# ReforCELL
# (278997)

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# 0. Project & Partnership description

## General Overview

- Project full title: Advanced Multi-Fuel Reformer for Fuel CELL CHP Systems
- Duration: 3 years, 01 February 2012 up to 31 January 2015
- Budget: 5,546,194 Euros
- Partnership/consortium description:

11 European organisations from 6 countries:

6 Research Institutes and Universities

5 top industries (4 SMEs) in different sectors (from hydrogen production to catalyst developments to boilers etc.)

1 TECNALIA, Spain
2 TU/e, Netherlands
3 CEA, France
4 POLIMI, Italy
5 SINTEF, Norway
6 ICI, Italy
7 HYGEAR, Netherlands
8 SOPRANO, France
9 HYBRID, Netherlands
10 QUANTIS, Switzerland
11 JRC, Netherlands

# 1. Project achievements: Objectives (2)

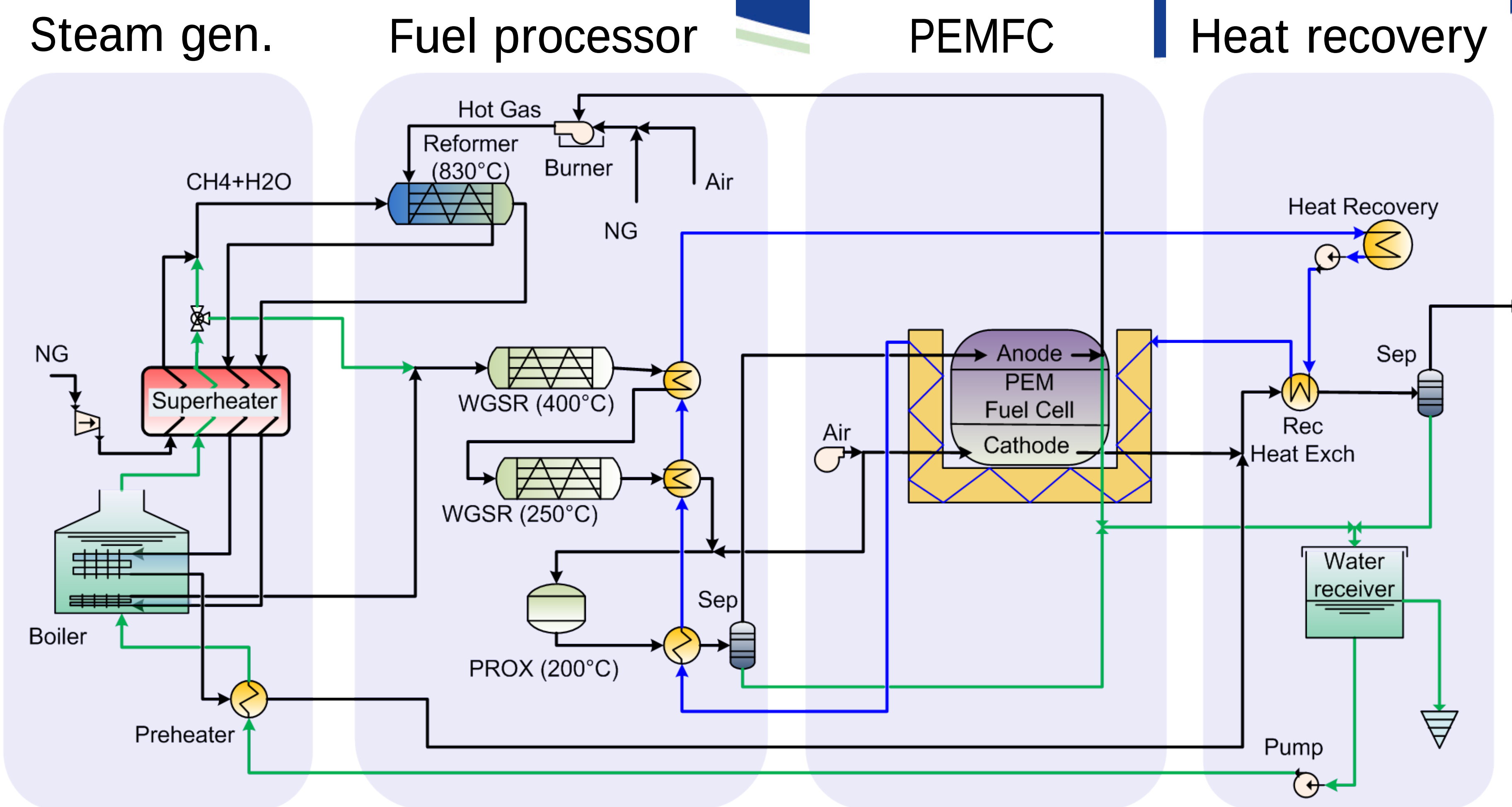
To **improve the efficiency** of the **PEM fuel cell micro-CHP system** with an **innovative multi-fuel processor** (5 $Nm^3/h$ of hydrogen) while **reducing the system cost** from the state of the art to achieve cost bellow 5000 €/kWel by 2020.

The **target** is a net electric efficiency higher than 42% using natural gas and an overall efficiency higher than 90 %.

**HOW?**: By the **development of a novel catalytic membrane reactor (CMR) for hydrogen production** with:

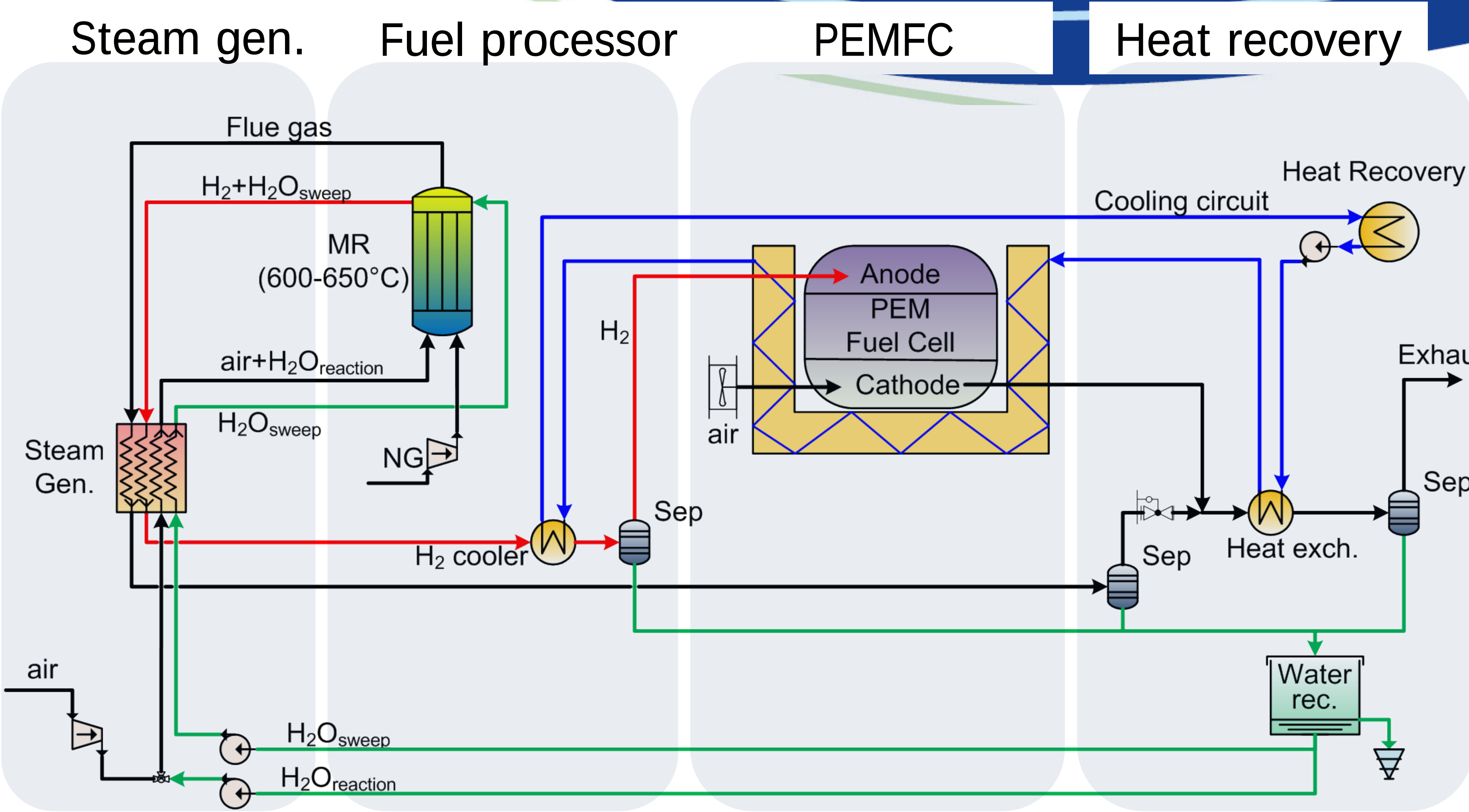
- Improved **performance** (high conversion at low temperature for the autothernal reforming reaction)
- Enhanced **efficiency** (reduction of the energy consumption of at least 7 – 10 %)
- Long **durability** (30.000 hours) under CHP system working conditions

# 1. Project achievements: Traditional reforming concept




PEM m-CHP unit using traditional reforming for fuel processing

# 1. Project achievements: ReforCELL concept




PEM m-CHP unit using catalytic membrane reactor for fuel processing

# 1. Project achievements:
# ReforCELL concept: Catalytic membrane reactor

***Benefits***

- Increase in the overall efficiency of the process due to integration and intensification.
- Production of **hydrogen with very high purity** (>99,99 %) due to the infinite perm-selectivity of the membrane for this gas component.
- Reduction of components in the reformer (heat exchangers) and in the BoP (auxiliary elements).
- Reduction of the reforming temperature (<700 C) for NG processing.
- Reduction of $CO_2$ emissions to 50 % by intrinsic $CO_2$ capture.
- Easier recyclability due to the reduction of components and materials in the reactor.

# 1. Project achievements: Scientific & Technical objectives (1)

Related to the **novel multi-fuel CMR processor**:

- ✓ Develop an advanced catalyst able to catalyse reforming reactions under moderate (<700 C) conditions and resistant to sulphur compounds and coke formation and at reduced cost.
- ✓ Develop new hydrogen permeable membrane materials with improved separation properties, long durability, and with reduced cost.
- ✓ To asses the large scale production of the membrane developed.
- ✓ Understand the fundamental physico-chemical mechanisms in membranes and catalysts.
- ✓ To design, model and build up novel multi-fuel catalytic membrane reactor configurations based on the new membranes and catalysts for small-scale pure hydrogen production (5Nm3/h of hydrogen)
- ✓ To validate the new membrane reactor configurations, and design a semi-industrial Autothermal Reforming (ATR) prototype for pure hydrogen production

# 1. Project achievements: Scientific & Technical objectives (2)

Related to the **integration and validation of the multi-fuel reformer into the PEM fuel cell CHP system:**

- ✓ To design the optimum CHP system (aided by simulation tools) in order to achieve a complete system able to achieve the targets in performance and cost.
- ✓ To test the reliability of the novel reactor with a Fuel Cell CHP system
- ✓ To assess the health, safety and environmental impact of the system developed, including a complete Life Cycle Analysis (LCA), of the developed system.

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# 1. Project achievements: Approach (1)

WP1. Management [TECNALIA]

WP8. LCA and Safety analysis [QUANTIS]

**WP2. Industrial specifications of FC micro-CHP [ICI]**

**WP3. Catalysts development [HYBRID]**
- Catalyst preparation
- Catalyst characterisation
- Activity test

**WP4. Membrane development [SINTEF]**
- Material for membranes
- Membranes development and characterization

**WP5. Lab scale reactors [TU/e]**
- Integration in micro-structured membrane reactors
- Testing and model validation

**WP6. Novel ATR prototype [HYGEAR]**
- Design of Pilot
- Set up and testing
- FAT
- Testing and validation
- Process design & Simulation

**WP7. Integration and validation of micro-CHP system [ICI]**
- Fuel Cell stack selection
- FC - CHP system optimization
- Integration and testing

WP9. Dissemination and Exploitation [HYGEAR]

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# 1. Project achievements: Milestones (1)

| Milestone no. | Milestone name | WPs no's. | Lead beneficiary | Delivery date from Annex I |
|---|---|---|---|---|
| M3.1 | Selection of experimentally validated catalysts for lab scale (WP5) membrane reactors | WP3 | HYBRID | M12, M18 |
| M3.2 | Conformation and scale-up of catalytic materials for implementation in prototype (WP6) | WP3 | HYBRID | M22 |
| M4.1 | Improved membranes supports | WP4 | TECNALIA | M10, M16, M20 |
| M4.2 | Membranes for lab scale and prototype catalytic reactors | WP4 | SINTEF | M12, M18 |

# 1. Project achievements: Milestones (2)

| Milestone no. | Milestone name | WPs no's. | Lead beneficiary | Delivery date from Annex I |
|---|---|---|---|---|
| M5.1 | Lab scale reactors validation | WP5 | TU/e | M20 |
| M5.2 | Validation of CMR simulation | WP5 | TU/e | M24 |
| M6.1 | Pilot scale prototype reactor ready for testing | WP6 | HYGEAR | M30 |
| M6.2 | Validation of Process simulation | WP6 | HYGEAR | M30 |

# 1. Project achievements: Milestones (3)

| Milestone no. | Milestone name | WPs no's. | Lead beneficiary | Delivery date from Annex I |
|---|---|---|---|---|
| M7.1 | Selection of an optimized PEMFC stack | WP7 | CEA | M24 |
| M7.2 | Identification of CHP system to test | WP7 | ICI | M24 |
| M7.3 | Validation of the CHP system | WP7 | SOPRANO | M36 |
| M8.1 | Screening Life Cycle Assessment | WP8 | QUANTIS | M24 |
| M8.2 | Full Life Cycle Assessment | WP8 | QUANTIS | M36 |

# 1. Project achievements: Testing procedures (1)

- ✓ There are different levels of testing procedures.
- ✓ Catalysts, membranes and lab-scale reactors: In house testing procedures that could be considered as non-standarized test procedures by the S&T community.
- ✓ ATR Reformer (pilot scale):
  - The reactor will be designed and manufactured according the “Pressure Equipment Directive” of the EC (97/23/EEC).
  - In house quality procedures will be used for the final assembly of the ATR reactor, subcomponents and control system.
  - Factory Acceptance Test (in house testing procedures) on the final prototype
- ✓ Fuel Cell: Testing procedures previously develop by JRC under the FCTESTNET/FCTESQA project will be the base to define the test protocols and to develop test methods for endurance testing of PEFC stacks in m-CHP.

# 1. Project achievements: Testing procedures (2)

- IEC 62282-X-YYY Fuel Cell Technologies. This is a series of standards divided into 7 parts, covering stationary, portable, and micro FC power systems.
- EN 50465 Gas appliances - Fuel cell gas heating appliances - Fuel cell gas heating appliance of nominal heat input inferior or equal to 70 kW.
- ISO/DIS 14687-3 Hydrogen Fuel – Product Specification — Part 3: Proton exchange membrane (PEM) fuel cell applications for stationary appliances. Classification of hazardous areas (CEI-EN-60079-10)
- Gas Appliance Directive (90/396/EEC)
- Electromagnetic compatibility Directive (2004/108 EC)
- Low Voltage Directive (2006/95/EC) & Machinery Directive (2006/42/EC)

# 1. Project achievements: Progress (1)

- ✓ The Project started on February the 1st, 2012
- ✓ Progress is according to the planned Annex 1.
- ✓ WP2 Industrial specification of Fuel Cell CHP system has been finalised
  - ❑ The goals was to define the industrial requirements for introduction of CHP system in industry
  - ❑ The analyse was based on: 1) industrial objective, 2) market characteristics, 3) system criticity, 4) comparison with competitors 5) economic evaluations
  - ❑ Every point of the analysis was divided into subsystem and a study was conducted to try to identify the most critical aspects and the correct way to reduce its impact.

# 1. Project achievements: Progress (2)

- ✓ WP2 Industrial specification of Fuel Cell CHP system has been finalised
  - ❑ Guideline for product development was found (i.e. use as standard component as possible or precious metal refining after use)
  - ❑ Competitiveness of the system emerge in comparison with other fuel cell system as well as with commercial system but payback time is still to hight (higher than 5 year depending on the country). Production cost should be reduced.
- ✓ WP3 Catalyst development: First Ni based catalysts both commercial and new developments have been developed, activity tests are been carried out.
- ✓ WP4 Membranes development: Processes are operational. First Pd based selective layers have been deposited. Studies on interdiffusion layers and support quality are on going.

# 2. Alignment to MAIP/AIP: Application Area

**ReforCELL correspond to MAIP/AIP objectives for Stationary Power Generation & CHP** and especially: "**SP1-JTI-FCH.2010.3.3 Component improvement for stationary power applications**"

a) Improve the performance of individual components of fuel cell systems (e.g. fuel cell units, reformer, heat exchangers, fuel management and power electr.);
b) The understanding and optimization of interaction between BoP components and mature stacks.

**ReforCELL *will contribute* to the development of mass market** by reducing the cost of micro-CHP systems for stationary application (i.e.; domestic).

**ReforCELL *will contribute* to the development of European industry** by proposing alternative solution compared to competitors

# 2. Alignment to MAIP/AIP: MAIP/AIP targets

| Expected output AIP<br>Topic: 14<br>Call: 2010 | | Objectives Project | Status at 50% of the project | Expected revised objectives |
|---|---|---|---|---|
| *Viable mass production* | | *Mass production technologies are considered in the development* | N/A | |
| *CHP life time (years)* | *> 10* | *> 10* | N/A | |
| *Electrical efficiency (%)* | *> 42* | *> 42* | N/A | |
| *Overall efficiency CHP (%)* | *> 80* | *> 90* | N/A | |
| *Cost target by 2020 (kW)* | *5000* | *5000* | N/A | |
| *Reciclability* | *yes* | *LCA and safety study* | N/A | |

# 3. Cross-cutting issues

- ✓ Dissemination & public awareness
  - Public website (www.reforcell.eu)
  - 6 monthly newsletter & public project presentation
  - Towards national and international organisation related to ReforCELL
  - Participation in international and national conferences and workshops
  - Final dissemination workshop
- ✓ Safety, Regulations, Codes and Standards
  - Safety issues addressed in WP8 (LCA and safety issues) for both the CMR and the complete system. Identification and evaluation of safety parameters (i.e. CMR: prevent thermal runaways or hot spots)
  - The development of the final m-CHP system could provide a feedback on regulation, codes and standards

# 4. Enhancing cooperation and future perspectives : Technology Transfer / Collaboration

- ✓ Interaction with projects:
  - CACHET II (Carbon Capture and Hydrogen Production with Membranes – FP7)
  - CARENA (Catalytic membrane reactors based on new materials based on new materials for C1-C4 valorization – FP7)
  - DEMCAMER (Design and manufacturing of catalytic membrane reactors by developing new nano-architectured catalytic and selective membrane materials – FP7)
  - COMETHY (Compact Multifuel-Energy to Hydrogen converter – FCH JU)
  - MICROGEN 30 (30 kWe CHP system with PEFC for residential applications – Italy)
  - PREMIUM ACT (Predictive Modelling for Innovative Unit Management and Accelerated Testing procedures of PEFC – FCH JU)

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# 4. Enhancing cooperation and future perspectives : Project Future Perspectives

- ✓ Exploitation
  - Mid-Term exploitation internal workshop
  - Final dissemination and exploitation workshop (including an open event)
  - Plan for using and dissemination of foreground & exploitation plans relevant for the ATR membrane reactors and the micro-CHP system
- ✓ Needs/opportunities for increasing cooperation
  - ReforCELL is a clear example of collaboration between industry, research centers and universities
  - This partnerships can be increased in future projects and common initiatives to improve the research collaboration and to exploit the benefits of ReforCELL
- ✓ Future research approach (examples)
  - Micro-CHP systems fueled by biogas
  - Micro-CHP systems fueled by liquid fuels

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## Thank you for your attention

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