Premium Act

PREdictive Modelling for Innovative Unit Management and ACcelerated Testing procedures of PEFC

(256776)

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CEA

Premium Act

Premium Act/2

1. project & partnership description

Improvement of stationary PEFC systems durability (40000h required!)

→ A reliable method to predict system lifetime, benchmark components and improve operating strategies

WP1 - Specifications

WP2 – Experiments under real operating conditions

WP3 – Quantification of components degradation

WP5 – Lifetime prediction methodology

WP4 – Predictive Modelling

WP6 - Dissemination

WP7 - Management

- **Expected achievements**

➔ **Operating strategies,** enhancing lifetime of given MEAs in given stack and system

➔ **Design of a lifetime prediction methodology based on coupled modelling and composite accelerated tests experiments** (ranking of selected MEAs in real conditions and then following accelerated tests)

- **Technical aspects**

✓ **Two fuel cell stack technologies for stationary power applications:**

→ DMFC and H2 reformate PEMFC CHP systems

✓ **Experimental investigation**

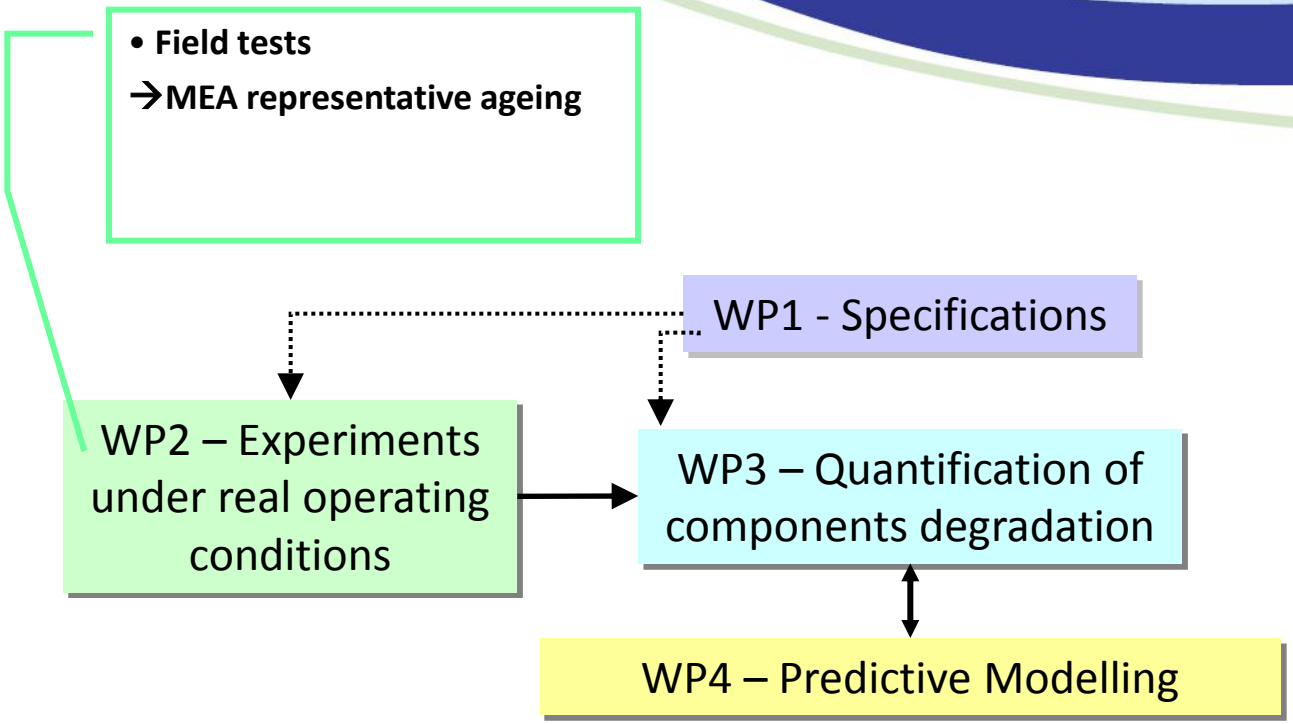
→ Tools to quantify & correlate performance and components degradation to operating conditions

✓ **Multi-physics modelling**

→ Tools to combine degradation phenomena and analyse their global impact on durability

Premium Act/2

1. Approach in performing the activities



WP6 - Dissemination

WP7 - Management

Premium Act/2

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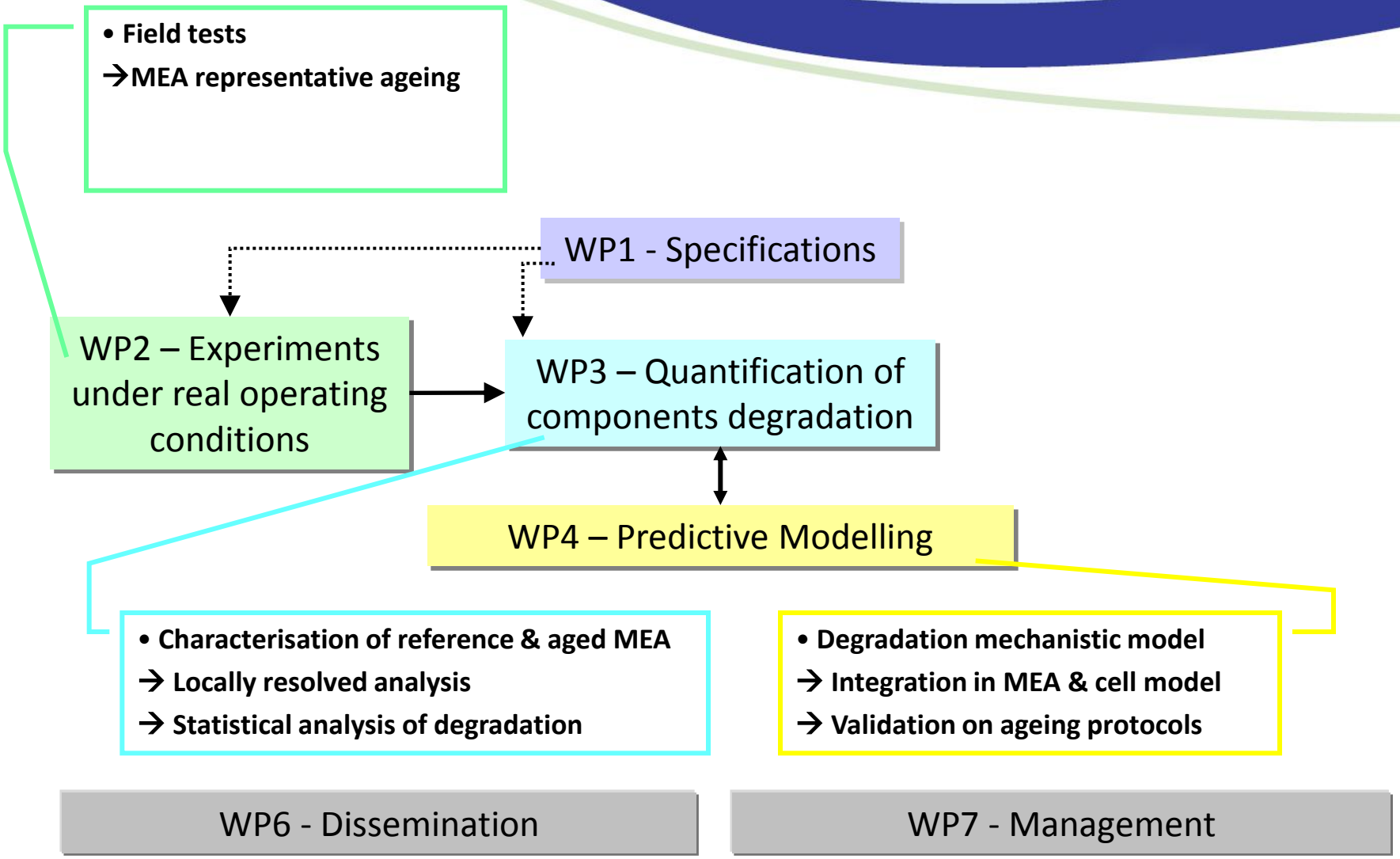

Premium Act/2

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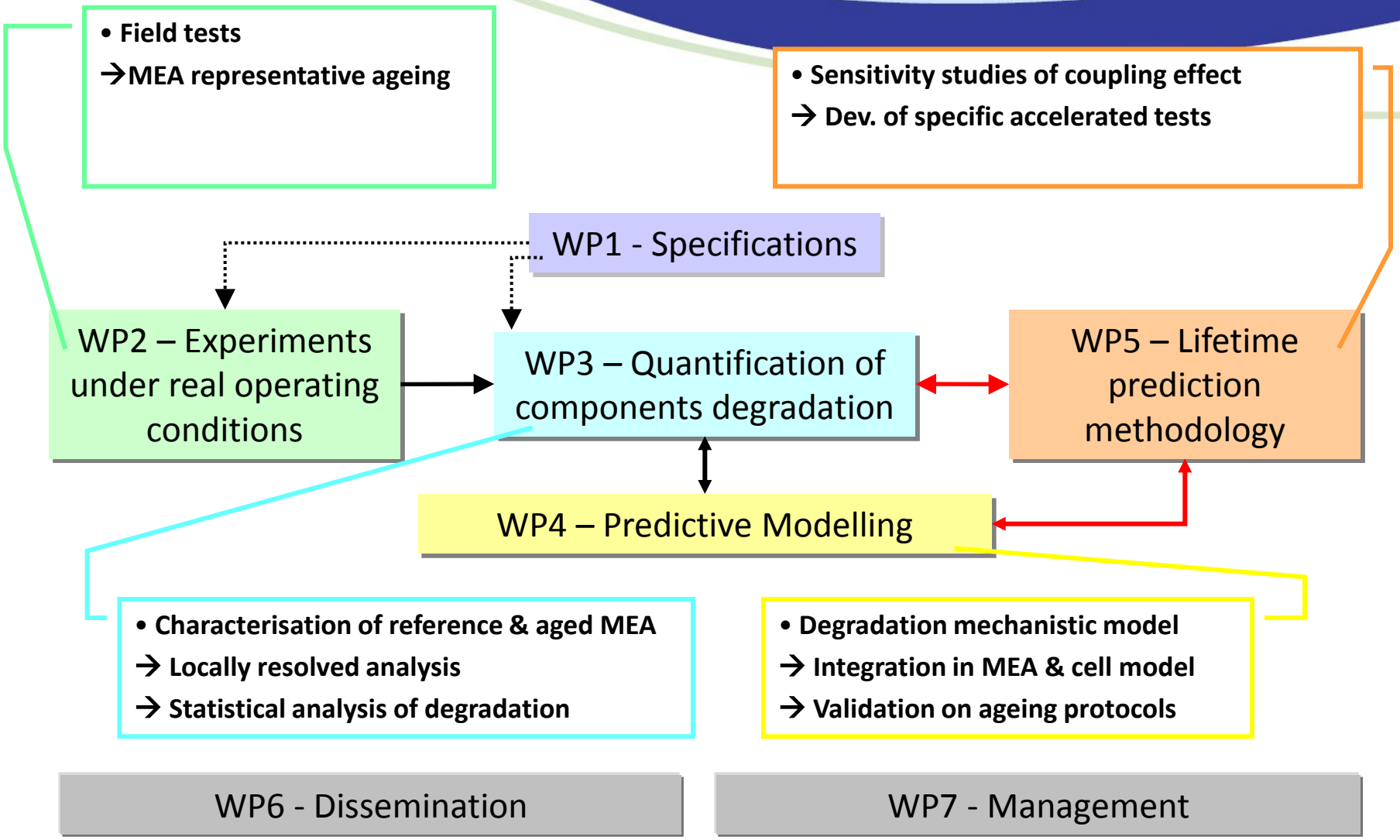


Premium Act/2

1. Approach in performing the activities

- Field tests
→MEA representative ageing
→ Validation of strategies
→ Ranking of different MEAs

- Sensitivity studies of coupling effect
→ Dev. of specific accelerated tests
→ Life time prediction of different MEAs

WP1 - Specifications

WP2 – Experiments under real operating conditions

WP3 – Quantification of components degradation

WP5 – Lifetime prediction methodology

WP4 – Predictive Modelling

- Characterisation of reference & aged MEA
→ Locally resolved analysis
→ Statistical analysis of degradation

- Degradation mechanistic model
→ Integration in MEA & cell model
→ Validation on ageing protocols

WP6 - Dissemination

WP7 - Management

- **Ageing studies**
  - ✓ MEA, stacks and systems defined

IRD reference components

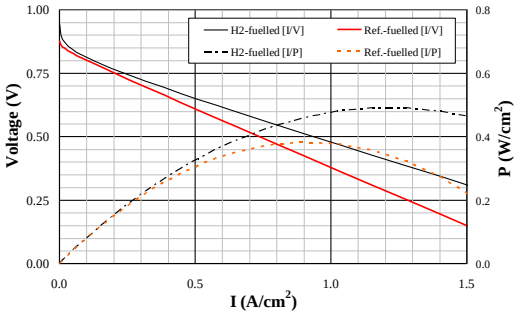
LT PEM 5-layer Reference MEAs

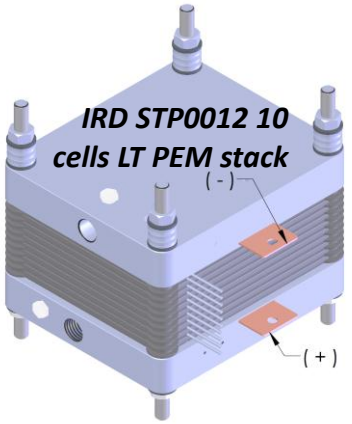
Description	Product ID	Catalyst loading
Anode GDL	Sigracet 35DC	
Anode Catalyst	Hispec 10000	0.3 mg PtRu/cm^2
Membrane	Nafion® N212CS	
Cathode Catalyst	Hispec 9100	0.5 mg Pt/cm^2
Cathode GDL	Sigracet 35DC	

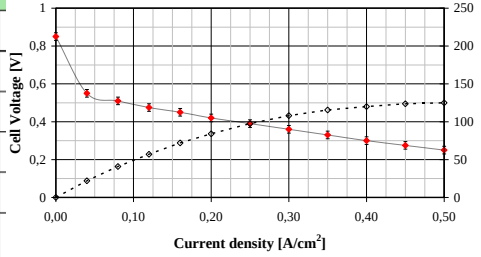
DMFC 5-layer Reference MEAs

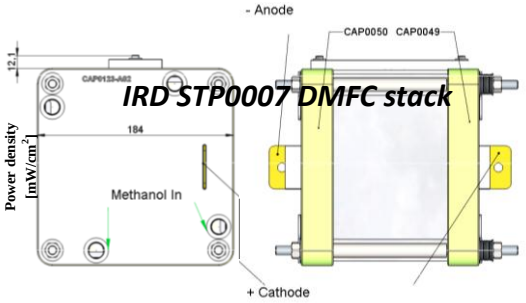
Description	Product ID	Catalyst loading
Anode GDL	Sigracet 35DC	
Anode Catalyst	Cabot Dynalyst 62RKR4	1.8 mg PtRu/cm^2
Membrane	Nafion® N115CS	
Cathode Catalyst	Cabot Dynalyst 65KR2	1.2 mg Pt/cm^2
Cathode GDL	Sigracet 35DC	

MEAs









➔ *Same reference MEAs planned for different testing objects, operating parameters and ex-situ investigation studies*

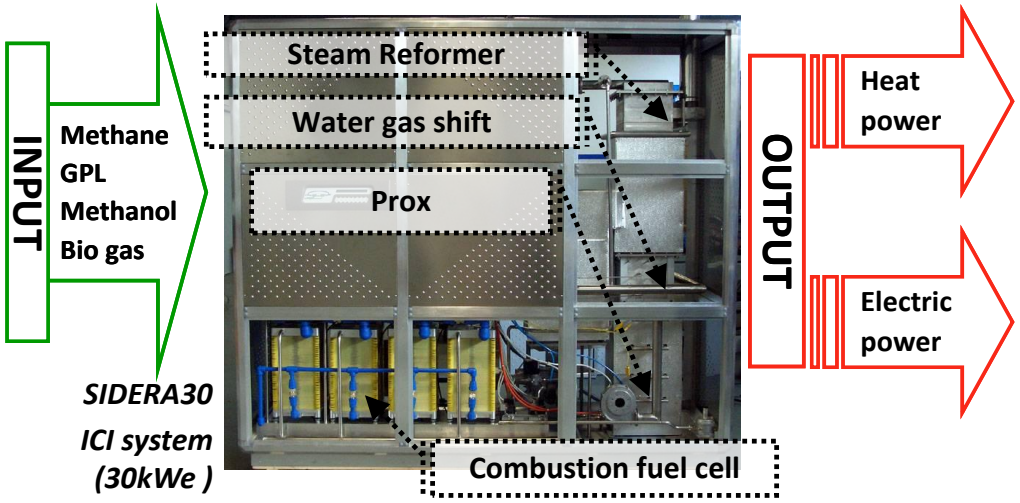
- **Ageing studies**
  - ✓ MEA, stacks and systems defined

Field tests: ICI, SOPRANO, IRD systems

Specific operating conditions & applications

→ specific parameters to be considered as main issues for degradation studies at small scale:

- ✓ **Fuel composition (CO?, air bleeding?)**
- ✓ **Current & T cycles**
- ✓ **Reversible strategies**



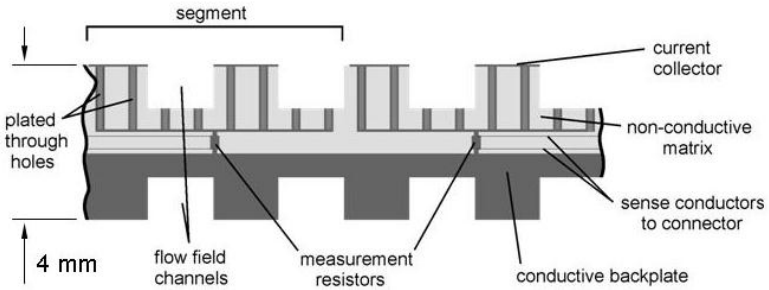
→ Improvement of the measurements and control in progress: gas analysis before and after the stack, simultaneous single cells potential, heat management (ICI)

→ Representative conditions to be applied on MEAs at small scale

- **Characterizations for degradation investigation and quantification**

✓ In-situ measurements (SC & stacks)

DLR local current density & temperature measurements



Example for a PCB setup for PEFC

➔ ***Printed circuit board to be adapted based on the design of the bipolar plates of the IRD PEFC stacks***

➔ ***Need to adapt material/techno of the PCB for DMFC stacks***

✓ Ex-situ local investigation (CEA, DLR, IRD, JRC, POLIMI)

Main techniques available for microstructure analysis : SEM/TEM, XRD, IR, XPS, AFM

Methods identified for relevant analyses of materials or MEA properties such as: electrochemical activity; mechanical strength; gases and water transport

➔ ***Characterizations to be performed on reference non aged MEAs (& then after ageing in representative conditions)***

• Degradation models development

✓ PEMFC model

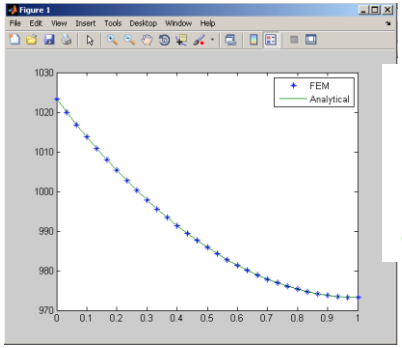
Implementation of non-isothermal conditions in MEMEphys model (CEA)

✓Better understanding of temperature impact (cycles and gradients) onto the degradation mechanisms

✓ Possibility to propose operation strategies and accelerated protocols incl. non homogeneous temperature

Improvement of gases transport description

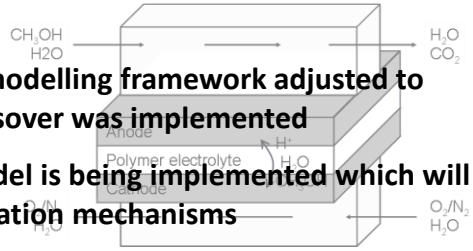
✓ Modified description at GDL level → domain discretization + interface transport phenomena + thermal balance



Finite element model in progress → first program validation for a simple case

✓ DMFC model

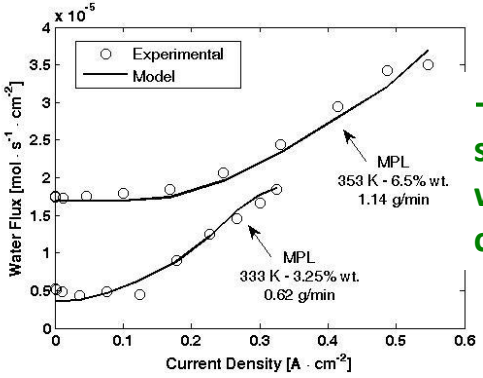
Development of degradation mechanistic models (DLR)



✓ Existing PEFC & SOFC modelling framework adjusted to DMFCs → Methanol crossover was implemented

✓ Elementary kinetic model is being implemented which will form the basis for degradation mechanisms

Improvement of water transport description (POLIMI)



→ Accurate simulation of water flow at cathode outlet

→ *to be completed before PEMFC/DMFC interactions & validation*

Further steps: interaction with experimental data for common proposal of AccT and strategies

- Correlation of the project with the corresponding Application Area (as mentioned in MAIP/AIP documents)
  - **Application area: Stationary Power Generation**
    - "emphasis on long-term basic research to better understand degradation/failure mechanisms and the lifetime requirements of all 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."

Topic: "Fundamentals of fuel cell degradation for stationary power application"

→ "Research on critical parameters and operating conditions that impact degradation and life time of cells and stacks, for all power ranges and fuel cell technologies"

- Detailed project activities versus MAIP/AIP document targets
  - ✓ Direct link between previously described activities & targets (Cf. approach slides)
    - **Application** - µ-CHP systems with different requirements
      - 2 Fuel Cell types / fuels : DMFC (Methanol) & PEMFC (reformate)
      - Power ranges: from 500W stack to 30kWe PEM CHP syst.
    - **Technical activities**
      - FC tests (system, stack and cell levels): nominal and critical conditions
      - Studies of the microstructure & properties before/after ageing
      - Modelling of the degradation mechanisms

      → **Identification of main parameters enhancing degradation**

      → **Development of accelerated tests**

      → **Proposal & validation of lifetime prediction methodology**

Premium Act/3

2. Alignment to MAIP/AIP

- Identify and comment on gaps/bottlenecks in RTD&D proposed by MAIP/AIP documents
  - *Most topics of Premium Act are considered in the MAIP/AIP*
  - ✓ **DMFC technology is not directly included in the implementation plan whereas currently subjected to a significant commercial interest**

- Comments on priorities and topics possibly under/over-estimated in the AIPs in terms of technical challenge
  - *For stationary applications, degradation understanding and durability improvement are the right priorities*
  - ✓ **Durability of 40000 hours: too wide requirement**
  - → **more focused targets to be proposed / specific application**
  - → **technical challenges to be more related to components or operating conditions constraints**

- Training and Education
  - Post-doctoral researchers, PhD and MSc students involved in activities at CEA, DLR & POLIMI
- Safety, Regulations, Codes and Standards
  - possibility to contribute to future standards definition thanks to project outcomes on traditional and accelerated testing & on degradation models
- Dissemination & public awareness
  - **FC papers & conferences (incl. exhibition for indust.) (All partners)**

Preliminary activities:

- CEA: ISE - Nigata (Sept. 2011)
- CEA, DLR, IRD, JRC, POLIMI : Int. workshop on degradation issues - Thessaloniki (Sept. 2011)
- POLIMI : EFC11 - Rome (Dec. 2011) "Effects of flooding on DMFC performance: 1D+1D model development and experimental validation“

➔ **Public workshop planned the 26 & 27th of Sept. 2012 at Grenoble: “Characterization and quantification of MEA degradation processes”**

- Technology Transfer / Collaborations
  - **Interaction with EU projects**
    - Use of knowledge & results from DECODE project [degradation mechanisms, modelling data, investigation methods]
    - Exchanges planned with new JTI 2011 proposals e.g. IMPACT, IMPALA, PUMAMIND… [degradation, water management, modelling]
  - **Interactions at national level** (French, German, Italian or Danish FC projects)
    - Possible exchanges and use of knowledge & results from national funded or other collaborative projects (all partners)
    - **Interaction with the national Real FC project is started: first exchanges regards experimental data and testing methodology (POLIMI - Italy)**
  - **Interactions at international level**
    - Possible exchanges about methodologies (for all technical aspects of testing, characterization or modelling) thanks to:
      - close direct relationships with other industrial groups, institutes or universities
      - involvement in international working groups (IEA, standardization bodies…)

- Project Future Perspectives
  - Proposed future research approach and relevance & Need/opportunities [for increasing cooperation, building alliances & for international collaboration]
    - **RTD topics: Emphasis on fuel/methanol purity**

      Development of more generic ACCT for DMFC and PEMFC
    - **Premium Act: balanced consortium with 3 industries developing FC systems**

  → possible extended collaboration for further optimisation of the FC systems studied

  → possible extension to other industries or institutes interested in the approach
    - ***At international level: contribution to future definition of RCS (methanol purity, degradation tests or models)***
  - Possible contribution to the future FCH JU Programme
    - **Include research and demonstration of methanol/greenfuel based fuel cells e.g. DMFC in the implementation plan.**
    - **Recommendations for projects dedicated to specific systems development:**
      - Proposition of; exp./model methodology for degradation study; ex-situ investigation methods and testing protocols; validated prediction methodology

Premium Act

Thank you for your attention