LoLiPEM - Long-life PEM-FCH &CHP systems at temperatures ≥100°C (FCH-JU - G.A. 245339)

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Partner number	Partner name	Country
1 (coordinator)	CNR – Institute on Membrane Technology	Italy
2	The University of Roma “Tor Vergata”	Italy
3	The University of Provence	France
4	The University of Saarbruecken	Germany
5	Edison S.p.A.	Italy
6	FuMA-Tech GmbH	Germany
7	MATGAS 2000 AIE	Spain
8	Cracow University of Technology	Poland

Project goals, targets, and milestones

The **main objective** of the present project is to give a clear demonstration that **long-life SPG&CHP systems based on PEMFCHs operating at temperatures ≥ 100°C can now be developed** on the basis of recent knowledge on the degradation mechanisms of membranes disclosed by some participants in this project.

In order to conciliate the achievement of the main objective with the need of durability, low cost and an easy management, investigation of several sub-objectives will be necessary concerning development of stable and less expensive membranes, development of more stable catalytic electrodes as well as physical-chemical characterizations of the obtained products.

Sub-objectives …

- Creating stable Perfluoro Sulfonic Acid (PFSA, e.g. Nafion) membranes operating with current density at least 0.7 A/cm^2
- Long term durability for stationary FC operation in air at temperatures by at least 20°C higher than that of the state-of-the-art
- Creating new stable non perfluorinated ionomers, such as sulfonated aromatic polymers (SAPs, e.g. SPEEK, SPEEK-WC, Fumion, etc), much less expensive than PFSA in order to reduce the cost of the co-generation systems
- Reducing the costs by optimizing the water management and the cell pressure using new equations recently developed

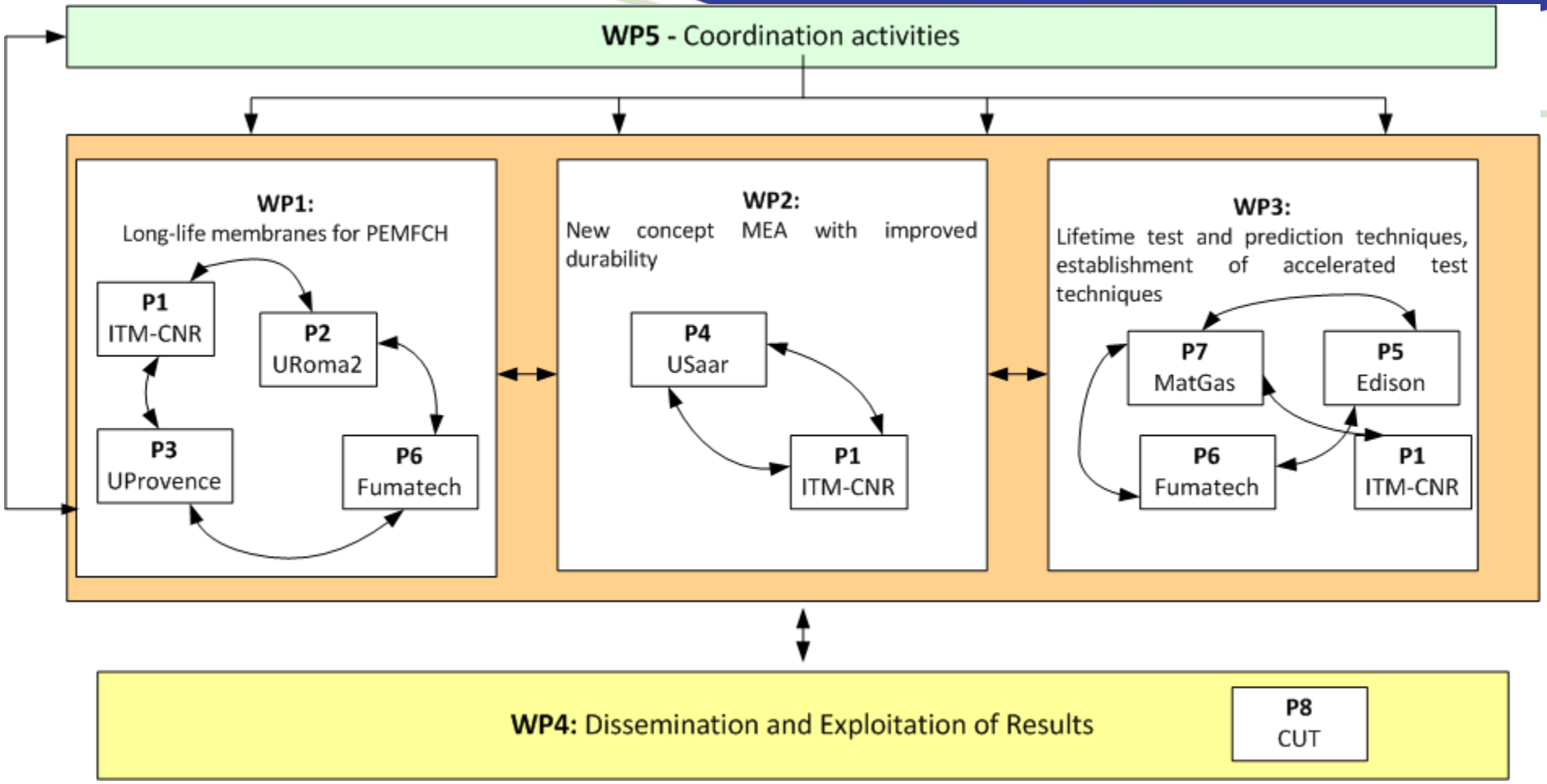
… Sub-objectives

- Creating new catalytic electrodes more stable at the operating temperatures
- Reducing the cost of the high temperature FCH by facilitating the replacement (“use and discard”) of MEAs
- Establishment of accelerated test techniques and lifetime prediction methods
- Benchmarking the single-cell performances at temperatures ≥ 100°C
- Prototype development of a Modular multi-PEMFCHs system for Combined Heat and Power
- Exploiting the results in terms of patents for the industrial partners, publications in high impact international journals and top international conferences, reaching out to the public and increasing the awareness of this technology

Specifications foreseen in LoLiPEM project

PEM parameters	PFSA	SAPs
	End of project	End of project
operating temperature of membrane (maximum)	120°C	140°C
operating temperature in fuel cell (maximum)	120°C	140°C
membrane conductivity @ 90%RH	> 0.1 S/cm	> 0.07 S/cm
liquid water uptake @ 100°C	40%	< 50%
mechanical integrity @ RH cycling and condensing conditions	Yes	Yes
Durability @120°C	> 40.000 h within 10 years with start-stop	> 40.000 h within 10 years with start-stop
MEA performance @ 0.65 V	0.7 A/cm²	0.7 A/cm²

Interdependencies among the partners



Project structure

WP1 – Long-life membranes for PEMFCH

- Preparation of stabilized Perfluoro sulfonic acid (PFSA) membranes
- Cross-linked sulfonated aromatic polymers (SAP) membranes
- Ex-situ characterization of stabilized membranes.
- Permeation measurements for the evaluation of mass transport properties of the membranes

WP2 – New concept of MEA with improved durability

- Catalytic electrodes for temperature > 100°C
- Membrane-electrode assembly (MEA
- Design of use and discard MEAs: Design of a MoPEM system for facilitating the installation and replacement of a single PEMFCH.

Project structure

WP3 – Life-time tests and prediction techniques, establishment of accelerated test technique

- Durability studies of PEM-FCH & CHP system at temperature 100°C. Accelerated aging durability studies
- Long-term durability tests
- Post mortem analysis of MEAs
- To facilitate the installation and replacement of a single PEMFCH a prototype long-life Modular multi-PEMFCHs system for Combined Heat and Power (MoPEM-CHP) is designed

WP4 – Dissemination and exploitation of results

- Dissemination. Goal is to establish appropriate communication channels between the project consortium and external audiences .
- Exploitation. Strategy will put attention on potential markets, business models and management of IPR issues emerging during implementation of the project.
- Exchange of Researchers and seminars/workshops.

Strategies to improve the durability and the stability at T>100°C

To improve the durability and stability of the MEA at a temperature higher than 100°C, the following new strategies will be applied :

For the membrane:

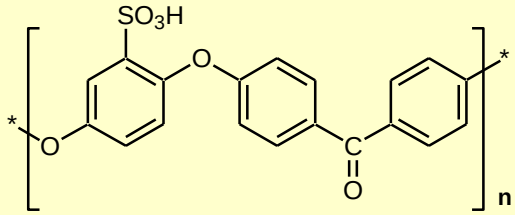
- Thermal annealing
- Chemical crosslinking

- For the catalyst
  - novel electrodeposition techniques from precursor layers, which enables to deposit electrocatalysts directly onto gas diffusion layers (GDL) and thus transforms them directly into gas diffusion

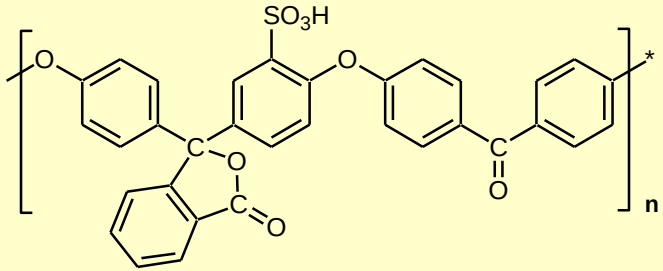
WP 1. Long-life membranes for PEMFCH
Most significant results

Crosslinked SAPs (SPEEK, SPEEK-WC, Fumion® ST310, Fumion® STO305, Fumion® S60, Fumion® S340, Fumion® S204) **membranes endured temperatures up to 140°C, reaching, in some cases, a conductivity of 0.07 S cm^{-1} at 100°C and 95% RH**.

(A)

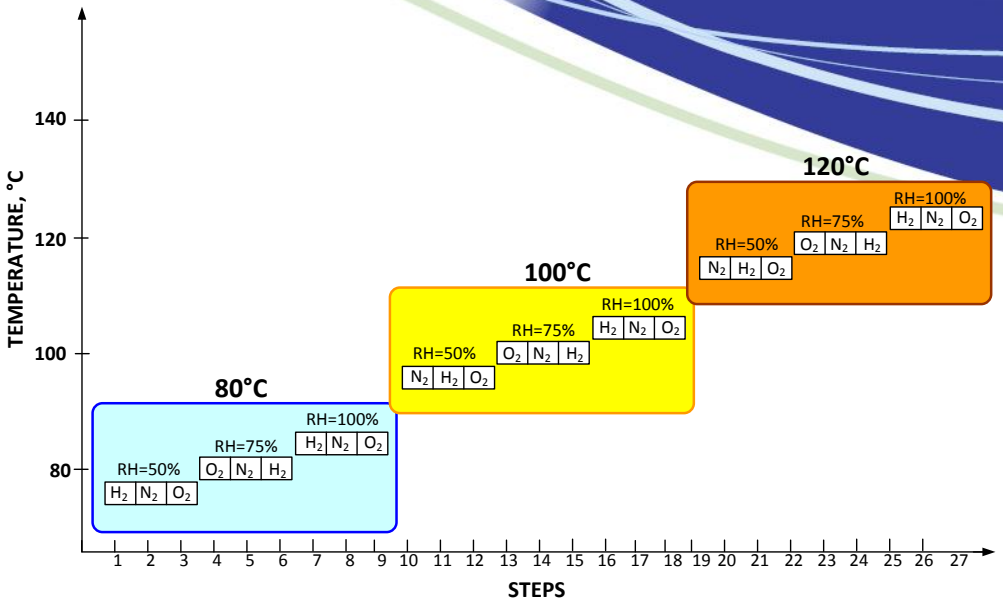


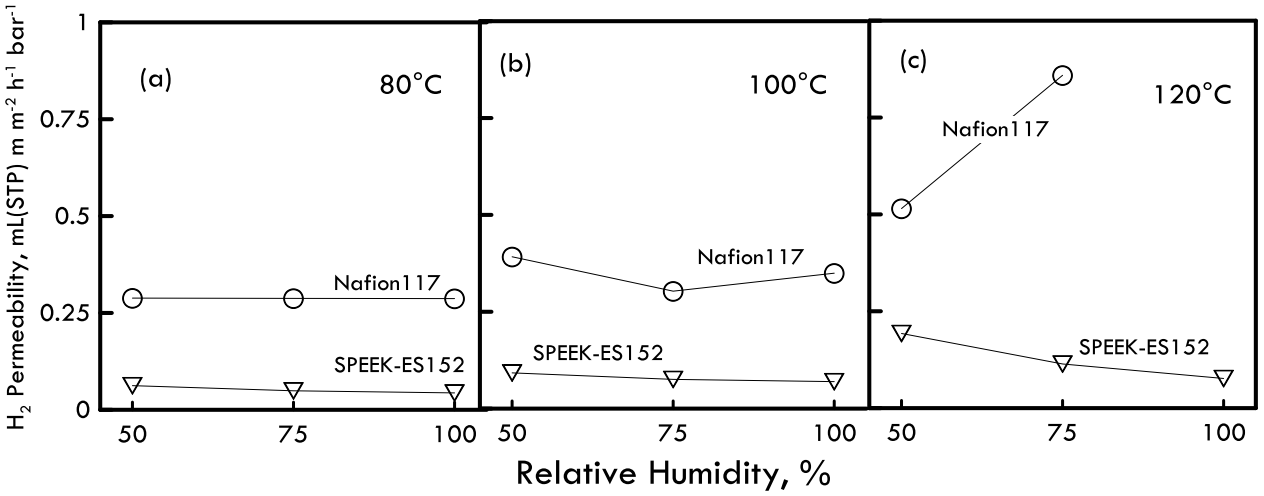
(B)



We demonstrated that for PFSA membranes, **the thermal annealed Nafion 212 is stable up to 120°C**.

Mass transport properties measurements

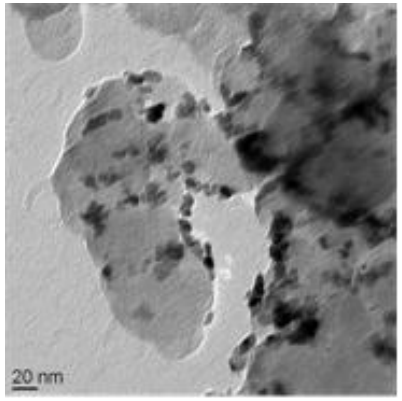


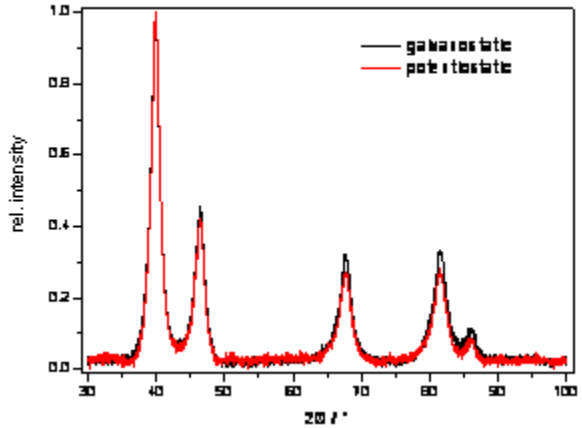


The mass transport properties measurements confirmed a high durability of membranes under stressed conditions. Globally, the SAP membranes showed significant higher fuel barrier properties (lower permeability) than native Nafion.

WP 2. New concept of MEA with improved durability
Most significant results

- The electrocatalyst prepared in this project are very good, although the particle size of the nanoparticles is considerably larger . The larger size means higher stability regarding the particle growth at elevated temperatures
- As a result of the electrodeposition process the degree of catalyst utilization is much higher: essentially all of electrocatalyst nanoparticles are in contact with both the ionically conducting ionomer and the electronically conducting electrode materials.



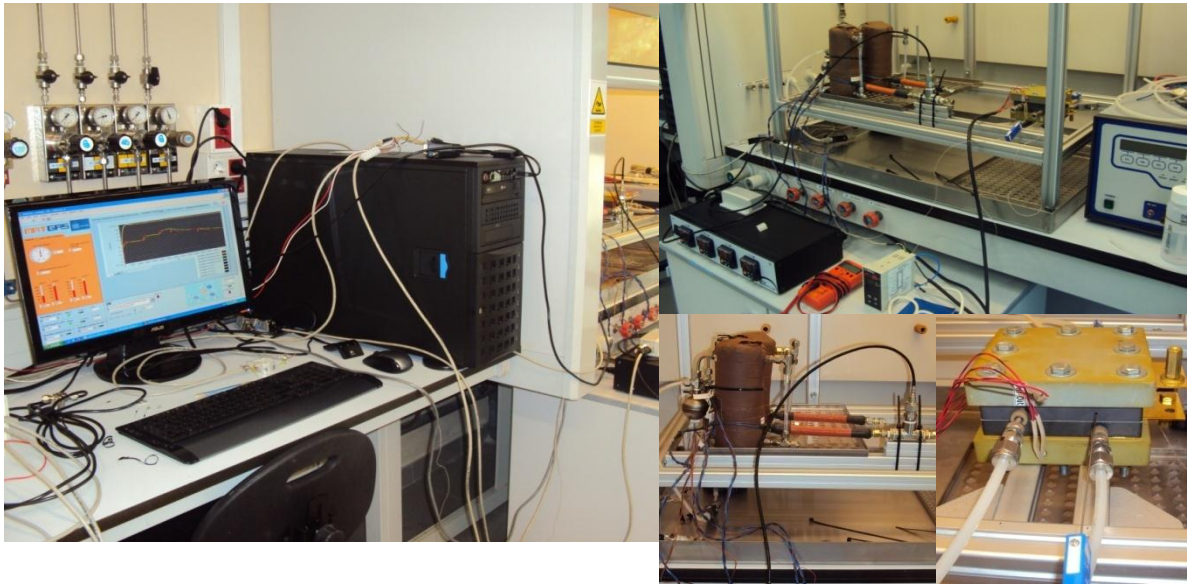


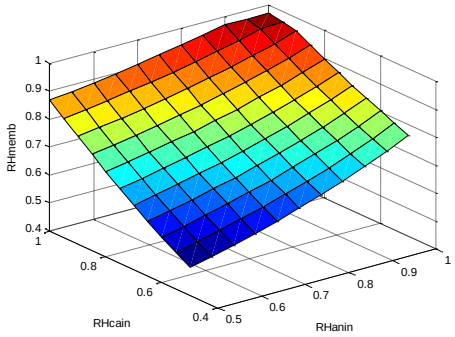
WP 3. Lifetime test and prediction techniques, establishment of accelerated test techniques. Most significant results

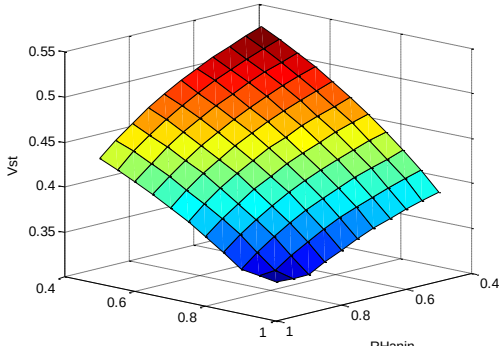
A protocol for MEAs characterization and accelerated tests has been elaborated and used for characterization at high temperature.

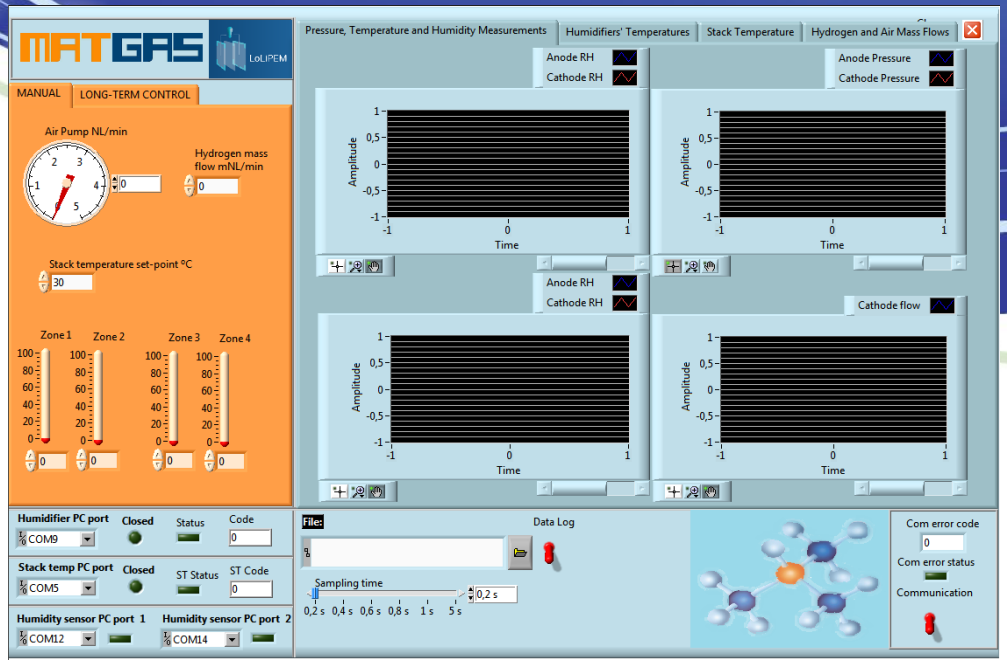
WP 3. Lifetime test and prediction techniques, establishment of accelerated test techniques. Most significant results

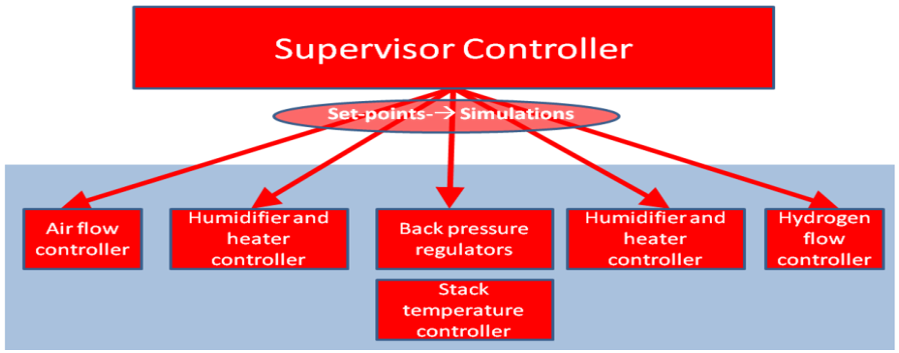
The bench system has been improved including the control system specifically operating on the temperature and relative humidify as required by the project and it has been utilized with some MEAs.

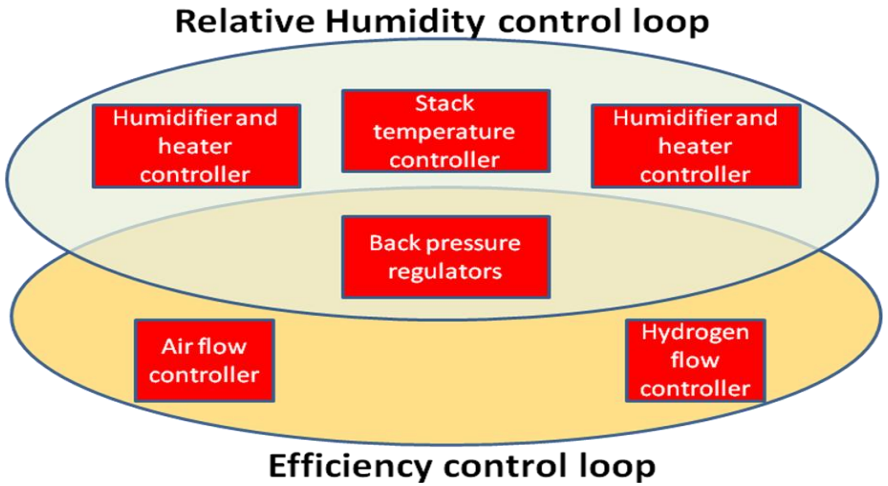




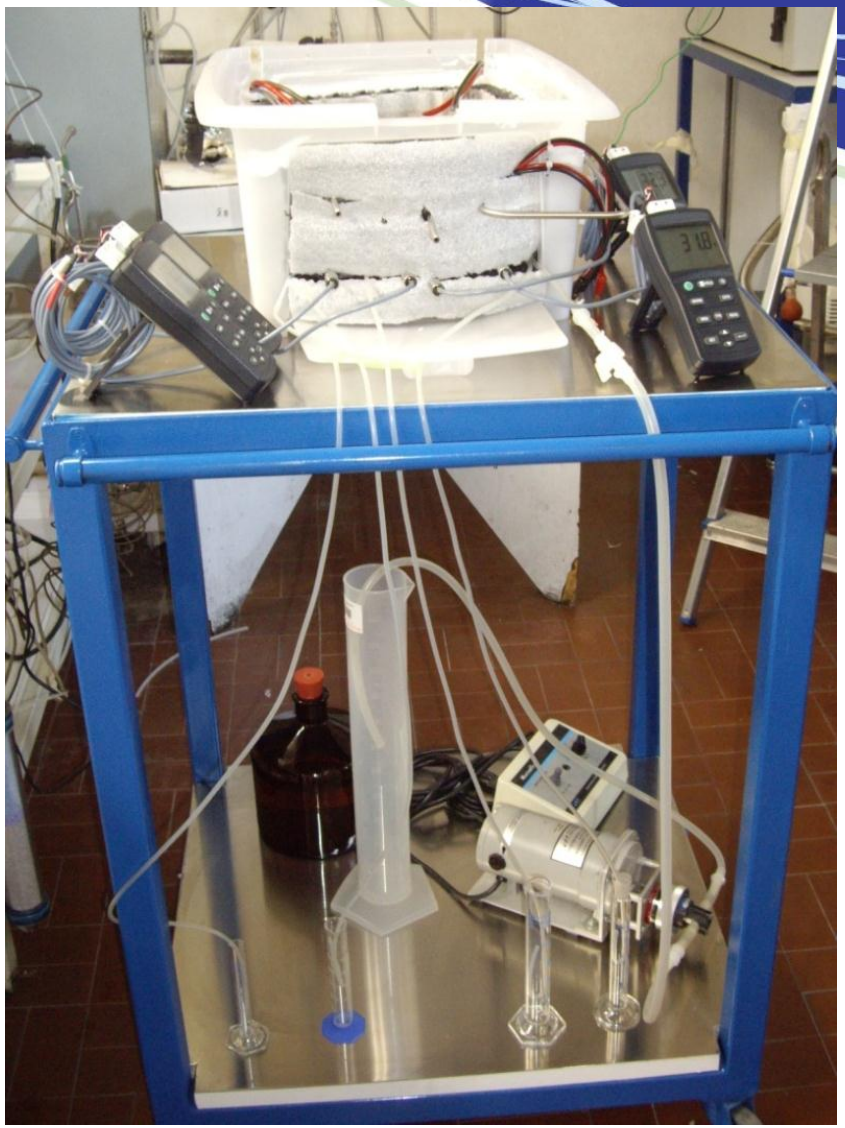



MATGAS
LoLiPEM
MANUAL
LONG-TERM CONTROL
Air Pump NL/min
Hydrogen mass flow mNL/min
Stack temperature set-point °C
Zone 1
Zone 2
Zone 3
Zone 4
Humidifier PC port
Closed
Status
Code
Stack temp PC port
ST Status
ST Code
Humidity sensor PC port 1
Humidity sensor PC port 2
Pressure, Temperature and Humidity Measurements
Humidifiers' Temperatures
Stack Temperature
Hydrogen and Air Mass Flows
Anode RH
Cathode RH
Anode Pressure
Cathode Pressure
Cathode flow
Amplitude
Time
File:
Data Log
Sampling time
Com error code
Com error status
Communication


Supervisor Controller
Set-points--> Simulations
Air flow controller
Humidifier and heater controller
Back pressure regulators
Stack temperature controller
Humidifier and heater controller
Hydrogen flow controller


Relative Humidity control loop
Humidifier and heater controller
Stack temperature controller
Humidifier and heater controller
Back pressure regulators
Air flow controller
Hydrogen flow controller
Efficiency control loop

MOPEM



The MoPEM-CHP system has been designed and built to allow the easy replacement (“use and discard”) of MEAs.

In addition, the system is designed to allow adiabatic operations maximizing the recovery of heat produced by cogeneration.

Dissemination & public awareness

The web site www.lolipem.eu is operative and the project brochure has been printed and is available as pdf file

Deliverables of first 18th month

Del. no.	Deliverable name	Status
1.1	PFSA membranes	Delivered
1.2	SAP membranes measurements	Delivered
1.3	Set-up for permeation measurements	Delivered
2.1	MEAs suitable for temperature higher than 100°C	Delivered
4.1.	LoLiPEM project brochure	Delivered
4.2.	LoLiPEM website up and running	Delivered
4.3	Workshop on “Membrane Materials: Preparation and Characterization”	Delivered
4.4	Establishment of the strategy of exploitation	Delivered
4.5	Workshop on “Electrochemistry – Electrocatalysis”	Scheduled for March 2012, 25-27th

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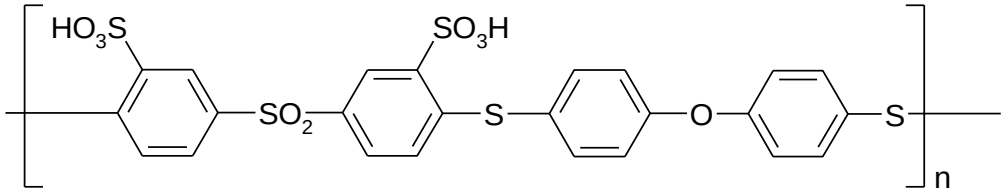
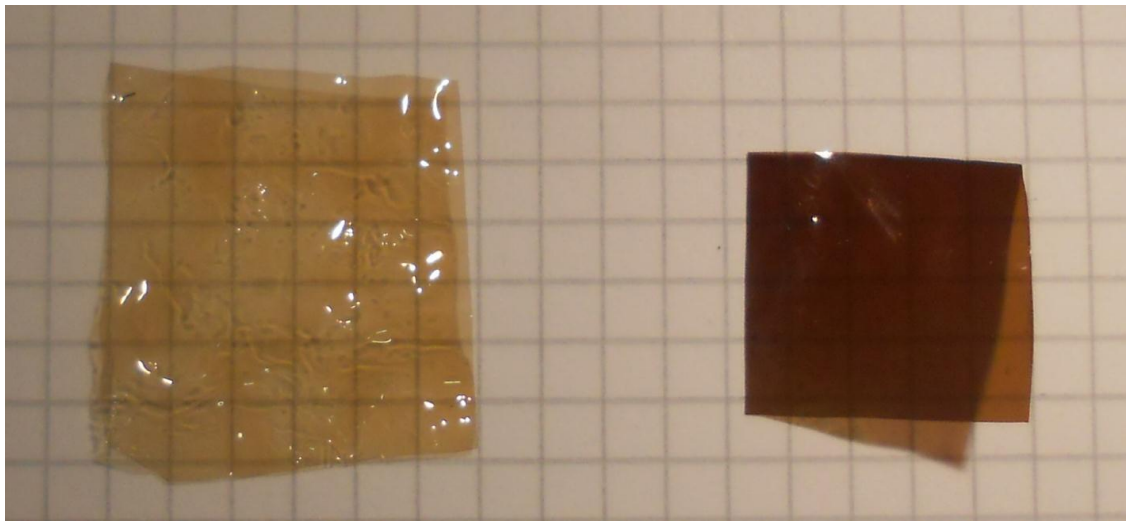
5.1	Progress report
5.2	Progress report
5.4	Mid Term report (including management)





- membrane cast from DMAc
- heat-treated at 180 °C / 15 h
- soluble in boiling water
- soluble in hot DMAc

→ No crosslinking in DMAc

- membrane cast from DMSO
- heat-treated at 180 °C / 15 h
- insoluble in boiling water
- insoluble in hot DMAc

→ Crosslinking in DMSO

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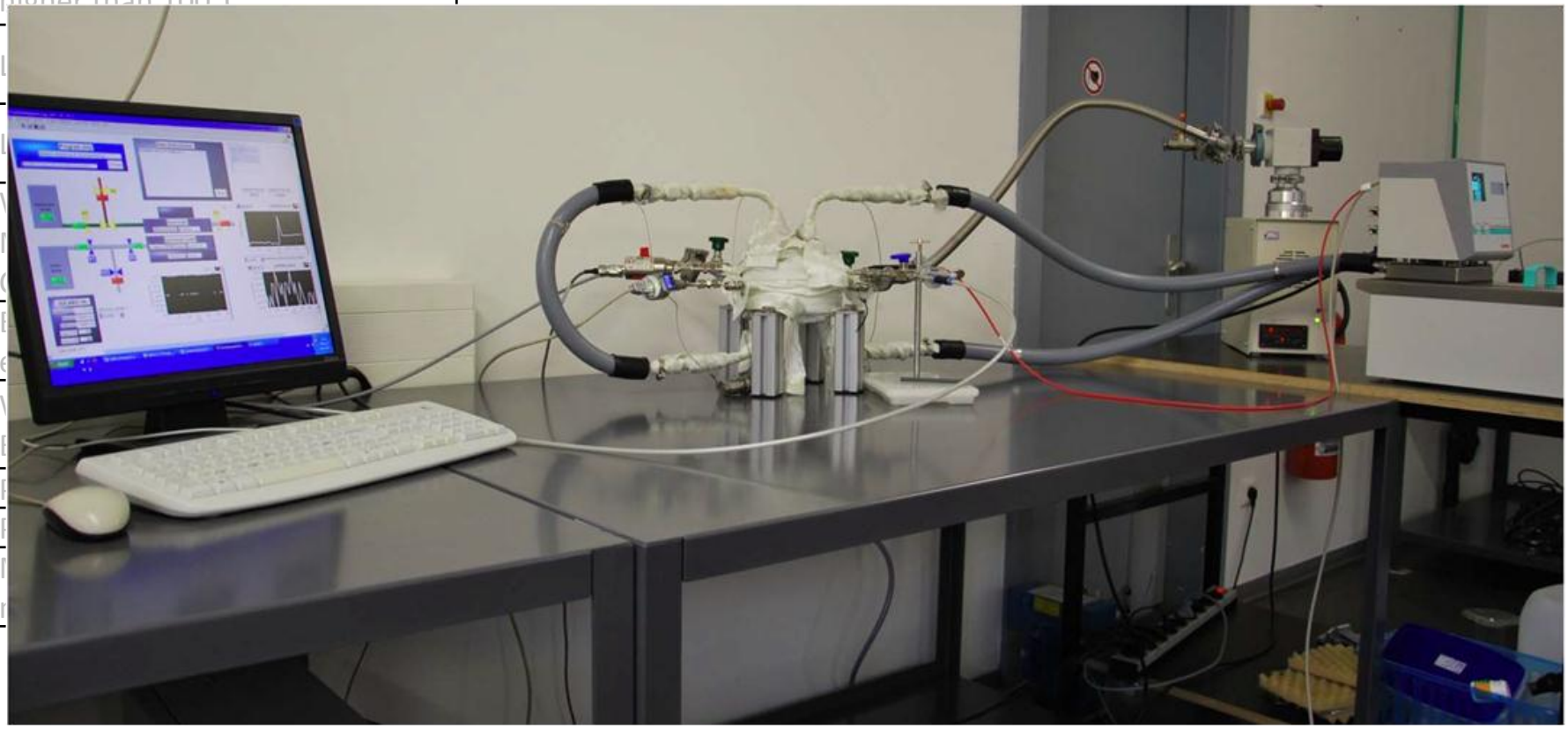
4.4	
4.5	
5.1	
5.2	
5.4	



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Project

LoLIPEM is a research project devoted to the development of new **membranes, electrodes** and a **CHP** module for **stationary power generation & combined heat and power (SPG&CHP)** systems, based on Polymeric Electrolyte Membrane Fuel Cell Hydrogen **(PEMFCH).**

A PEMFCH operating in the temperature range of **100-130°C** is highly desirable and could be decisive for the development of SPG&CHP systems based on PEMFCHs.

LoLIPEM aims to operate in this temperature range above **100°C** exceeding the state-of-the-art (70-80°C) which represents the main drawback for the PEMFCH development. Operating temperatures above 100°C would have several advantages including easier warm water distribution in buildings, reduced anode poisoning due to carbon monoxide impurities in the fuel, improved fuel oxidation kinetics, etc.

The **main objective** of the **LoLIPEM** project is to give a clear demonstration that long-life SPG&CHP systems based on **PEMFCHs operating above 100°C** can now be developed on the basis of recent knowledge on the degradation mechanisms of ionomeric membranes and on innovative synthetic approaches recently disclosed by some participants of this project.

Some key points in the research activities are:

1. development of long life (longer 40000 hours) perfluoro sulfonic acid membranes and sulfonated aromatic polymer membranes operating at a current density of at least 4000 A m^{-2}
2. development of long-life catalytic electrodes and Membrane Electrode Assemblies (MEAs)
3. development of a prototype of a modular SPG&CHP system including more PEMFCHs built with the new long-life MEAs
4. The understanding of **degradation mechanism**, by means of accelerated aging tests and long-term single cell measurements, in order to predict the life-time and give feedback to the developing of membranes and electrodes
5. **benchmarking** of the performance of a single-cell and the modular prototype against the best literature results.

The operating **temperature of interest** for the **LoLIPEM project** is in the range of **100-130°C** for both new membranes, electrodes, MEAs and the whole modular system.

The project will benefit of the synergy arising from the know-how of leading research groups of universities and research institutes as well as from the technical knowledge and expertise of industries and utility companies involved in fuel cell development and testing.

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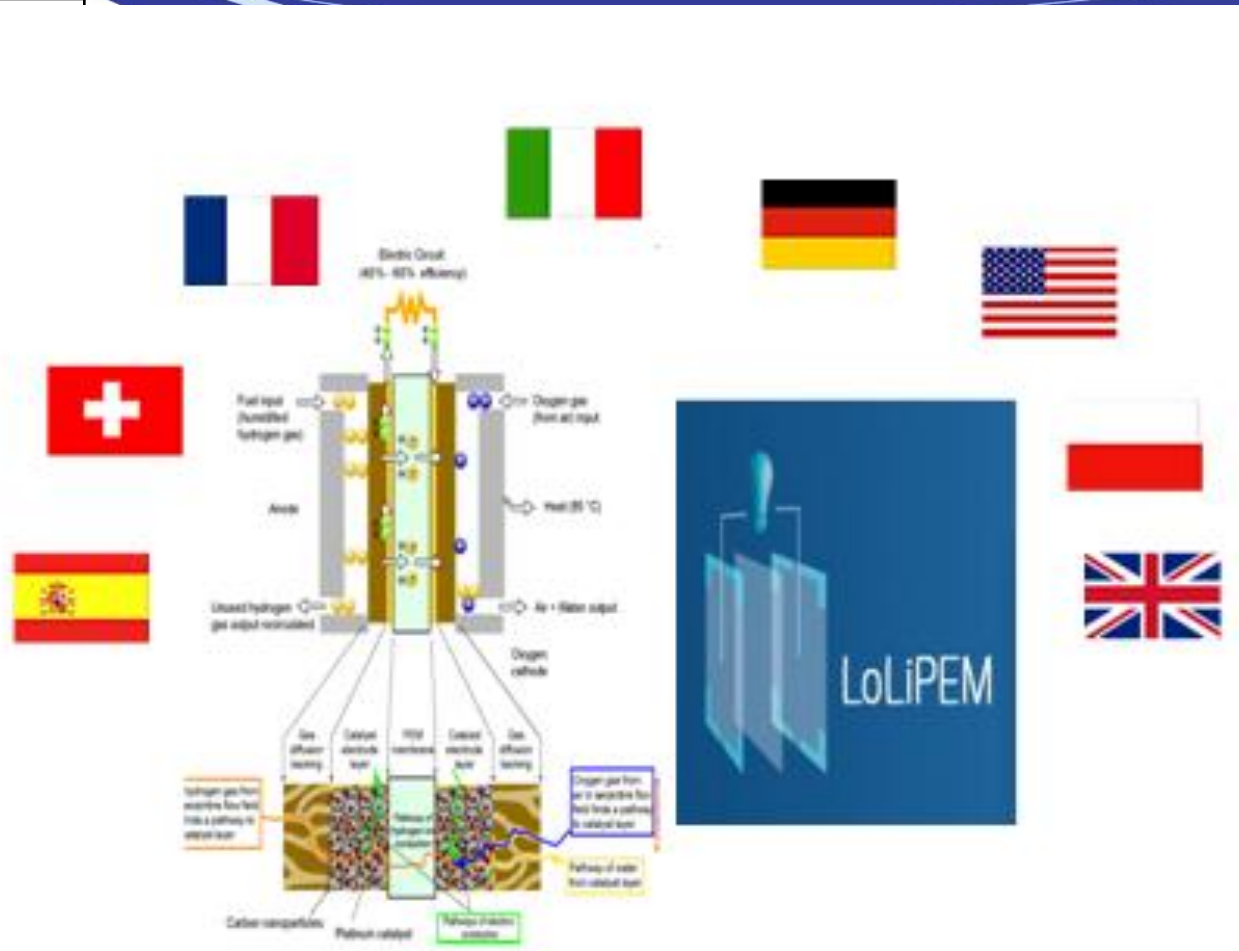

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Deliverables of first 18th month

Intern. Workshop Electrocatalysis

St. Ingbert near Saarbrücken, Historical Steel Company („Alte Schmelz“)

Sunday, 25 March 2012 Welcome reception
Monday, 26 March 2012 Conference
in the evening Conference Dinner
Tuesday, 27 March 2012 Conference, end 13:00 h

Main topics: fuel cells, batteries, electrolysis, photoelectrocatalysis, bioelectrocatalysis

4.5	Workshop on “Electrochemistry – Electrocatalysis”
5.1	Progress report
5.2	Progress report
5.4	Mid Term report (including management)

Milestones

Milestone no.	*Milestone name*	*Delivery date from Annex I*
M1	Kick off meeting	achieved
M2	PFSA membrane stability ex-situ test	achieved
M3	SAP membrane stability ex-situ test	achieved
M4	Single PEMFCH design and realization	achieved
M5	Modular multi-cell system design and realization	achieved
M6	Degradation and lifetime test	achieved
M7	Innovative MEA working above	Foreseen M24
M8	Cost of use and discard MEA	Foreseen M30
M9	Publications, patents, conferences	During the project activity

Milestones foreseen and achieved within 18th month

Milestone no.	Milestone name
M1	Kick off meeting
M2	PFSA membrane stability ex-situ test
M3	SAP membrane stability ex-situ test
M4	Single PEMFCH design and realization
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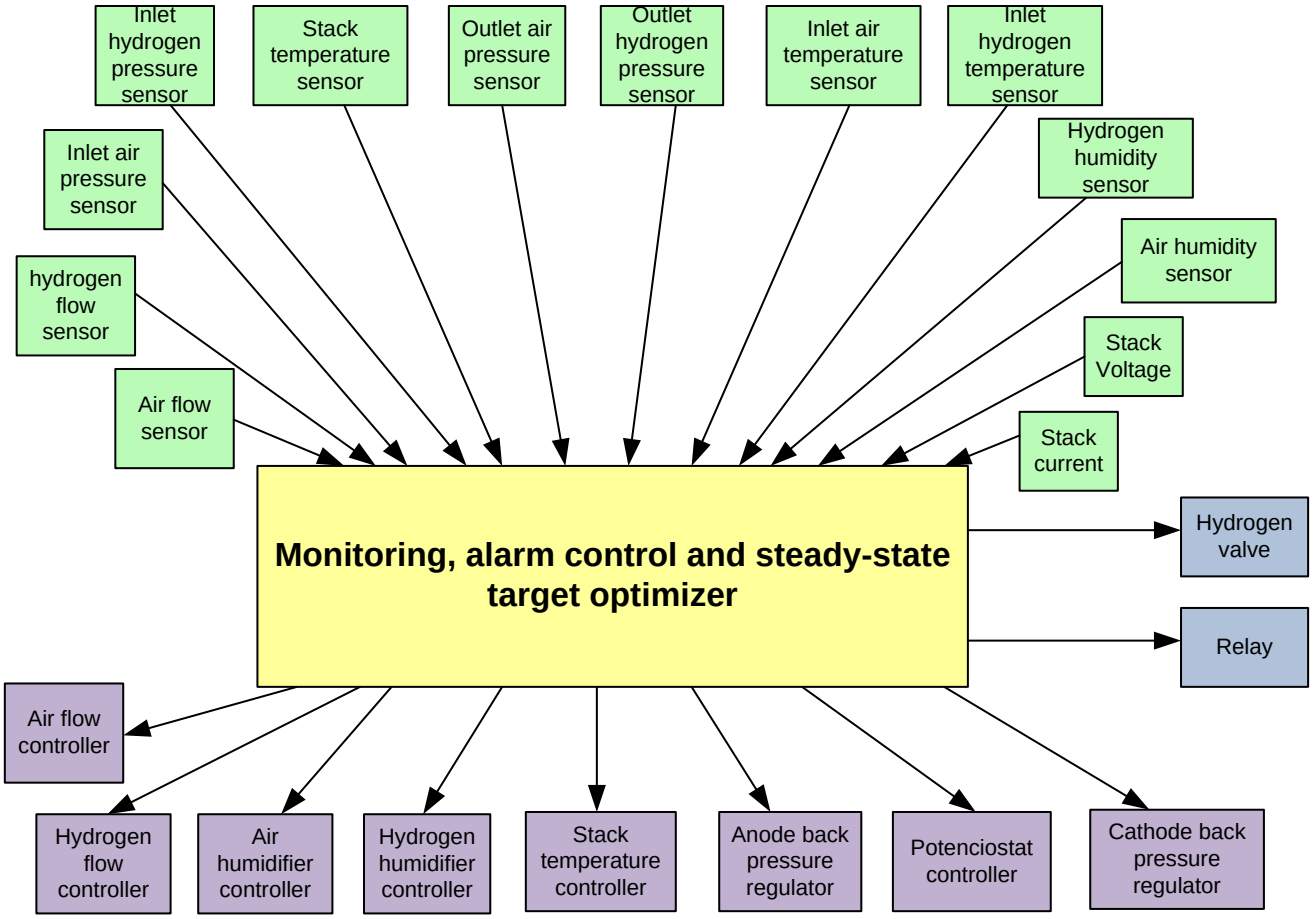

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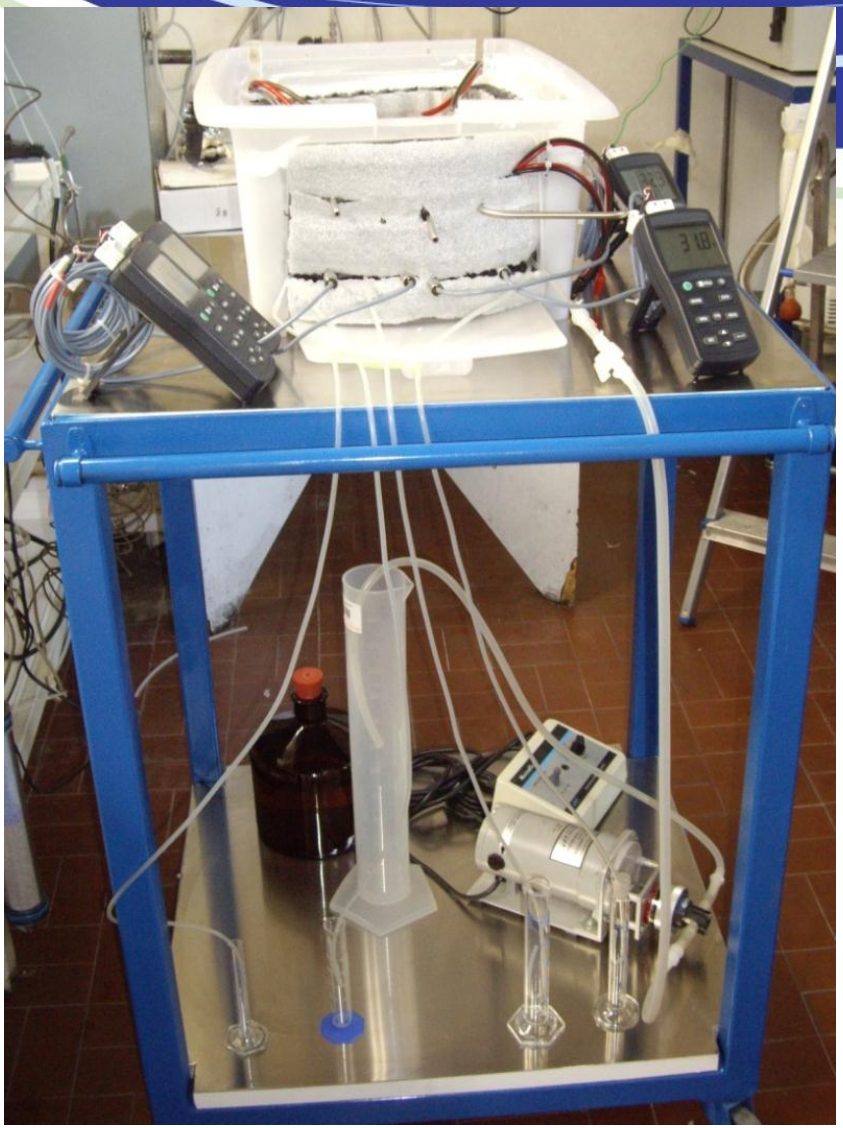
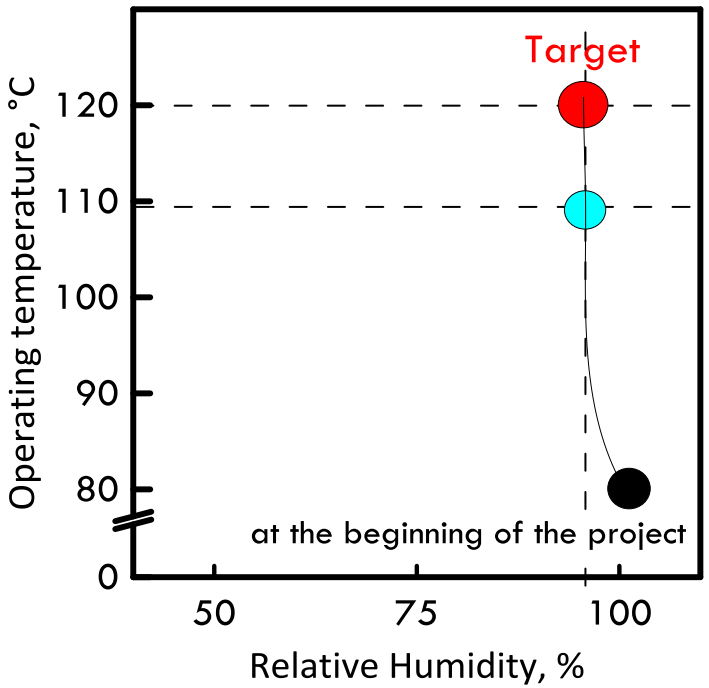


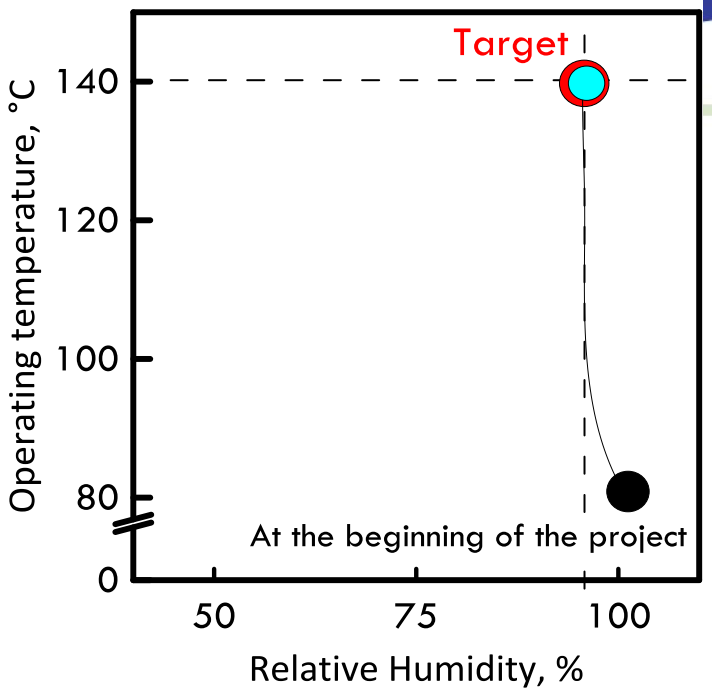
Where we are where we are going….

PEM-PFSA Membrane



Status of the hydrothermal resistance of the thermal annealed Nafion membrane

PEM-SAP Membrane



Status of the hydrothermal resistance of the thermal crosslinked SPEEK membrane

Thank you for your attention