# PEMICAN

## PEM with Innovative low cost Core for Automotive applicatioN

**(256798)**

**Start date 01/04/2011; duration 36 months**

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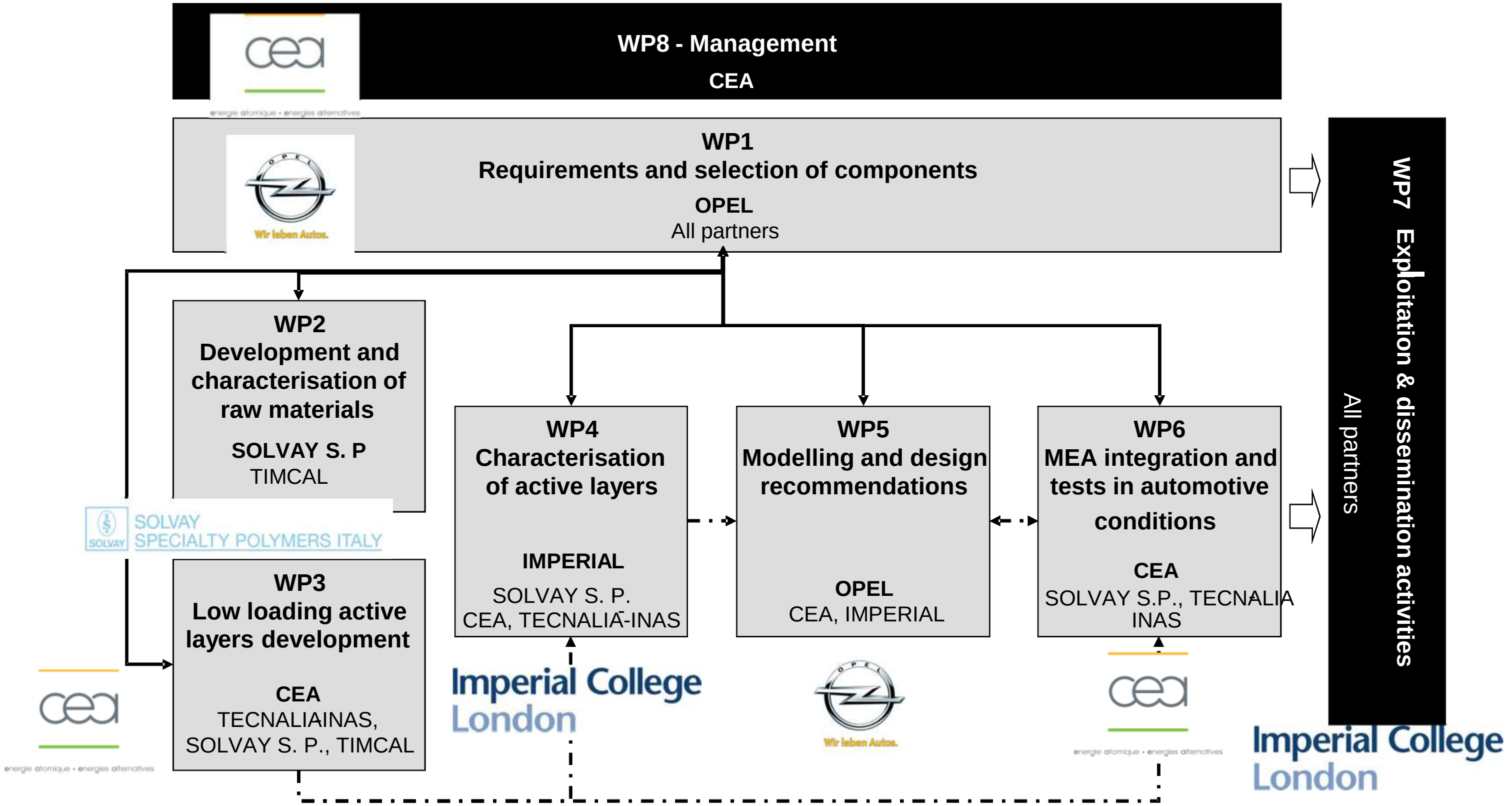
*(French Atomic and Alternative Energy Commission)*

## 1. General overview

Reduce Pt cost of PEMFC down to ideally 0.15 gPt/kW for automotive application

### 6 partners



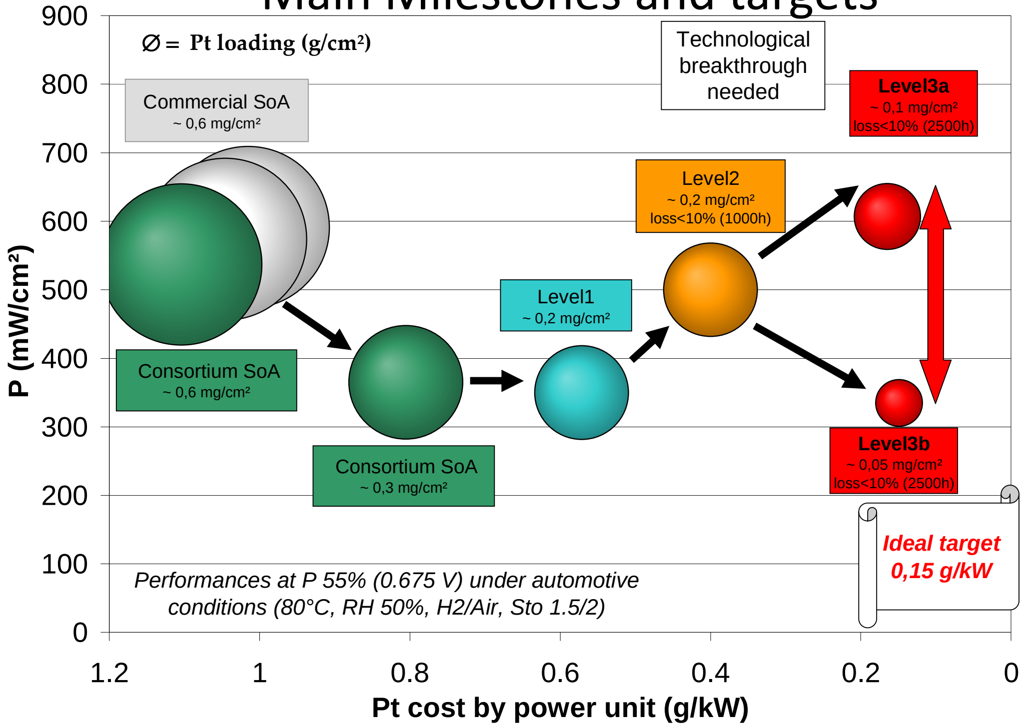
Focus on pure Pt

Reduce Pt cost (gPt/kW) combining two complementary approaches

- ***Reduce quantity of badly used Pt*** (gPt/cm²) by locating Pt where necessary => design (modeling and manufacturing processes)

- ***Increase performance*** (kW/cm²) by increasing transfer properties => raw materials and design

Main Milestones and targets



## Technological

- ***Develop raw materials to increase performance (kW/cm²)***
    - *Ionomer: increase proton conductivity, water handling and gas diffusion*
    - *Carbon black: improve water management (add Carbon in the ink for cathode) and reduce Pt size (MPL for anode)*

- ***Manufacture active layers with reduced Pt quantity and good performance***
    - *Thin anodes (DED, PVD…)*
    - *Structured cathodes with gradients of Pt, C and ionomer (ink jet, screen printing…)*

## Scientific

- ***Improve knowledge of active layers:*** *$H^+$ conductivity, gas diffusion, structure, fundamental electrochemistry…*

- ***Improve modeling*** to better link local properties of CL to performance *; more reliable inputs and experimental validation → basis for future design tools?*

# 1. First progress: Test protocols for automotive application

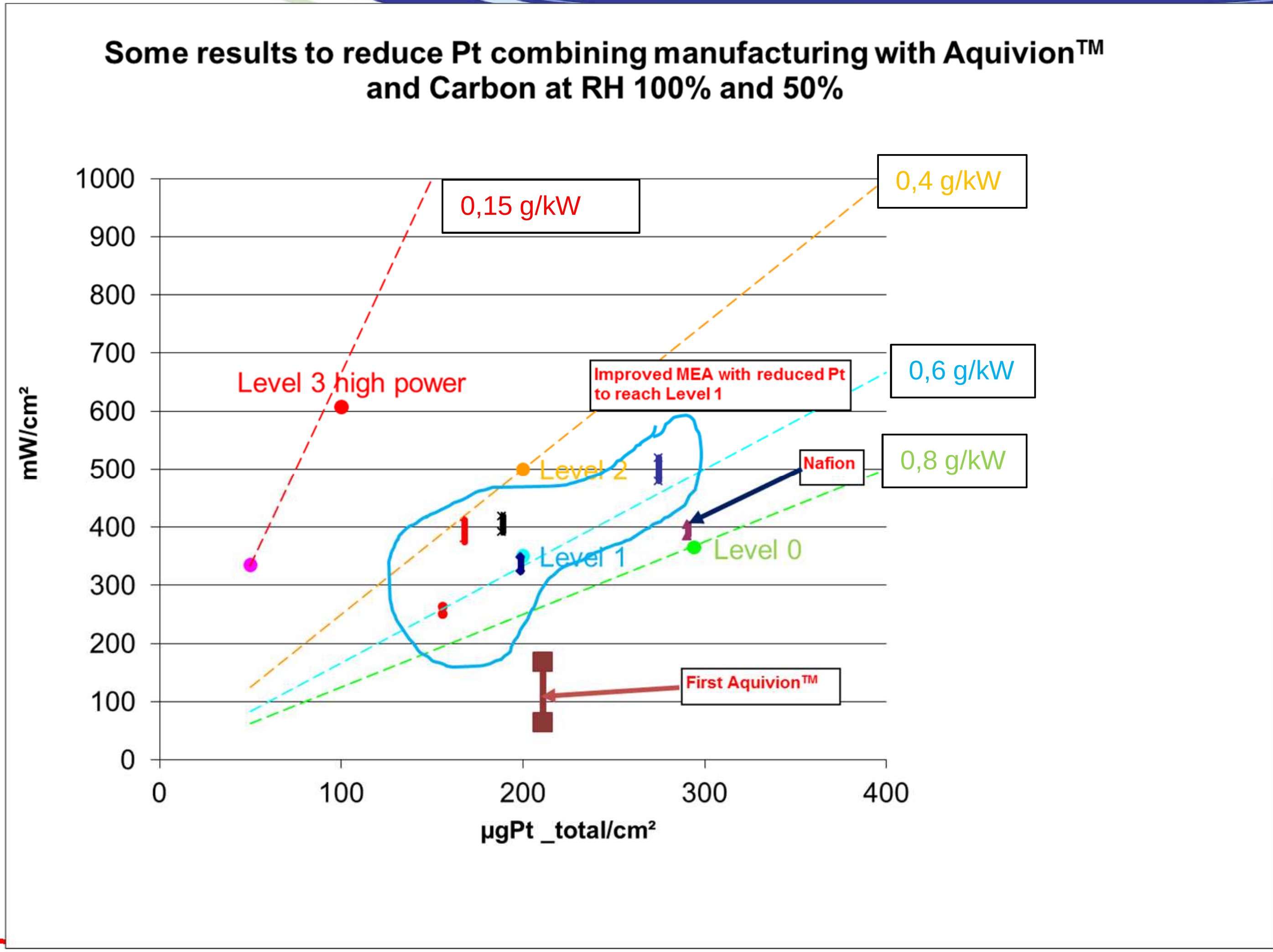
- ***Tests for selection of materials***
  - *Performance tests:*
    - *Single cell 25 cm², 1.5 bar, $H_2$/Air, Sto 1.2/2*
    - *Polarization curve at RH=100% and RH=50% for T=80°C*
    - *Effect when reducing RH (100%=>16%) at i=0.6 and 0.12 A/cm² for T=64°C*
  - *Durability tests:*
    - *Chemical stability: 500h, T=90°C, RH=30%, $H_2/O_2$*
    - *Cyclic stability: up to 2000h, T=90°C, RH=40%(A)/60%(C), $H_2$/Air, $i_{min}$=0.12 and $i_{max}$=0.6 A/cm², Sto 1.5/1.8*

Test conditions are a combination between DoE and Decode conditions

⇒Will be used to select the most promising MEAs => Level 1, Level2, Level3

- ***Specific tests for model validation and analysis***
  - *Higher Sto for more uniform working conditions*
  - *Single cells 5-25 cm²; influence of RH, $\%O_2$, $\%H_2$, T, P, materials…*

⇒Will be used to validate the modeling

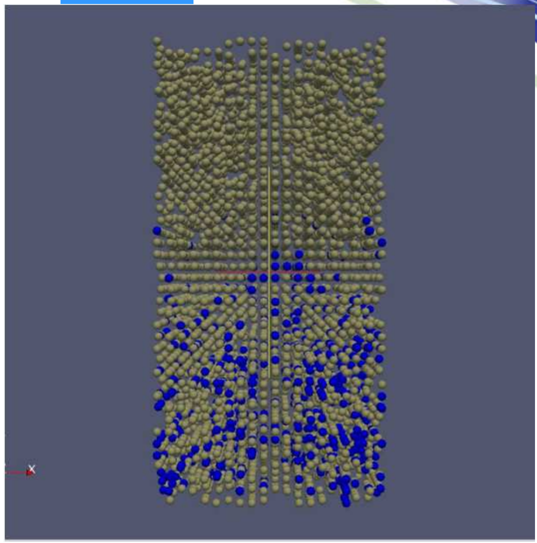



- *MEA Level 1 has been reached combining improved Aquivion™, C blacks and manufacturing process ➔ next priority is to increase power density*

Pt

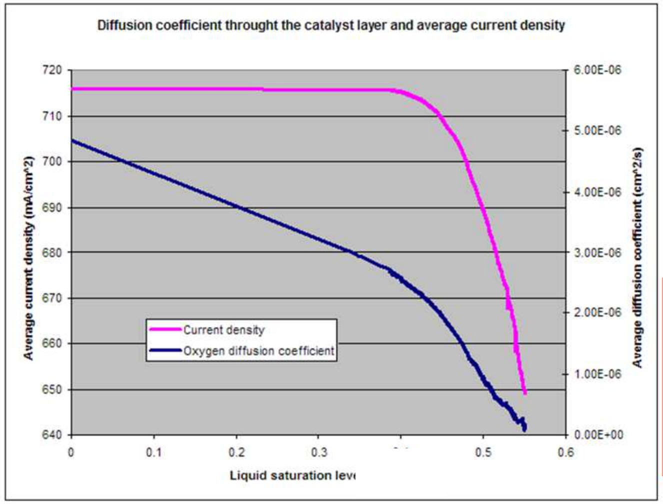
## *1. Scientific progress*

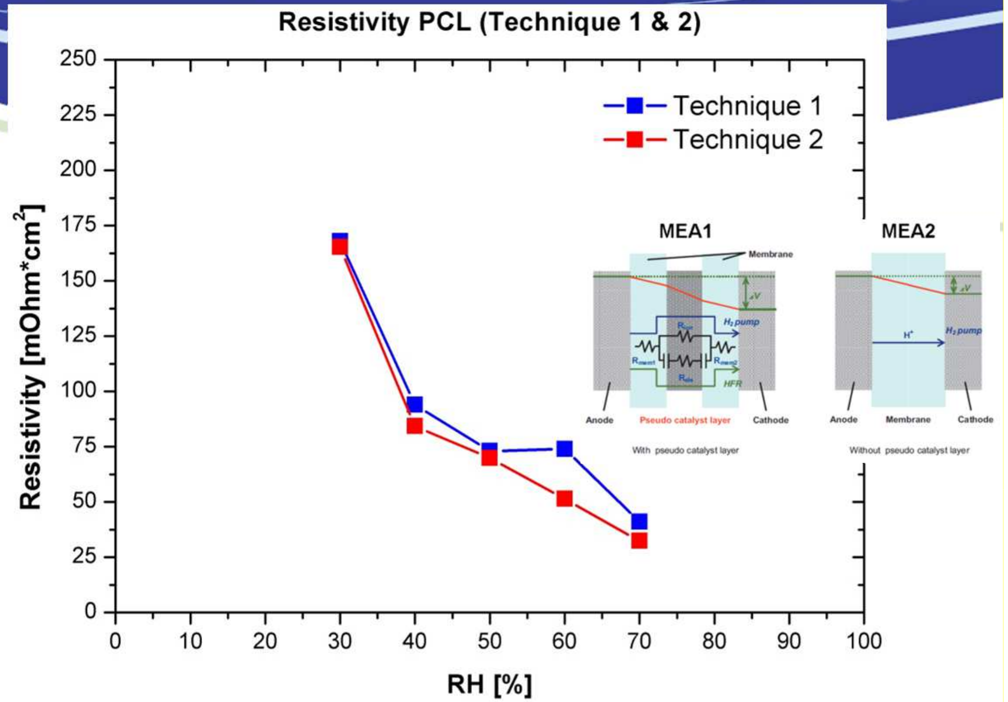
GDL



Membrane

Liquid invasion through the AL, Pore Network Simulation




Ionic resistance of the peudo active layer as determined at CEA according to the two techniques described by Iden et al.

*Innovative experimental and numerical tools are under development to better understand the link Pt quantity/structure/transfer properties/performance*

H. Iden, A. Ohma, K. Shinohara, Analysis of proton transport in pseudo catalyst layers, Journal of the electrochemical society 156 (9) (2009) B1078-B1084

- ***MEA Level 1*** (M12; ~0.6 g/kW; ~350 mW/cm²)
  - achieved

- ***MEA Level 2*** (M24; ~0.4 g/kW; ~500 mW/cm²), same as Level1 but include
  - Gradients (cathode) and DED (anode)
  - Advanced ionomer and carbon
  - First fundamental electrochemical analysis, $e^-$ conductivity measurements
  - Design recommendations from improved modeling
  - Durability tests

  ➔ Priority is now to increase the power density and ensure good durability

- ***MEA Level 3*** (M36; ~0.15 g/kW; ~350-**600** mW/cm²), same as Level2 but include
  - Measurements of $H^+$ conductivity, gas diffusion
  - "Coupling" between local (Pore Network) and performance modeling
  - Design recommendations from models with experimental validation and better inputs
  - Cathode and anode with precise Pt/C/ionomer localisation (rib/channel, inlet/outlet, thickness)

## *2. Correlation of PEMICAN with the corresponding Application Area*

- ***Pemican corresponds to MAIP/AIP objectives for Automotive Application*** and especially **“Topic SP1-JTI-FCH.2009.1.3: Development and optimisation of PEMFC electrodes and GDLs”**

⇒ reduction of catalyst loading, optimised composition and morphology of the catalyst layers, high quality manufacturing methods, increase of performance

⇒ Pt-loadings < 0.15 g/kW at > 55% efficiency and > 5000h lifetime at dynamic operation (car)

- ***Pemican will contribute to the development of mass market*** by reducing cost of PEMFC technology for Automotive Application

- ***Pemican will contribute to the development of European Industry:***
  - Partners can propose alternative solutions compared to competitors (Aquivion$^{TM}$, new Carbon Black, manufacturing processes…)
  - A EU Industrial Boarding (MEA manufacturers, end-users) has been set-up

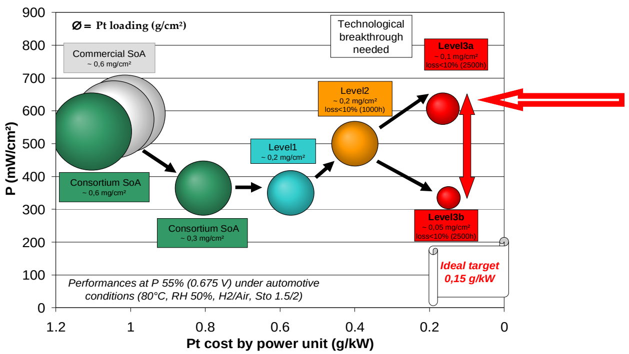
- ***General project activities***
  - Structuration of CL combined with advanced ionomer and carbon should allow increasing performance (water management, $H^+$ conductivity, gas diffusion…)
  - Combination between modeling, characterization and high quality manufacturing processes should allow optimizing CL to reduce Pt cost

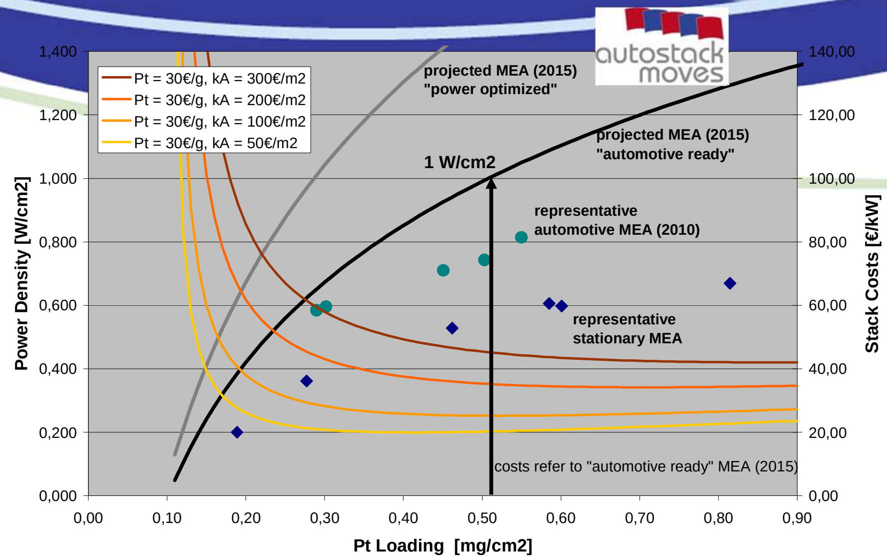
- ***Current results***
  - Possibility to manufacture active layers with reduced Pt loading has already been checked (gradients, PVD, DED)
  - Innovative characterization and modeling are under development to better understand the link Pt loading/local properties/performance ➔ design?
  - Advanced and tailor made raw materials are under development in order to optimize the system
  - MEA Level 1 has been reached

# 2. Gaps and bottlenecks in MAIP/AIP and priorities under-estimated

- ***Pt should be reduced but keeping high power density***
(outputs from Autostack, February 2011)

⇒ have this in mind for PEMICAN!




The curve Power density vs Pt loading will be crucial

⇒ if a "plateau" exists ➔ an optimum in Pt loading will minimize the cost

⇒ if kW/cm² decreases always with gPt/cm² ➔ Pt loading allowing ~ 1W/cm² will reduce the cost

⇒ **Pemican will aim at increasing such a curve to higher power densities** (materials, design, processes…)

- ***Water management is a key issue*** as it impacts
  - performance (drying/flooding)
  - durability (reversible/non reversible degradation)
  - cost (gas access to the active sites)

Pemican will address this but only for CL

⇒ include such a topic in the future (GDL, membrane, MEA…)?

⇒ increase power density

# *3. Cross-cutting issues*

- ***Training and Education:***
  - Internal short-courses with industry and students (Tecnalia, Imperial)

- ***Safety, Regulations, Codes and Standards:***
  - Possible link with the Spanish standardization committee AENOR AEN/CTN 206/SC 105 "FUEL CELLS" (Tecnalia)

- ***Dissemination & public awareness***
  - Presentation in conferences, publications, patents
  - Public web-site
  - Open workshop (under discussion)

# 4. Technology Transfer / Collaborations

- ***Interactions with industry***
  - Industrial Partners: Opel, Timcal, Solvay Specialty Polymers
  - Industrial Boarding:
    - IB could propose requirements to Pemican and discuss possible technology transfers (for instance MEA manufacturing processes and design)
    - First meeting planned at CEA-Grenoble, 21/11/2012
    - Second meeting will be proposed at the end of the project
  - Possible link (Opel) with European Concil for Automotive ReD (EUCAR)
- ***Interactions with projects***
  - Possible collaborations with Spanish institutions to be discussed via the Spanish Hydrogen Association (Tecnalia)
  - Discussion and possible material exchanges with starting projects (for instance Impact, Impala at JTI) aiming at reducing cost, increasing performance and durability of PEMFC

- ***Future research approach***
  - PEMICAN ➔ better understanding of fluid transport and electrochemistry in a CL and more reliable modeling
  - The proposed approach for CL design could be used with other catalysts, or Pt alloys

⇒ results (manufacturing processes, modeling, design, knowledge…) could be used as a basis for future projects to reduce even more Pt cost and increase performance

- ***Need/opportunities for increasing cooperation***
  - PEMICAN is an example of collaboration between industry (manufacturers, end-users), research centers and universities

⇒ This partnership can be increased in future projects and common initiatives to improve the research collaboration and to exploit the benefits of PEMICAN

- ***Need/opportunities for international collaboration***
  - Exchange of information with DoE to be discussed

# PEMICAN

## Thank you for your attention