

Simulation, statistics and Experiments  
Coupled to develop Optimized and Durable  
 $\mu$ CHP systems using Accelerated Tests

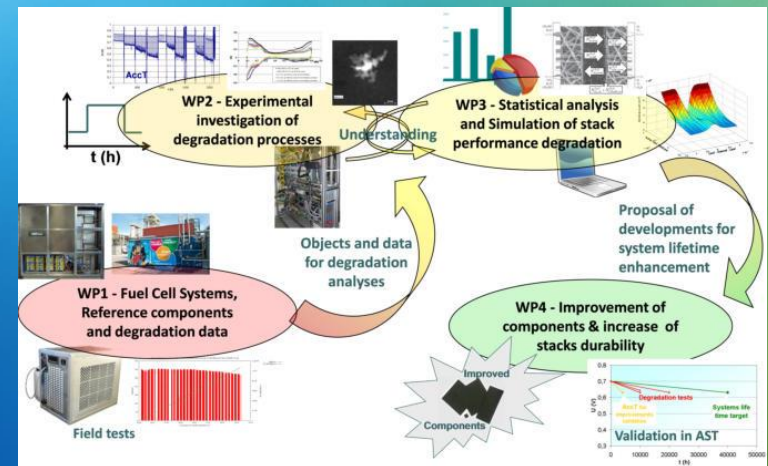
# Second Act

(621216)



Sylvie Escribano  
CEA/Liten

[www.second-act.eu](http://www.second-act.eu)



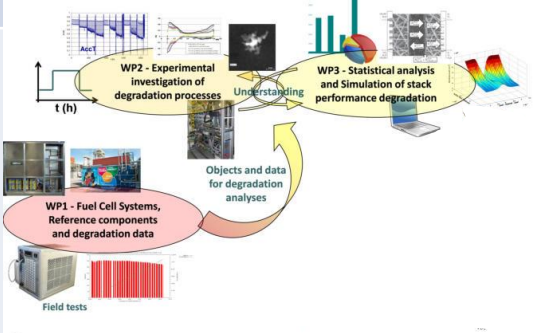
# Second Act OVERVIEW

- Simulation, statistics and Experiments Coupled to develop Optimized aNd Durable  $\mu$ CHP systems using ACcelerated Tests
- AIP SP1-JTI-FCH.2013.3.1 - Improving understanding of cell & stack degradation mechanisms using advanced testing techniques, and developments to achieve cost reduction and lifetime enhancements for Stationary Fuel Cell power and CHP systems
- 01/05/2014 to 30/04/2017
- Total budget: 4 643 707 € - FCH JU contribution: 2 523 254 €  
SINTEF / additional funding NRC Norway (< € 130 000)

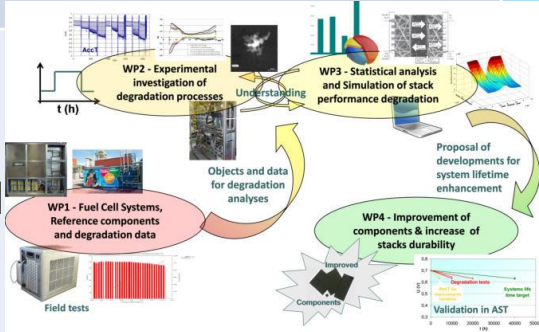


- Overall purpose of project: to improve understanding of stack degradation and propose durability improvements for  $\mu$ CHP systems using PEMFC or DMFC.
- 45% completed

# PROJECT TARGETS AND ACHIEVEMENTS

Programme objective/target	Project objective/target	Project achievements to-date	Expected final achievement
<b>MAIP / Stationary FC system lifetime</b>			
<p><b>Lifetime requirement of 40,000 h for cells and stacks</b></p> <p>1-Degradation and lifetime fundamentals related to materials and typical operation environments for all power ranges.</p> <p>2-Proposal of new or improved materials</p>	<p>1-Better understanding [cells &amp; stack] [H<sub>2</sub>, Reformate &amp; DMFC]</p> <p>2-Demonstrating lifetime improvements [stack core components modifications] (enabling &gt;20,000 h for H<sub>2</sub> syst. case)</p>	<ul style="list-style-type: none"> <li>Reference test objects defined [MEAs, cells &amp; stacks]</li> <li>Ageing tests conducted in nominal or accelerated conditions [test stations or systems]</li> <li>Data analyses &amp; degradation investigations [exp. &amp; modelling tools]</li> </ul>	 <ul style="list-style-type: none"> <li>Identification of possible improvements</li> <li>Implementation of modified MEA components</li> <li>Confirmation of reduced voltage degradation [selected protocols]</li> </ul>

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<b>AIP / Systems lifetime improvement</b>			
<p>Identify improvements and verify these in existing cell and stack design</p>			

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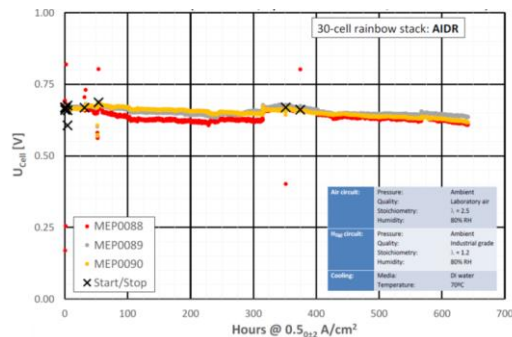
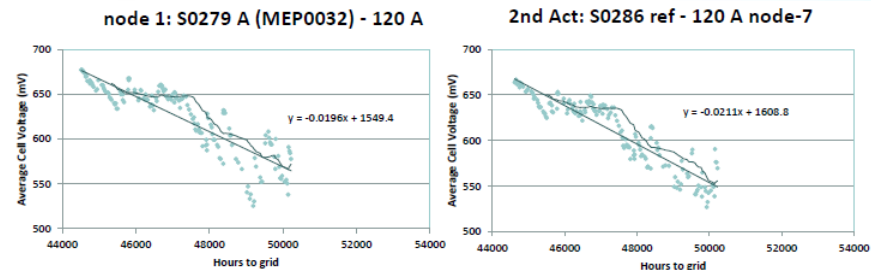
## AIP / Systems degradation causes

Identify, quantify and document relevant degradation and failure mechanisms over the long term (i.e. >20,000 hours)

Collection, production and statistical analysis [ageing data - cell, stack, system - 3 FC techno]

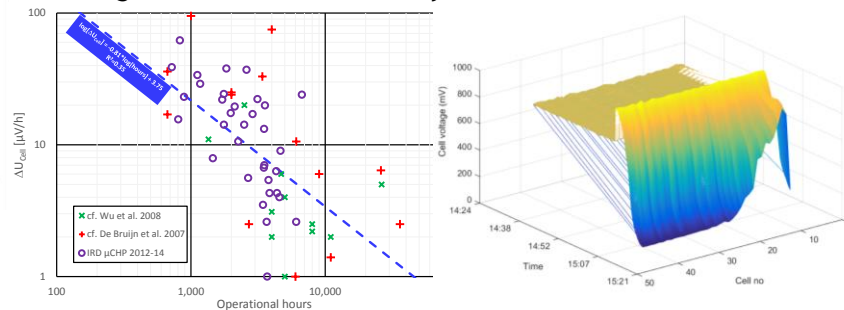
Collection of ageing data from past projects and existing field test systems  
Additional ageing tests in progress on tests stations and also in the 70kW power plant reaching 50000 hrs.

	System	Partner	Stack (200 or 20cm <sup>2</sup> )	SC test (25 or 200cm <sup>2</sup> )
Hydrogen	1.2 & 1.5 kW <sub>AC</sub>	IRD	Nedstack	Sintef
Reformate	50 kW	Nedstack	CEA	DLR TUG JRC
	30 - 10 & 3kW	ICI	ICI	Sintef
Methanol	500 / 800 W	IRD	CEA	CEA JRC
			IRD	Polimi IRD



### → Statistical analyses

Link between performance losses & specific events  
Plotting tools evaluation for analysis of transients & failure modes



- Extensive ageing tests
- Data collection incl. Tests of cells and stacks (~>1000 hrs) & >3000 hrs on a power plant reaching 50000hrs of operation

# PROJECT TARGETS AND ACHIEVEMENTS

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## AIP / Applications-relevant investigations

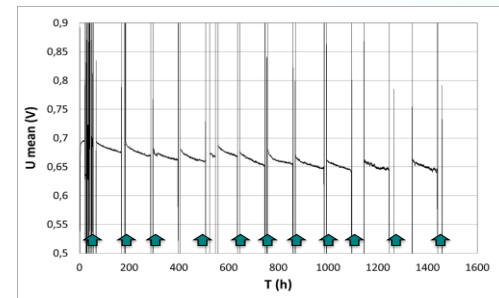
Quantification by **accelerated testing** and/or by durability testing under **harsh conditions**, compared to **application-relevant conditions**.

Iterative loops of **testing** and **numerical simulation** coupled with advanced **in-situ** or **ex-situ** analyses.

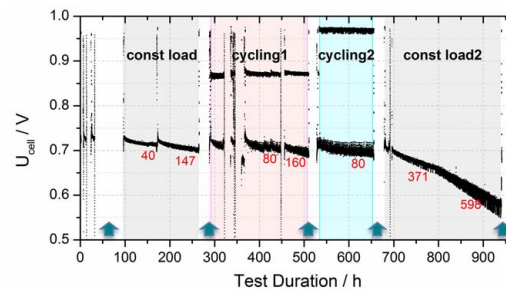
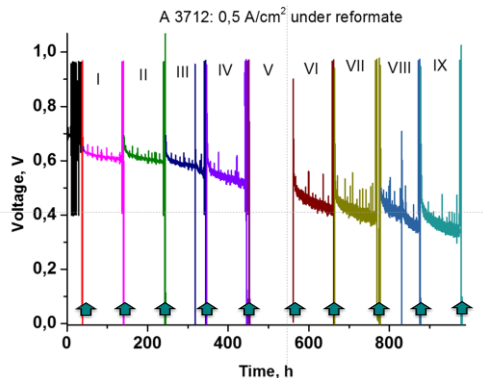
**Reversible** and **non-reversible** degradation of performance studied with **ageing tests** coupled to **ex-situ analyses** and **modelling** for better evaluation of mechanisms impact.  
Proposal and application of accelerating degradation tests.

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↑ **In-situ Electrochemical analyses Specific diagnostics during ageing tests**



→ **Ex-situ analyses at EoT (XPS, TEM)**



- Extensive ageing tests
- Data collection incl. Tests of cells and stacks (~>1000 hrs) & >3000 hrs on a power plant reaching 50000hrs of operation

# PROJECT TARGETS AND ACHIEVEMENTS

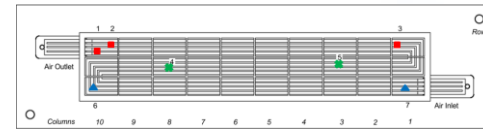
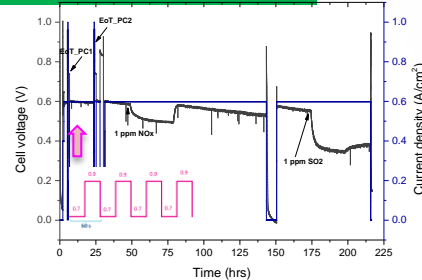
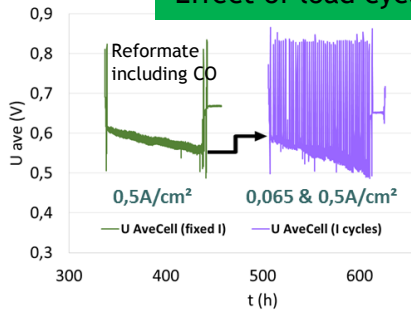
Programme objective/target

Project objective/target

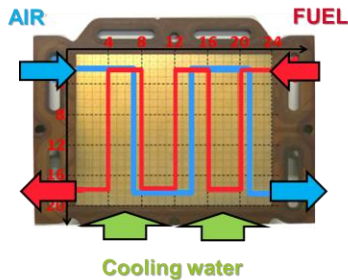
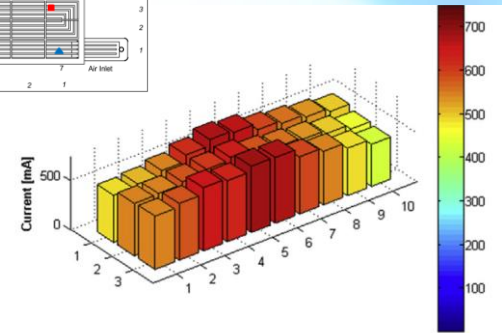
Project achievements to-date

## AIP / Applications-relevant investigations

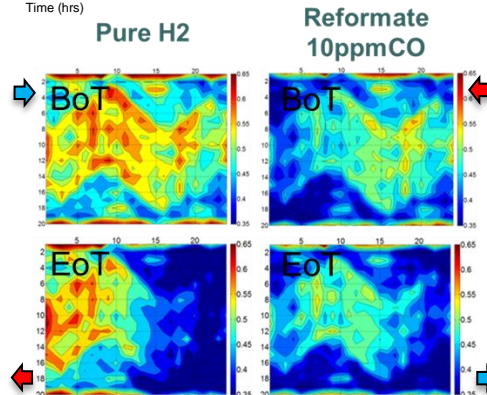
### Accelerating & harsh conditions Effect of load cycles and contaminants



Segmented SC: effect of pinholes on local losses (normal operation or fuel starvation).



S++ in PEMFC stack: effect of fuel and ageing mode



Local in-situ measurements /  
Segmented cells  
Initial heterogeneities ~ f(conditions)  
Impact of ageing conditions on the  
heterogeneities  
Diagnostics

# PROJECT TARGETS AND ACHIEVEMENTS

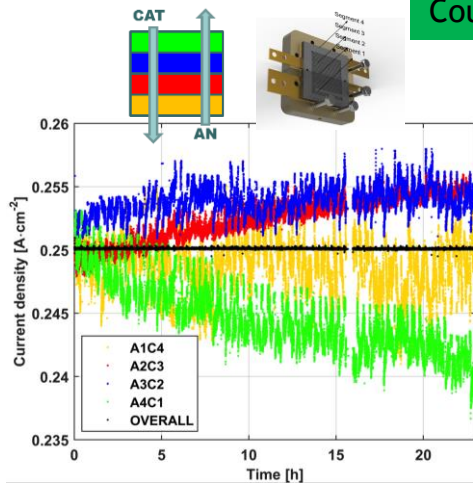
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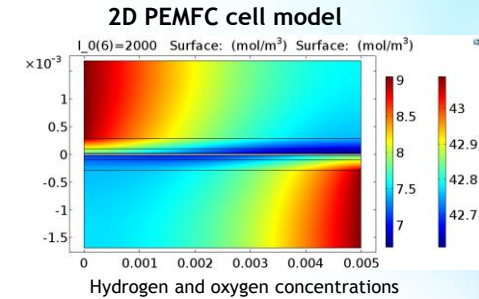
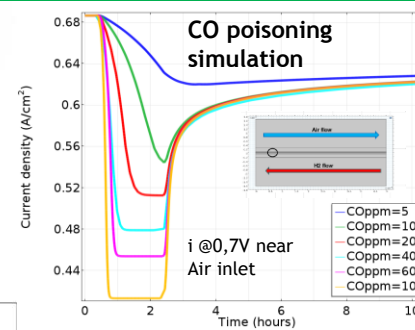
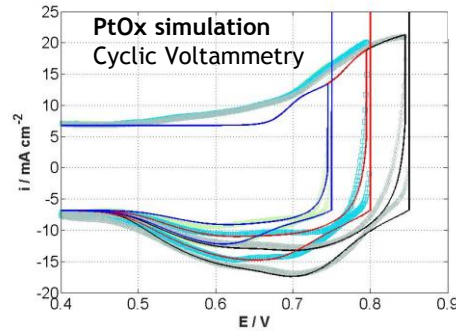
Project achievements to-date

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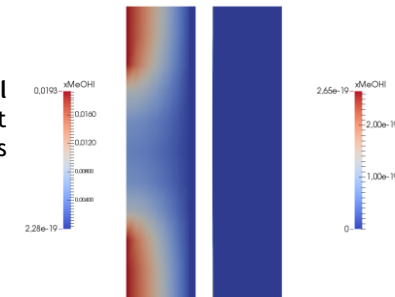
Understanding performance losses reversibility & degradation heterogeneities  
Coupling mechanisms & local conditions in cell models



Specific experiments with segmented cell & internal reference for local analyses and modelling validation of reversible losses during DMFC operation.



2D DMFC cell model  
Investigate the effect of heterogeneities





# RISKS AND MITIGATION

- Understanding of reversibility & heterogeneities
  - Risk related to the objectives concerning identification of causes for local performance degradation
  - Ageing data are interpreted thanks to experimental and modelling investigations but causes still unclear → *additional specific experiments*
- Durability improvements
  - Risk related to the objectives concerning demonstration of reduced degradation thanks to components improvement for three technologies.
  - Improvements will be proposed but it cannot be ensured that expected higher durability will be obtained for all the technologies considered at cell and stack level or reliable for system → *selection process*

# SYNERGIES WITH OTHER PROJECTS AND INITIATIVES

- Interactions with any international-level projects or initiatives
  - Second Act partners are involved in the IEA Advanced Fuel Cells implementing agreement, Annex 31 and Annex 35

Members can disseminate key aspects of Second Act in IEA workshops.
- Interactions with European-level projects
  - Premium Act, Keepemalive and Stayers**
    - Methodology, knowledge, protocols, ageing data used as bases
  - PUMAMIND**
    - Methodology and knowledge for models development.
  - MATISSE**
    - Joint development of segmented cell analyses

# HORIZONTAL ACTIVITIES

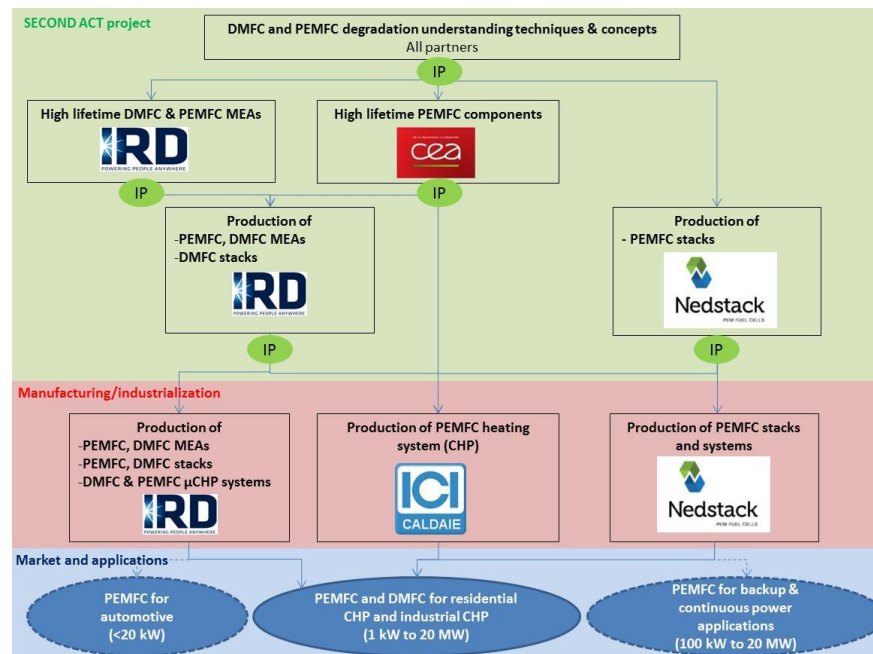
- Training activities organised by the project
  - **PhD students** involved at R&D partners
- Safety, regulations, codes, standards:
  - **TC105/WG11** (Single cell test protocols): SECOND ACT partners are involved in this international Fuel Cell technology committee. Possible to promote the project inside this group and investigate about the possibility to organize sessions about Fuel Cell degradation
- General public awareness:
  - EXPO2015 in Milan: general dissemination of FCH-JU contribution and Second Act by FCH-JU executive director during a public conference organized by Polimi on “*Energy and the integrated management of resources: system thinking for technician and policy makers*” (06/2015)

# DISSEMINATION ACTIVITIES

- 17 contributions to workshops and conferences in Austria, Belgium, Swiss, Germany, France and Greece
  - Several contributions to FDFC Toulouse & EFCF Luzern
- Publications:
  - **TU-Graz:** *Effect of pinhole location on degradation in polymer electrolyte fuel cells.* **J. Power Sources** (2015) 295, S. 336 - 348
  - **POLIMI, CEA, DLR, IRD:** *A combined in-situ and post-mortem investigation on local permanent degradation in DMFC* **J. Power Sources**, in revision

# EXPLOITATION PLAN/EXPECTED IMPACT

- FCH technology development
  - Better knowledge / degradation causes
  - Specific improvements for reduced degradation of 3 techno / systems considered
- Project's results exploitation



# Acknowledgements



Thank you for your attention