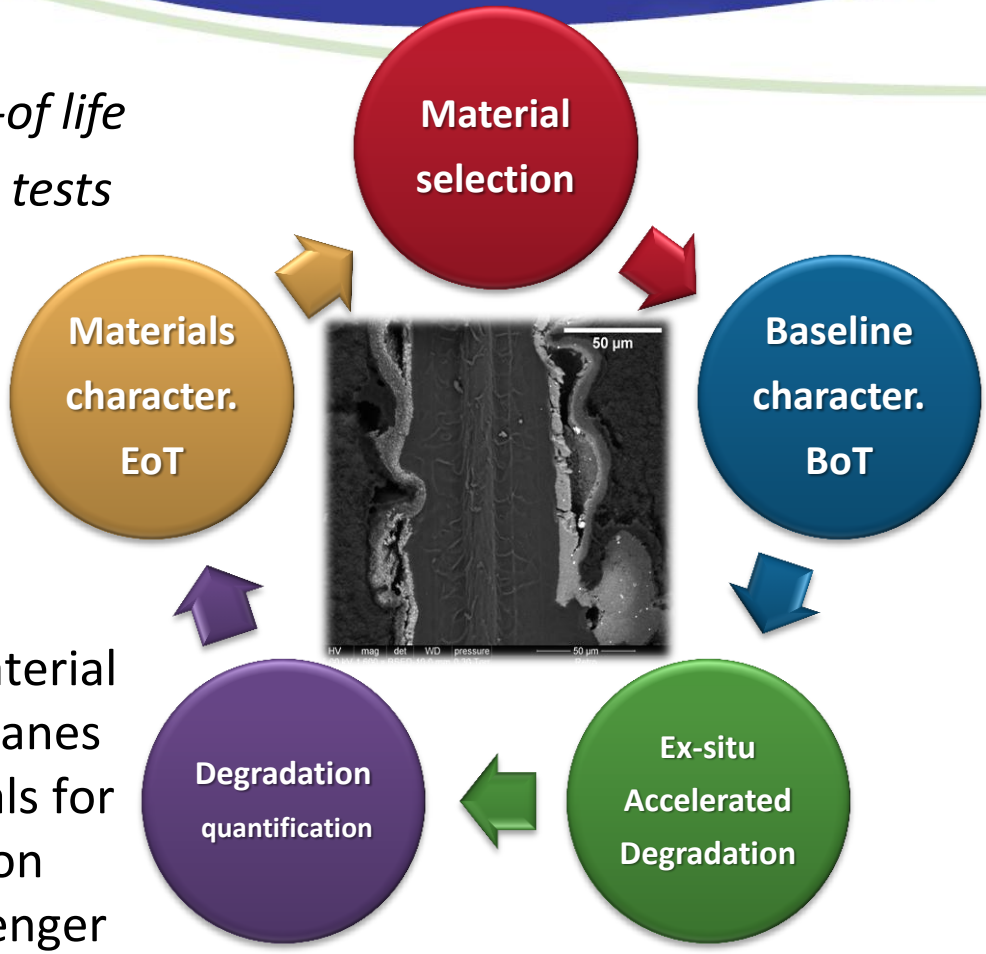
WP 3: *Ex-situ* characterization of materials

Main objective: To characterize MEA and stack components at
-beginning-of-life, end-of-test and end-of life

- *to develop ex-situ accelerated ageing tests for individual MEA component*
  - *bipolar plates, carbon-supports, supported catalysts, membranes*
- *to relate operation conditions to ex-situ characterization observations*

Main achievement:

- ✓ Provided invaluable insight into material properties for 4 generation membranes
- ✓ Contributed to selection of materials for final MEAs based on characterization
- ✓ Revealed the effect of radical scavenger ions on reducing Fluoride emissions



Technical Accomplishments & Progress

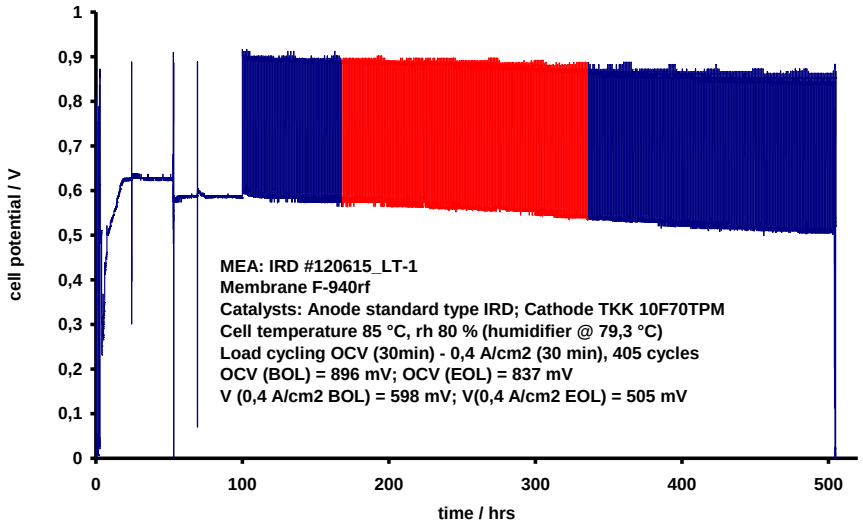
WP 4. Preparation and improvement of MEAs and components

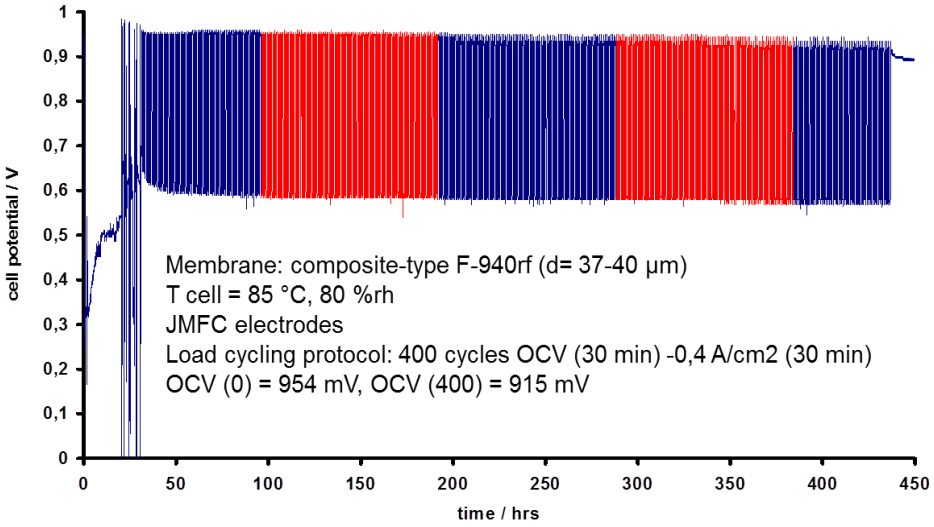
Objectives:

- To provide state of the art membranes, electrodes, MEAs and stacks.
- To develop and provide improved individual materials, MEAs and stacks with higher durability.

Main achievements:

- ✓ Improved membranes provided based on testing of 4 candidates
- ✓ Selection of improved catalyst materials from Tanaka (Japan)
- ✓ Very promising last membrane generation (radical scavengers)!





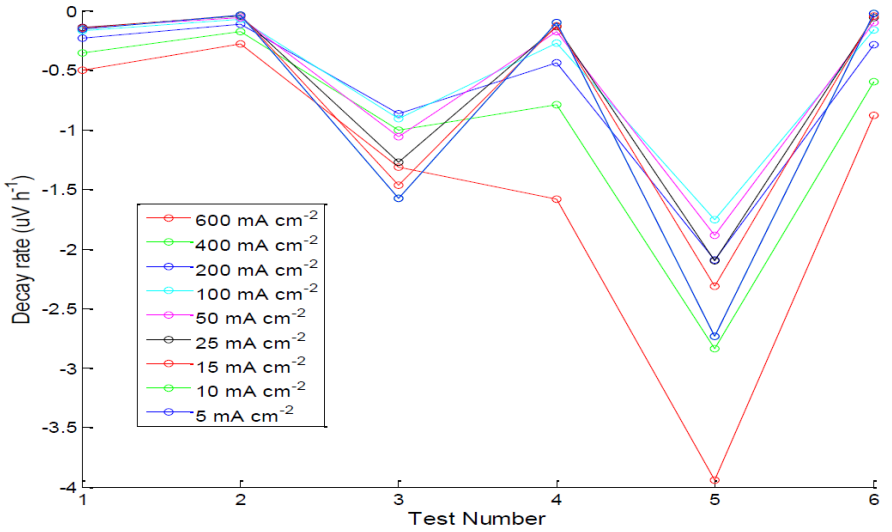
WP 5. Design & Evaluation of experiments

Objectives:

- Identify critical operating conditions for PEM fuel cell stacks
- Propose new Accelerated Stress Tests (AST) for PEM fuel cells
- Develop a lifetime prediction model

Main achievements

- ✓ Provided experimental design for Phase I of AST program (➔ WP2).
- ✓ Statistical analyses of Phase I data, identified main stressors
- ✓ Contributed to revision of ASTs (WP1).



Figure
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Table 9. Calculated Degradation Rates of Factors for the Fuel Starvation AST experiments.

		Degradation Rate (mV h^{-1})			
		@ Current Density [mA cm^{-2}]			
Factor (Unit)	Confounded w/Interaction	50	400	600	Mean
T (°C)	RH x J	-0.70	-1.04	-1.54	-0.96
RH (%)	T x J	0.71	0.70	0.81	0.85
J (A cm^{-2})	T x RH	-0.62	-0.52	-0.59	-0.72

Alignment to AA-S MAIP

Part 2, slide 1 of 4

- **MAIP Section 3.4.3 Stationary Power Generation & Combined Heat & Power:**

" The overall objective of this application area (AA-S) is to improve the technology for fuel cell stack and balance of plant components to the level required by the stationary power generation and CHP markets by bridging the gap between laboratory prototypes and pre-commercial systems."

"The goal of this application area is to achieve the principal technical and economic specifications necessary for stationary fuel cell systems to compete with existing and future energy conversion technologies. For example: electrical efficiencies should be >45% for power only units and >80% for CHP units, combined with lower emissions and use of multiple fuels. In addition, substantial effort is needed to address lifetime requirements of 40,000 hours for cell and stack, as well as competitive costs, depending on the type of application."

" Long-term and breakthrough orientated research will concentrate on degradation and lifetime fundamentals related to materials and typical operation environments for all power ranges.

Alignment to AA-S AIP08

Part 2, slide 2 of 4

- **AIP08 Section 2.2 Specific topics for the 2008 Call for proposals:**

"The emphasis of the application area Stationary Power Generation will be on ***long-term basic research to better understand degradation/failure mechanisms and the lifetime requirements of all technologically mature fuel cell stack types*** *(SOFC, MCFC,* ***PEMFC****) for different fuels and levels of power.*

For lifetime predictions, research is necessary to establish methodologies as well as tools for modelling*, operational controls* ***and diagnostics****.* ***Research should result in novel diagnostic*** *and control* ***tools and improvements of components*** *and systems* ***in terms*** *of functionality, performance and* ***lifetime****.*

Project Achievements vs. MAIP/AIP

Part 2, slide 3 of 4

- **KeePEMalive has:**

- gathered highly skilled European actors in a fruitful Pan-European cooperation
- established an overview of real-life operation conditions for µ-CHP applications
- identified the key stressors causing degradation through
  - *field tests with PEM fuel cells for µ-CHP applications*
  - *comprehensive in-situ single cell testing, incorporating long-term test*
  - *ex-situ characterization of cells and corresponding material changes*
- tested commercial materials as bench-mark for MEAs developed in consortium
- linked up to leading Japanese catalyst manufacturer Tanaka (using their product)
- manufactured and improved Membrane and Electrode Assemblies (MEAs)
- developed & revised the initial set of Accelerated Stress Test (AST) protocols
- provided feedback to project partner on MEAs performance and durability
- inspired industrial partner optimize operation conditions in on-going field-test
- Increased durability of µ CHP PEMFC stacks (3400 ➔ 17 000 h, target 40 000h)

➔ and thereby **achieved better understanding of degradation/failure mechanisms and valuable input for developing a lifetime prediction model**

Gaps & Priorities in RTD&D in MAIP/AIP

Part 2, slide 4 of 4

KeePEMalive has identified the following gaps/bottlenecks:

- *Inter-laboratory variance higher than expected, need to increase reproducibility and carry out replicate measurements to ensure reliable data*
- *Need for improved understanding of mutual influence of operational conditions on degradation (2nd and 3rd order interactions)*
- *Combined effects of chemical and mechanical degradation*
- *Adequate ratio of acceleration of degradation rates?*
- *Relevance of ex-situ degradation test with respect operation in real life*

Comments on priorities in terms of technical challenge:

- *Within the framework of the KeePEMalive project, priority is put on improved accelerated stress test protocols for fuel cells and materials*
- *Combined effects and mutual influence of stressing conditions will be addressed, but the area is too wide to be covered completely within the project*

Cross-cutting issues

Part 3, Slide 1 of 1

Training and Education

- *"International Summer School on Advanced Studies of Polymer Electrolyte Fuel Cells"*, TU Graz, 26th August – 1st September 2010, as part of the project.
- *"The hydrogen community in Vestenskov"*, master student lecture course, Montpellier, Jens Jacobsen, SEAS NVE, February 2012.

Safety, Regulations, Codes and Standards

- KeePEMalive activities are directed towards establishment of new AST protocols

Dissemination & Public Awareness, Publications

- Oral presentation of results from project (3 in 2010, 6 in 2011, 2 in 2012)
- Project website www.sintef.no/KeePEMalive
- Exploit the results by publishing in peer review journals:
  - *Ex-situ catalyst degradation, Membrane development, Results from AST Fuel Starvation & Continues Operation, Experimental design and Statistical analysis*

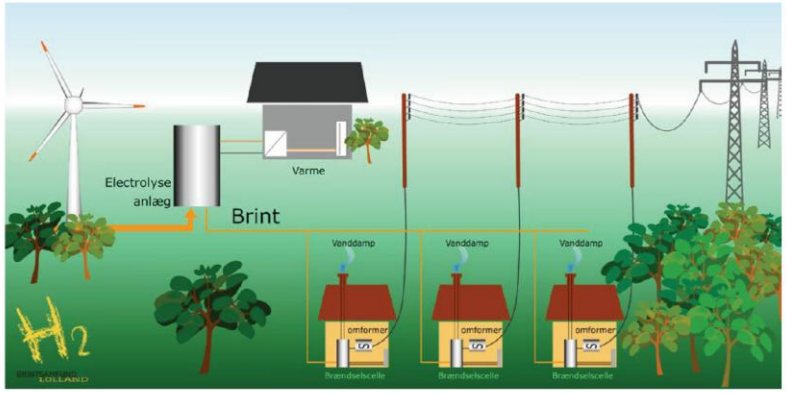
Technology Transfer / Collaborations

Part 4, Slide 1 of 3

The KeePEMalive project is linked to and interacts with a Danish µCHP demonstration project

seasonve Bass Baltic Sea Solutions

Danfoss lollandkommune



IRD Fuel Cell Technology

"Vestenskov

– the world's first hydrogen community"

3 Phases:

i) Electrolyzer for hydrogen production from wind (2006-2007)

ii) 5 selected homes equipped with µCHP (2007-2010)

iii) 35-40 selected homes equipped with µCHP (2010-2012)

Technology Transfer / Collaborations

Part 4, Slide 2 of 3

Collaborations and links, KeePEMalive project:

- Link to previous work on testing protocols performed within FCTEST^{QA}
- An active collaboration with the Japanese catalyst manufacturer Tanaka is formalized via FUMATECH, partner of the KeePEMalive project
- Informal collaboration and exchange of information between FCH JU funded projects "STAYERS" and "DECODE" through partners SINTEF & JRC
  - *Aiming at including parts of scientific findings from these projects in statistical analysis of degradation and model establishment*
- Exploit the results to further improve partners products

Project Future Perspectives

Part 4, Slide 3 of 3

KeePEMalive's Future Perspectives (M30-M42)

- Concentrate effort in WP2 and WP3 to provide more data to WP5 (modeling)
- Assess remaining resources and a potential redistribution of PMs between WPs
- Allocate more PM to WP6 Project Management (currently 2%)
- Disseminate results internationally, at EU, Member States and Regional levels

- Possible contribution to the future FCH JU Programme
    - *More reliable AST-protocols for stationary µCHP PEMFCs*
    - *Lifetime Prediction Model, code made available for use in new projects*

Acknowledgements

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New Energy World JU

fuel cells & hydrogen for sustainability

http://www.fch-ju.eu/

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