

# European and Italian scenario in the field of Hydrogen and Fuel Cells



**Angelo Moreno**

**ENEA - Renewable Energy Unit**

**C.R. Casaccia, Via Anguillarese 301**

**00123 Rome, Italy**

What is needed?

## Environmental, Secure, Competitive Energy

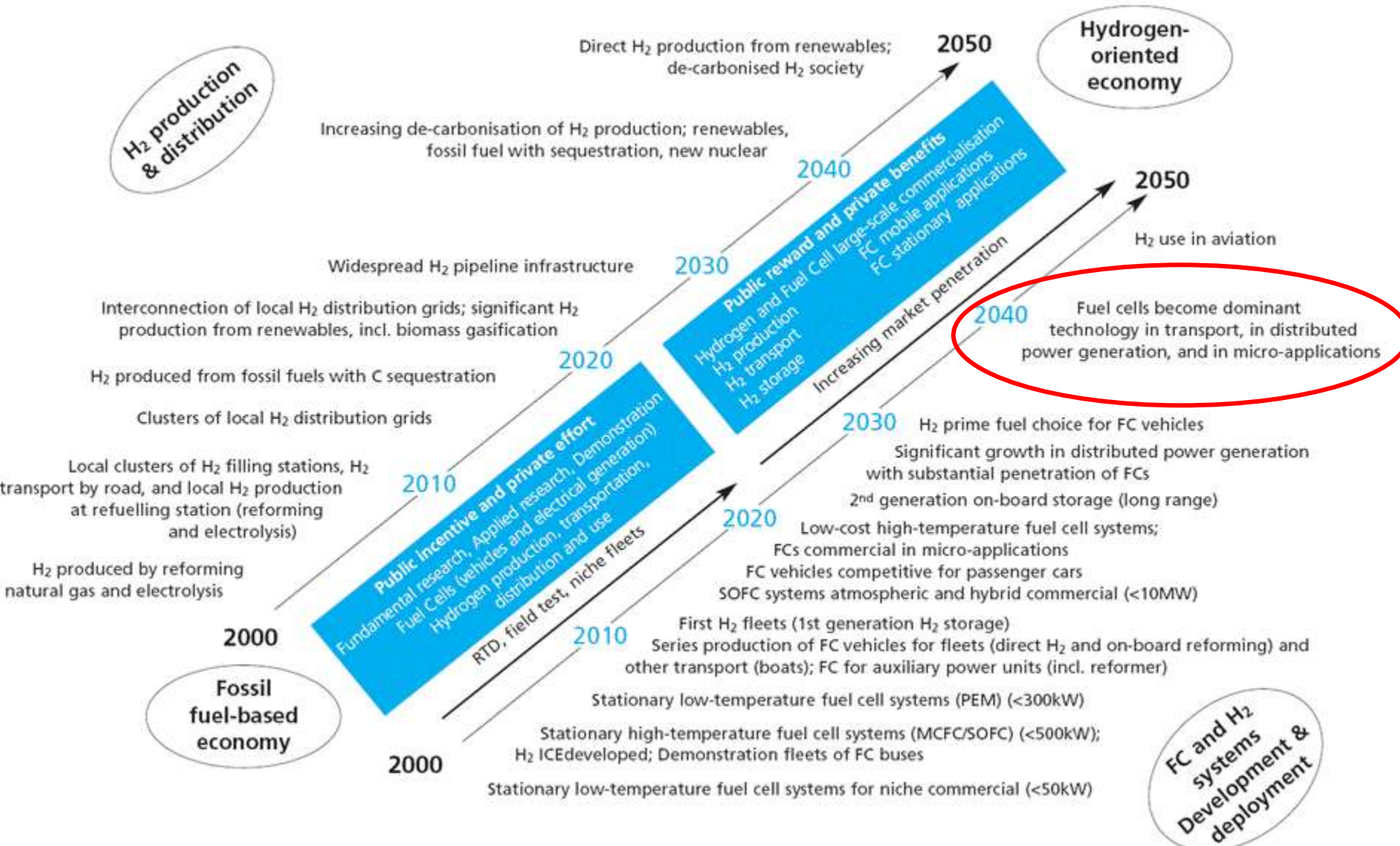
Today:

- Energy account for 80% of the Green House Gases
- EU imports 50% of the total energy consumed
- Investments of 1998 on Energy RTD was 4 times higher than today.

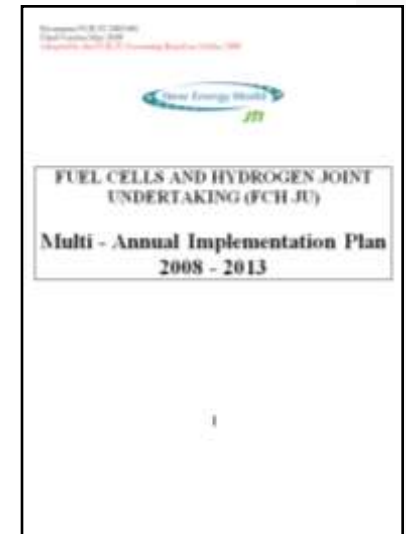
environmental  
secure  
competitive

- **by 2020 - 20/20/20**
  - 20% reduction in GHG emissions
  - 20% reduction in global primary energy consumption ( efficiency)
  - 20% share of renewable energy within total consumption
- **by 2050**
  - 80% reduction in GHG industrial developed countries – (G8 L'Aquila)
- **From 80% dependency on fossil fuels to 80% reduction in GHG emissions in 40 years**
  - A complete new strategy for the global energy system
  - Need to move to “**low carbon economy**”, not easy, cheap or immediate
  - Technology and **efficient use of resources** are “**a must**”

# European Hydrogen and Fuel Cell Roadmap



- **2002-2003** - High Level Group - Vision report: “*Hydrogen energy and Fuel Cells – A vision of our future*”
- **January 2004** - European Hydrogen and Fuel Cell Technology Platform – “Facilitate and accelerate the development and deployment of cost-effective, world class European hydrogen and fuel cell based energy systems and component technologies for applications in transport, stationary and portable power”
- **March 2005** - Elaboration of two key documents
  - “*Strategic Research Agenda*”
  - “*Deployment Strategy*”
- **June 2005** - Strategic Overview of the HFP
- **March 2007** - *Implementation Plan* - Four main Innovation and Development Actions (IDA)
- **FP7 2007-2013** - Hydrogen & Fuel Cell Joint Technology Initiative



[http://ec.europa.eu/research/fch/index\\_en.cfm?pg=documents](http://ec.europa.eu/research/fch/index_en.cfm?pg=documents)

- **Need for a highly focused RD&D programme:**
  - reduce FC system costs by a factor 10 (100 for transport applications)
  - enhance performance and durability of FC systems by a factor  $> 2$
  - reduce costs of hydrogen delivered by a factor  $> 3$
  - pursue novel hydrogen storage materials that meet vehicle operating range and packaging requirements
- **Need to combine private and public investment at EU scale to double present effort**
- **Integrated RTD programme including large-scale demonstrations (*Lighthouse Projects*) to bridge the gap between R&D and commercialisations.**



*Goals for commercialisation*  
portable applications by 2010  
stationary applications by 2015  
mass transport applications by 2020

### Snapshot 2020 - Key assumptions for Hydrogen and Fuel Cell Applications

	Portable FCs for electronic devices	Portable Generators & Early Markets	Stationary FCs Combined Heat and Power	Road transport
EU H <sub>2</sub> / FC units sold per year projection 2020	~ 250 million	~ 100.000 (~ 1 GWe)	100,000 – 200,000 (2-4 GWe)	0.4 – 1.8 million
EU cumulative sales projections until 2020	n.a.	~ 600.000 (~ 6 GWe)	400,000 – 800,000 (8-16 GWe)	1- 5 million
EU Expected 2020 Market Status	Established	Established	Growth	Mass market roll-out
Average power FC system	15 W	10 kW	< 100 kW (Micro CHP) > 100 kW (industrial CHP)	80 kW
FC system cost target	1-2 €/W	500 €/kW	2.000 €/kW (Micro CHP) 1.000-1.500 €/kW (industrial CHP)	< 100 €/kW (for 150.000 unit per year)



- European Commission
- European Industrial Group for Fuel Cell and Hydrogen (NEW-IG)
- European Group of Research and Universities for Fuel Cell and Hydrogen (N.ERGHY)
- Member States and Regions
- Budget and Cost Sharing 2008-2013



✓ European Commission	467 MEUR
✓ Industry and Research	473 MEUR
✓ Total Budget	940 MEUR



# Fuel Cell & Hydrogen Joint Undertaking

## Industry Grouping Members



67 companies

# Fuel Cell & Hydrogen Joint Undertaking



## Research Grouping Members

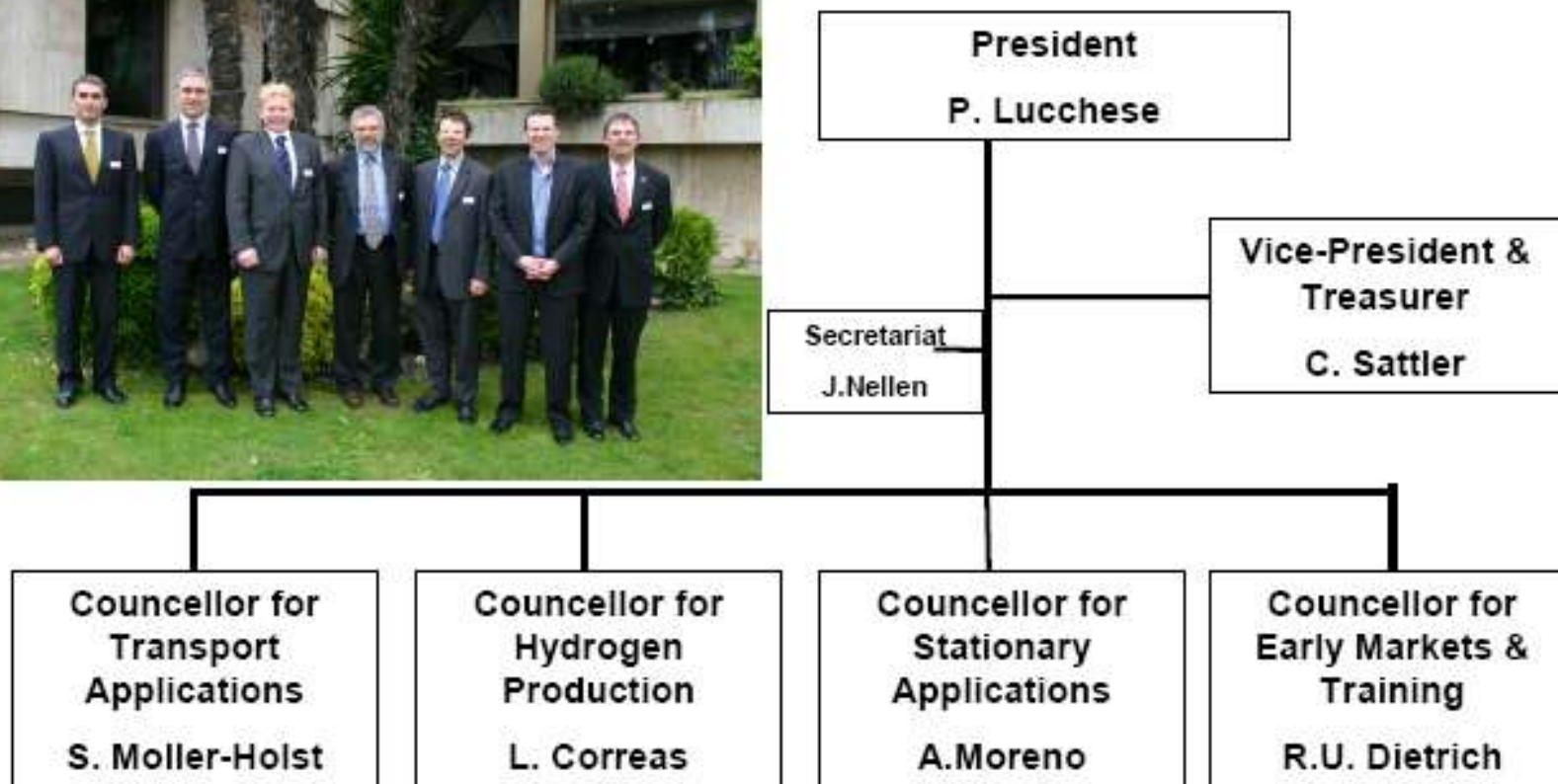


54 Universities  
Research institutes

# The Governing Board

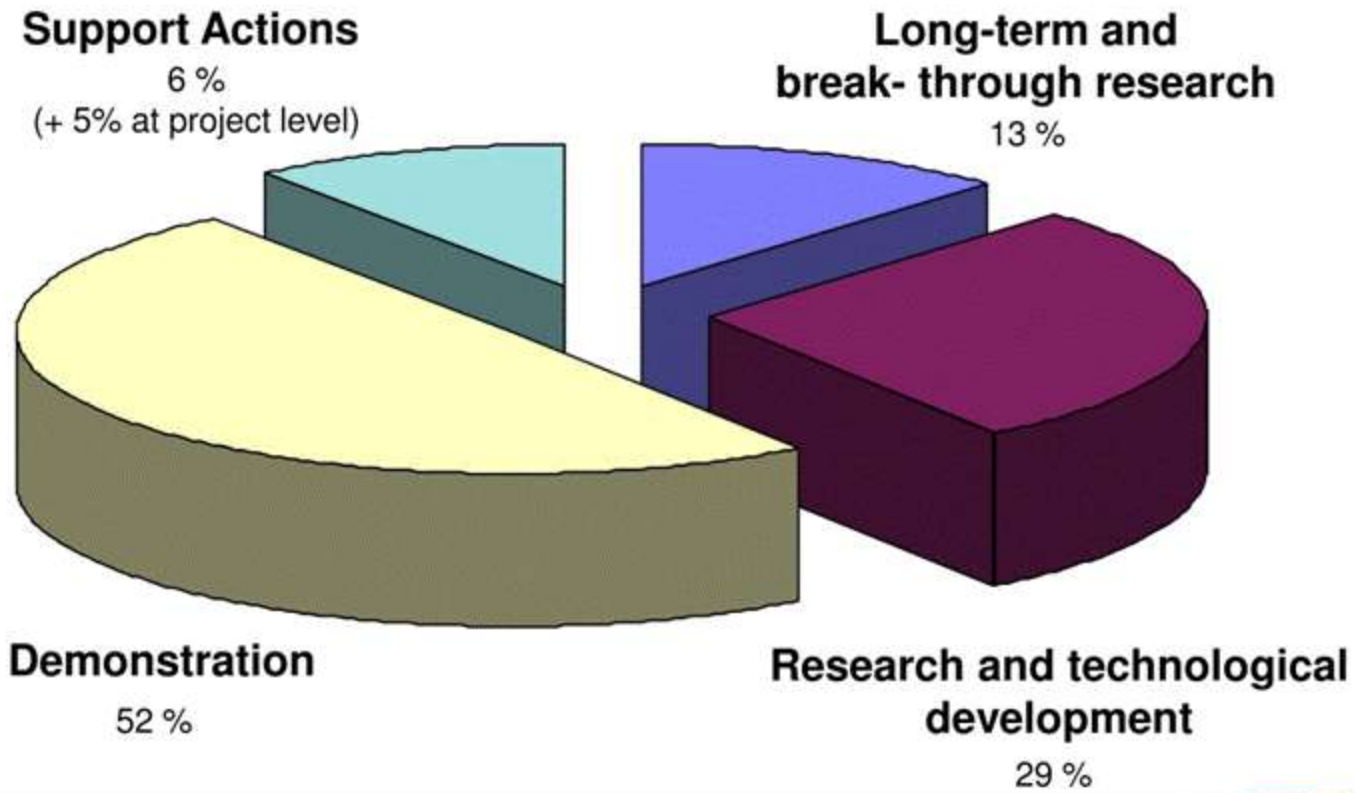






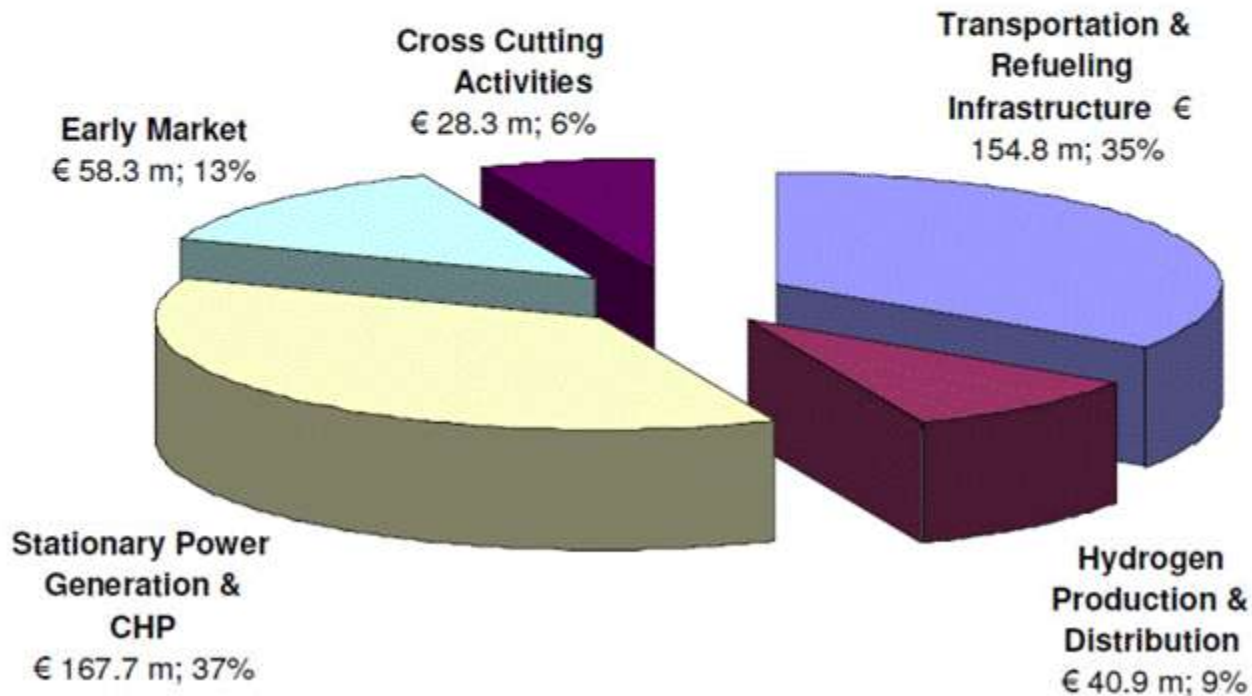
**€ 1 billion public and private investment**

By Action Category



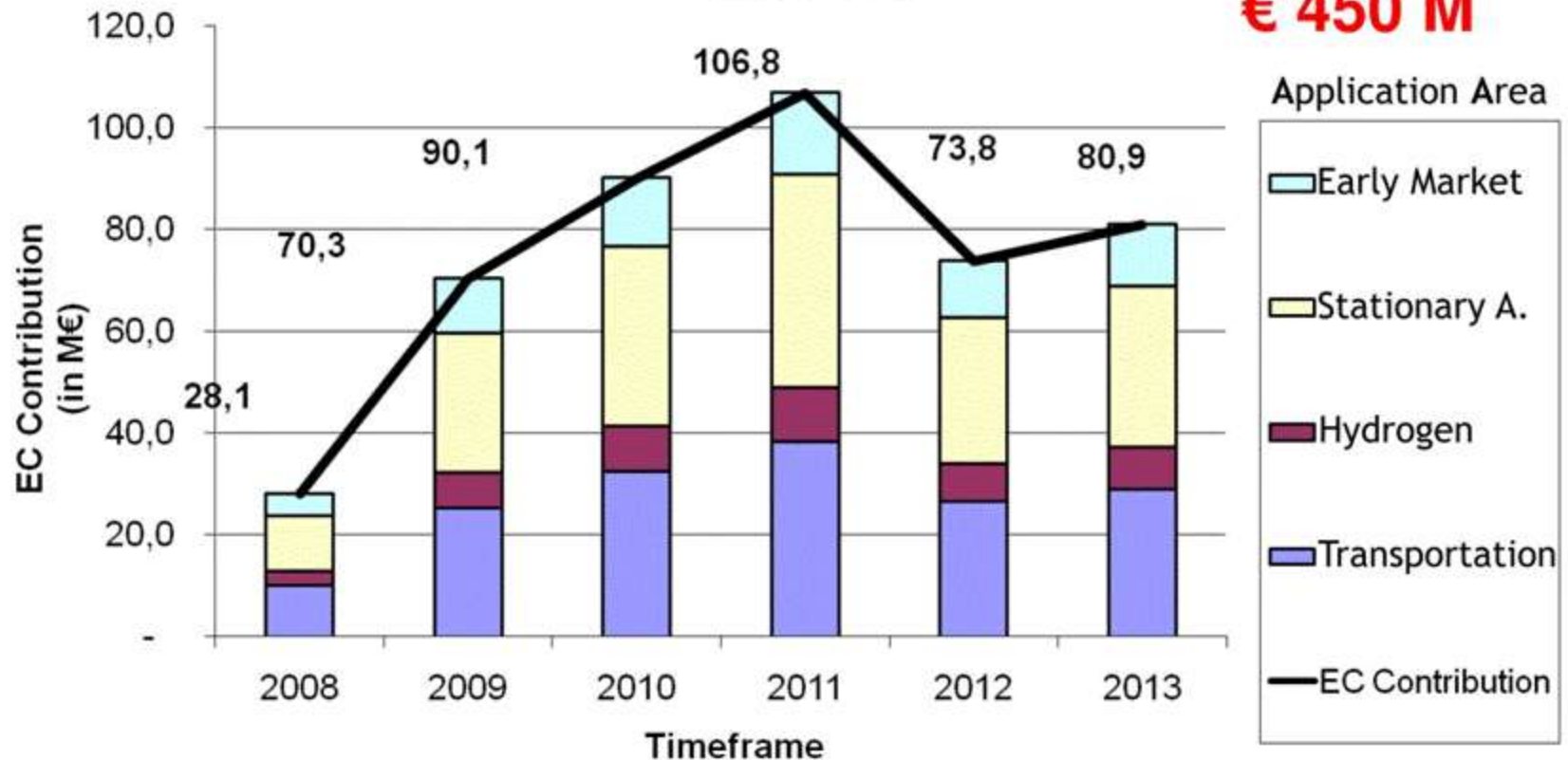
**€ 1 billion public and private investment**

By Application Area



### JTI - Operational Budget Breakdown 2008-2013

**Total EC  
€ 450 M**



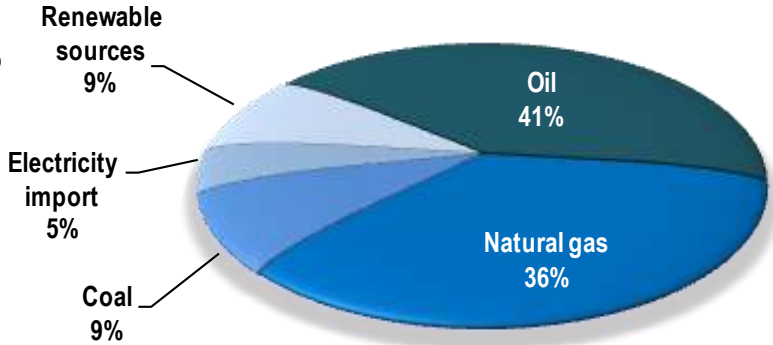


Application Area	M€
Area SP1-JTI-FCH.1: Transportation & Refuelling Infrastructure (10 topics)	36.0
Area SP1-JTI-FCH.2: Hydrogen Production & Distribution	16.0
Area SP1-JTI-FCH.3: Stationary Power Generation & CHP	38.0
Area SP1-JTI-FCH.4: Early Markets	15.0
Area SP1-JTI-FCH.5: Cross-cutting Issues	4.0

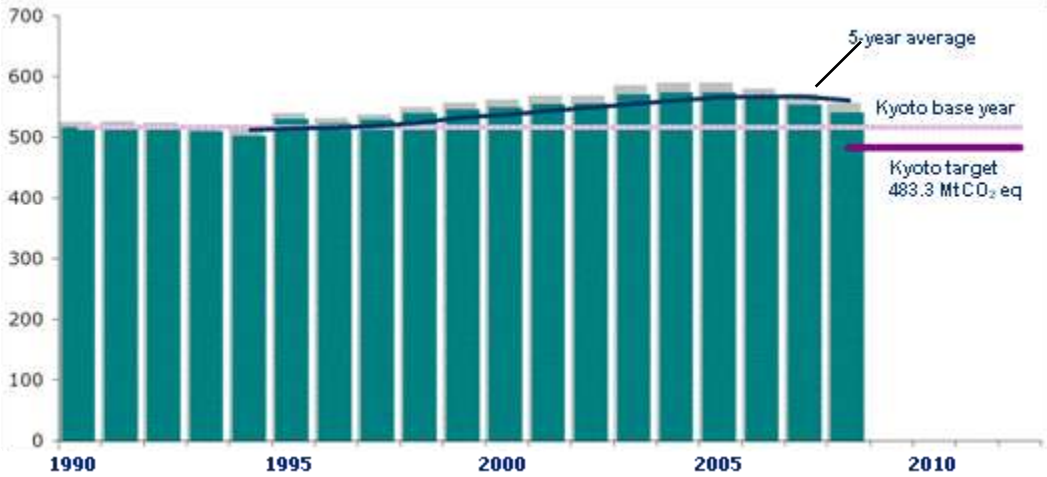
# Italian energy system and GHG emissions

## Primary energy demand: 192 Mtoe in 2008

- ◆ High dependence on fossil fuels (>85% imported)
- ◆ 9% of renewables, mainly hydroelectric
- ◆ About 5% of electricity import



- ◆ Large use of fossil fuels makes difficult reduce GHG emissions
- ◆ Average emissions over the period 2004-2008 were 8.5 % higher than the base-year level, still significantly above the target of - 6.5 % for the period 2008-2012



Emissions 1990 (base year) 516.3 MtCO<sub>2</sub> eq

Total GHG emissions 2008 540.7 MtCO<sub>2</sub> eq

# Key elements of Italian strategy in energy sector

- To increase **security of supply** of energy sources
- To increase **efficiency** in energy uses
- To avoid dangerous **climate change** and other serious negative social or environmental impacts of energy technologies
- To allow **competitive national development**



The strategy approach is twofold, acting on :

- the **supply side**, through
  - diversification of primary energy sources and reduction of dependence on imported fossil fuels
  - development of more efficient processes and technologies
- the **demand side**, trying to foster efficient and environmentally benign technologies in the final uses

# Italian activities on hydrogen and fuel cells

- ◆ In the last years, in Italy, the interest for hydrogen and its related technologies has grown according with similar trends characterising the major industrialised countries
- ◆ RD&D projects are being carried out in this field, in the frame of European and national programmes, with the involvement of industries, research organisations and users
- ◆ Many demonstration activities are promoted from Local Authorities (Regions and Municipalities)



## INTERNATIONAL COLLABORATIONS

- ◆ International Partnership for Hydrogen Economy
- ◆ Implementing Agreements IEA
- ◆ Fuel Cells & Hydrogen Joint Undertaking



# European and Regional Projects

- **FIAT Research Center** - Realization and demonstration of fuel cell vehicles (PANDA, HyTRAN and HySys Projects)
- **Piedmont Hydrogen System (SPH2)** - R&D on hydrogen technologies

- **Zero Regio Project** - Testing FC vehicles (Panda Hydrogen minifleet) and hydrogen infrastructures in Mantova
- **Methane/hydrogen blends Project** - Testing of a fleet of 20 ICE cars fuelled with HCNG blends; 2 ENI refueling stations in Milan

- **H2U Hydrogen University** - "Sailing boat to Hydrogen" (APU unit fuelled with H<sub>2</sub> from renewable sources)

- **Hydrogen along Motorway Bolzano-Modena** Multinergy refuelling station in south Bolzano (H<sub>2</sub> and HCNG blends)

- **Arezzo Project** - H<sub>2</sub> distribution network for goldsmith district and use in small cogeneration systems (PEFC); FC hybrid vehicle (H2kart Project)

- **Hydrogen Park** (Porto Marghera) - Development and application of hydrogen technologies in transportation and electricity generation

- **MultiEnergy Project** - Hydrogen refuelling dispenser in a multifuel station

- **ENEL Fusina** - Hydrogen power generation plant (gas turbine fuelled with H<sub>2</sub> supplied by chemical plants)

- **Filiera Idrogeno Project** (Pontedera /Pisa) Bipower FIAT Multipla (gasoline/H<sub>2</sub> mixture); H<sub>2</sub> production/ distribution

- **Vision Project** (Fincantieri) - Hydrogen boat in Venice

- **Sotacarbo Project** - Hydrogen production from coal

- **HyCHAIN Project** - Demonstration of urban fuel cell vehicles (10 out of 158)

- **Methane/hydrogen blends Project** (Forlì/Ravenna) - Testing of bus for public transport

- **Polo Idrogeno Lazio** - RD&D hydrogen technologies

- **UNIQUE Project** - Hydrogen from biomasses

- **H2-Tpl Project** - Hydrogen minibus in Rome public transport (CIRPS/ATAC, hydrogen from electrolysis)

- **Puglia Region Project** - Distribution network of hydrogen from renewable sources

- **Benevento** - FC vehicles development (motorcycle and van)

- **Mata&Grifone project** - Development of FC mini-bus and mini-van for Messina ATM

- **Messina (Giano project)** - Development of FC mini-car for small islands



## FISR PROGRAMME “HYDROGEN AND FUEL CELLS”

supported by the **Ministry of Education, University and Research** and **Ministry of Environment** through the Special Integrative Fund for Research (FISR)

**14 projects (8 on hydrogen technologies, 6 on fuel cells)**

*FISR funding : 90 M€*

*Total cost of the projects: 120 M€*

*Duration: 2005-2010*

## MINISTRY OF ECONOMIC DEVELOPMENT – RESEARCH FOR ELECTRIC SYSTEM

**Development of fuel cell systems (PEFC, MCFC and SOFC) for stationary generation**

Activities carried out at ENEA, CNR-ITAE, ERSE (ex Cesi Ricerca) , FN and university institutes

*MSE funding*

*I YEAR (2008) - 4.2 M€*

*II YEAR (2009) - 3,5 M€*

*III YEAR (2010) – 4,5 – 5 M€ - under discussion*



INDUSTRIA 2015



**Ministry of Economic Development** has launched in the 2007 the “Industria 2015” Program aimed at assisting Industrial innovation projects in the thematic areas:

- ◆ Energy efficiency
- ◆ Sustainable mobility
- ◆ New technologies for life
- ◆ New technologies for Made in Italy
- ◆ Innovative technologies for cultural heritage

*Hydrogen and Fuel Cells: 5 projects*

*MSE funding: 30,1 M€*

*Total cost of the projects: around 70 M€*

*Duration: 3 years*

## ENERGY EFFICIENCY

- **MICROGEN 30 / ICI Caldaie** - 30 kWe CHP system with PEFC for residential applications (6.08 M€ funded)
- **EFESO / Merloni Termosanitari** - 1-2.5 kW micro-CHP prototypes with SOFC (planar and tubular technologies) (10.92 M€ funded)
- **HYDROSTORE / Venezia Tecnologie** - Study and development of storage systems (metal hydrides) (5,3 M€ funded)

## SUSTAINABLE MOBILITY

- **VISION /Fincantieri** – Hydrogen ferry for Venice lagoon with fuel cell hybrid system (3.07 M€ funded)
- **PBI (Innovative Bus Platform) /Breda Menarinibus-** Systems for the safe and integrated mobility (vehicles and infrastructures for passenger and/or freight transport) (4.73 M€ funded)



## ***PEFC***

- ◆ MICROGEN project - 30 kWe CHP for residential applications
- ◆ Development of systems for transportation
- ◆ Prototypes of FCEV (car, bus, scooter)

## ***MCFC***

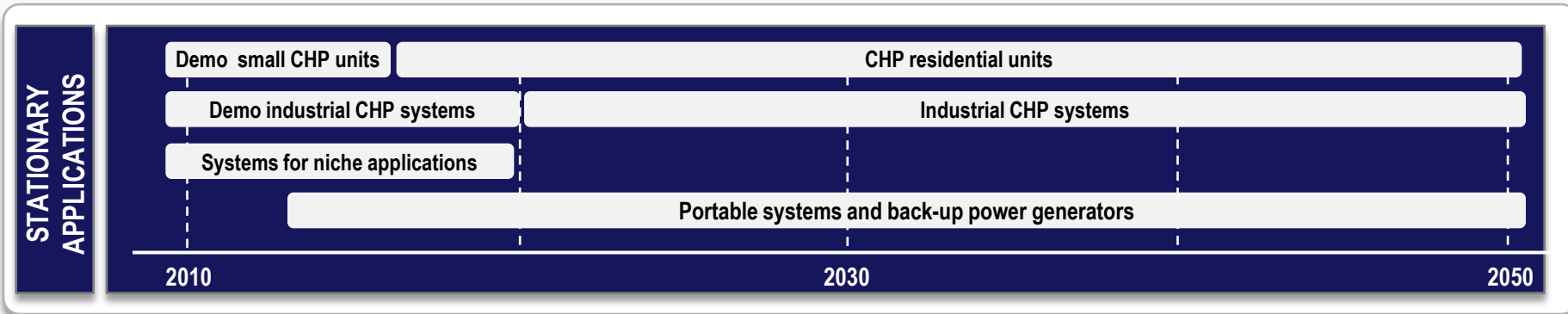
- ◆ Development of systems for stationary applications
- ◆ Development of integrated system based on “Waste to energy systems” and on biomass
- ◆ MCFC for CO<sub>2</sub> separation

## ***SOFC***

- ◆ Basic research on novel materials and components
- ◆ EFESO Project - 1-2.5 kW micro-CHP

## ***DMFC***

- ◆ Basic research on materials and components
- ◆ Development of stacks for portable applications



## Basic research activities

- ◆ Improvement of fuel cell performances and cost reduction through the development of innovative materials and components and development of relative manufacturing processes



## Systems under development

- ◆ Portable units for camping and leisure markets (< 1 kW) - *PEFC, DMFC*
- ◆ CHP systems for residential uses up to 30 kW - *PEFC, SOFC*
- ◆ 1-7 kW generators for back-up power and telecommunication sector - *PEFC*
- ◆ 100 kW - 1 MW plants for distributed generation - *MCFC*



PEFC



- Units in the range 150 W- 5 kW for different market sectors
- 1-5 kW CHP systems (LPG)
- 5 kW APU power generators (hydrogen)
- Power modules for transport use (fork lift, small hybrid vehicle)



Small-medium size micro-cogeneration systems (30 kW) fed with natural gas



3-7 kW UPS units fuelled with hydrogen



MCFC



- Development and demonstration of power systems up to 500 kW
- Demo project: MCFC in the CCS
- Systems for naval applications
- Manufacturing facility for stacks and power plants in Terni ; capacity 3 MW/y upgradeable to 10 MW/y



SOFC



Components and stack for integration in cogeneration systems (0.5-5 kW)



1-2.5 kW micro-CHP systems



- 3 years program 100% founded by Ministry of Economic Development, concerning:
  - **Energy systems**: both conventional (turbines, ICE) and innovative (FC)
  - **Fuels**: clean coal, H<sub>2</sub> (from fossil, from renewable, from wastes), secondary fuels, biomass, biofuels
- ENEA has, for the second year, about 20 M€ for several projects, among these:
  - ✓ MCFC integration into waste to energy chain (2 M€)
  - ✓ Clean coal: gasification and use of syngas both in gas turbine and in MCFC
- ENEA is discussing the approval of the third year (25 M€ of which 2.1 for MCFC in the “Waste to energy chain and CO<sub>2</sub> separation”)





## ENEA activities on Fuel Cell

### Biomass gasification coupled with MCFC

- ◆ System engineering
- ◆ Construction and testing of a 125 kW MCFC plant fuelled with biomass gasification (Trisaia Research Centre)



### Anaerobic Digestion

- Selection of suitable bacteria and process parameters
- Development of system fuelled with biogas (catalysts for gas clean-up, study of the influence of contaminants on cell performance (MCFC))
- Development of pilot scale systems (1 kW)



**EFESO**  
ELE20

## Environmentally Friendly Energy from Solid Oxide Fuel Cell

1- 2.5 kW micro CHP prototypes, based on solid oxide fuel cell technology for residential use  
*(planar and tubular configurations)*



The project aims at obtaining a system industrial cost that has a payback of 5 years in absence of economic incentives

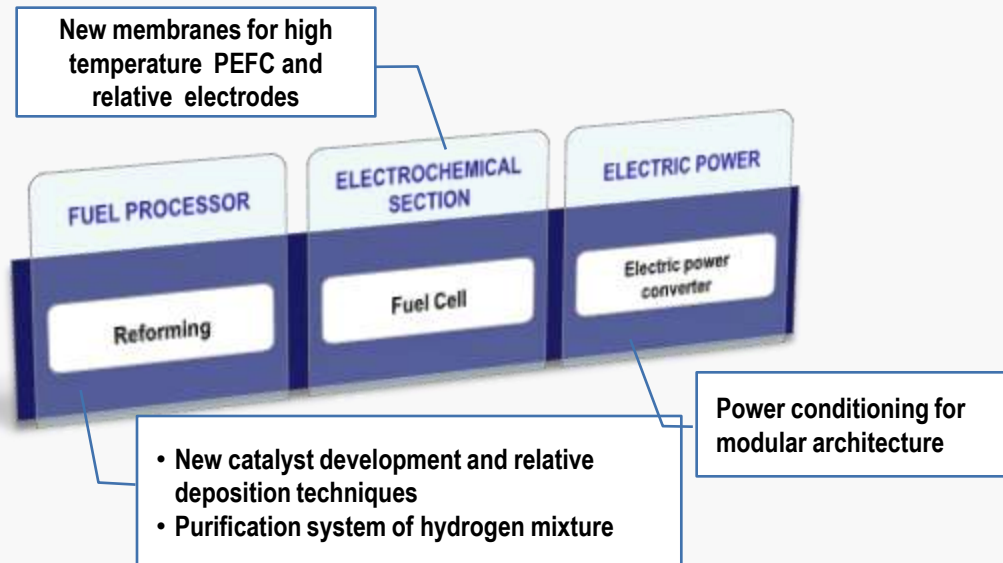
### Main Objectives:

- Realise 4 Micro CHP prototypes in the power range of 1 and 2.5 kWe, based on SOFC technology (both planar and tubular)
- Target the industrial cost that has a payback of 5 years in a non incentive economic overview.
- Target appliances for residential use both single-family and multi-family houses with low specific emissions.



## MICROGEN<sub>30</sub>

30 kWe CHP system based on polymer electrolyte fuel cells fed by natural gas for residential applications



### Main Objectives:

- ◆ high electrical efficiency (higher than 35%, and up to 40%, 10% higher than existing systems),
- ◆ global efficiency up to 85-90%,
- ◆ very low polluting gas emissions,
- ◆ high reliability and costs comparable with that of centralized boilers.

MICROGEN 30 presents **innovations** with respect to the systems actually in use, in terms of **design and performance of single components**



**PON - RICERCA E COMPETITIVITÀ 2007 - 2013 - Dec. Dir. prot. N.1/Ric del 18 gennaio 2010**  
**Settore/Ambito: ENERGIA E RISPARMIO ENERGETICO**

## FC - NEW GENERATION OF GREEN POWER FCNewGen

**UNDER REVISION**

FC - Nature Gen  
FC - Smart Gen  
FC - Elettra Gen  
FC - Wec Gen

Funded by Ministry of Education, University and Research

## PROJECTS TO THE SECOND REVISION PHASE:

1. FC-SMART GEN - Fuel Cell and SMART Hybrid GENERation from fossil and renewable sources
2. FC-NATURE GEN - Fuel Cell for NATural gas Ultra Reduced CO<sub>2</sub> Emissions integrated energy GENERation
3. FC-ELETTRA GEN - Molten Carbonate Fuel Cell for ELEctricity GENERation and CO<sub>2</sub> Capture in gas combined cycle plant.

## ◆ FCTES<sup>QA</sup>

Definition of testing procedures, codes and standards for FC in several application (2006-2009)



## ◆ FCTEDI

Dissemination of FCTES<sup>QA</sup> results and analysis of what is needed about normative, codes and standards for FC in stationary applications (2006-2009)



## ◆ HYSYS

Components developments for hybrid vehicles on Fuel Cell (2005-2009)



## ◆ MCFC-CONTEX

Study of degradation mechanism of MCFC and clean up systems ( FCH JU 20092-2012)



## ◆ FC-HY Guide

Development of a Manual for LCA applications to fuel cell (FC), for PEMFC, SOFC, MCFC (2010)



## ◆ FC-EuroGrid

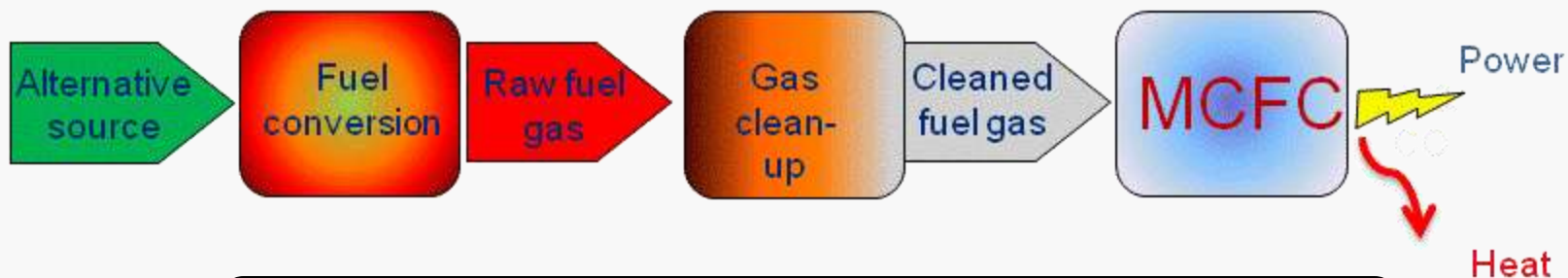
Development of benchmarks and targets for stationary fuel cell applications in Europe (2010-2012)



Partners: ENEA, MTU, AFCO, TUM, MAM, UNI GE,  
KTH, OCM-ICCPET

About 4.2 M€ (EU funds about 50%)

Duration : 3 years



**Contaminants & MCFC effects**

**Analysis Methods**

**Cleaning Strategies**

- CHP system demonstration for domestic application (1 kW<sub>e</sub>) integrated with a condenser boiler (24 kW<sub>t</sub>) in cooperation with Acumentrics
- Partner of EU projects FLAME SOFC and REAL SOFC
- Preparing a proposal inside the Italian program “Industria 2015” for the development of SOFC based system for domestic application between 1 – 3 kW<sub>e</sub> in cooperation with SOFCPOWER, ENEA,...



Product development  
(HoTbox™ *Htceramix*)

1999 – 2x50 kWp proof concept - Milan (I)



2004 - 2TWINSTACKS - Guadalix (Spain)

2005 - Tecnodemo - AL (I)

2006 - Mocami - Milan (I)

2007 - Tubitak -MRC - Turkey ( fuelled by diesel oil)



2007 - NIC – Terni (I)

2008 - GP1 – AL (I)

2007



2009

2008 - GP2 – AL (I)  
2009 – CO2-CCS focus  
2010 →MW class design



Ansaldo Fuel Cells has developed recently the new series of FA200 MCFC stacks and is going to design and manufacture the FA400, of higher size, to be used for MW class future plants

## Basic studies on durable and cost-effective components for high-temperature fuel cells running on alternative fuels

**Korean Principal Investigator**

**Suk Woo Nam**

**Center for Fuel Cell Research**

**Korea Institute of  
Science and Technology  
(KIST)**

**Foreign Principal Investigator**

**Angelo Moreno**

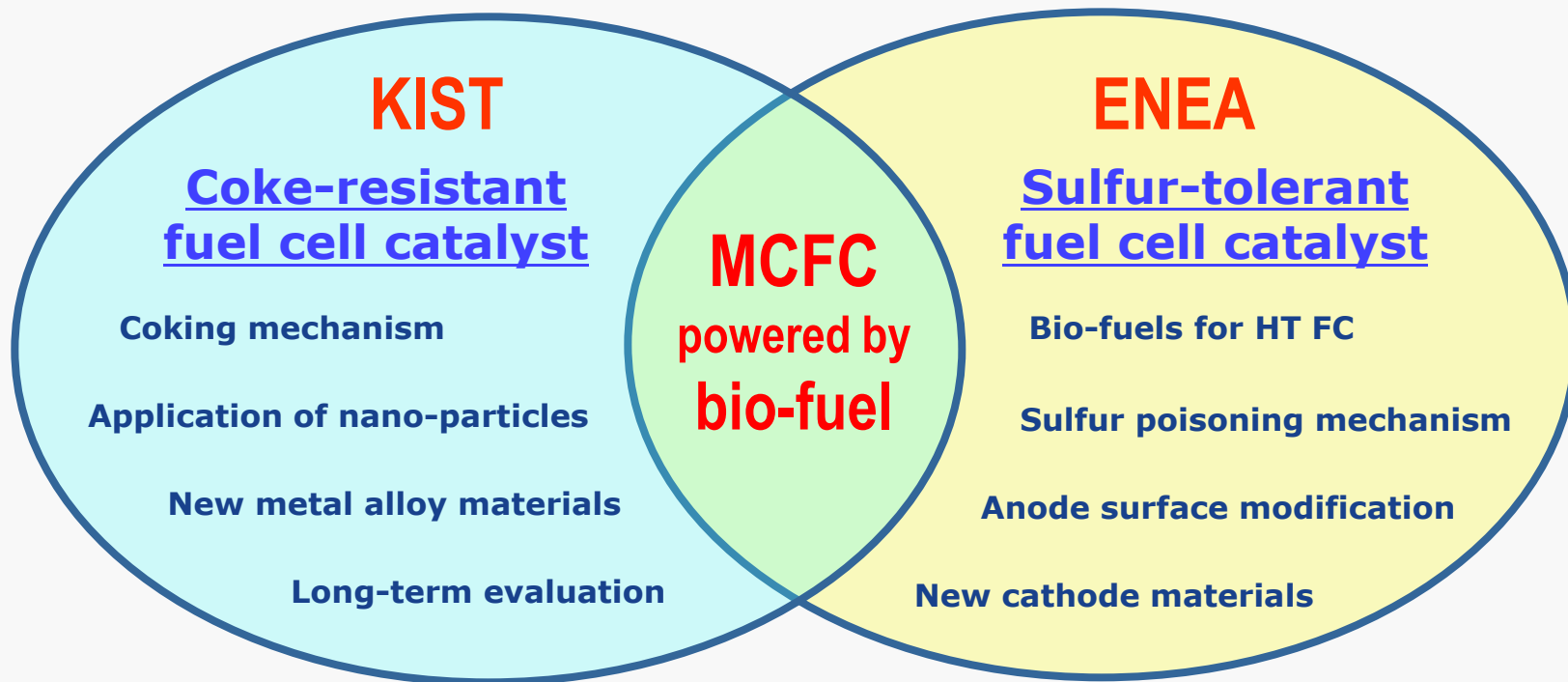
**High-Temperature Fuel Cell Project**

**Italian National Agency  
for New Technologies,  
Energy and the Environment  
(ENEA)**



- To develop original & fundamental technologies for **“MCFC powered by bio-fuel”** through KIST-ENEA complementary research collaborations.
- To commercialize the technologies through global network based on GRL.
- To upgrade the KIST-ENEA GRL to the world class research center: **Center of Excellence in MCFC.**

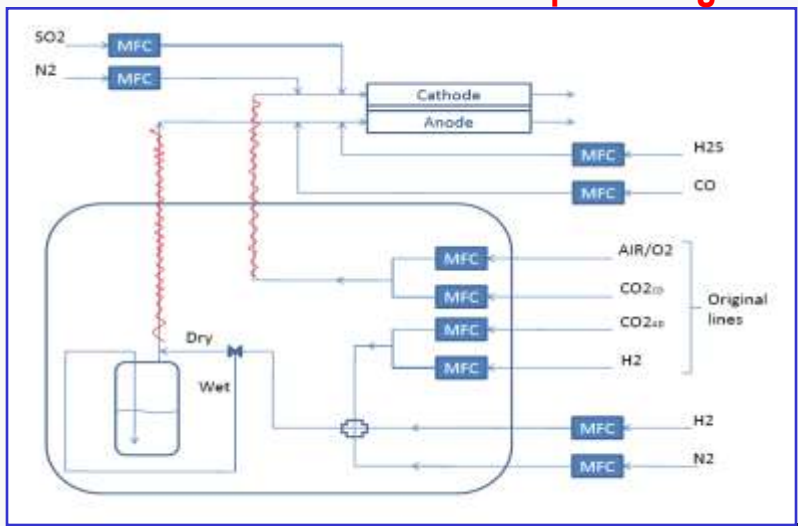
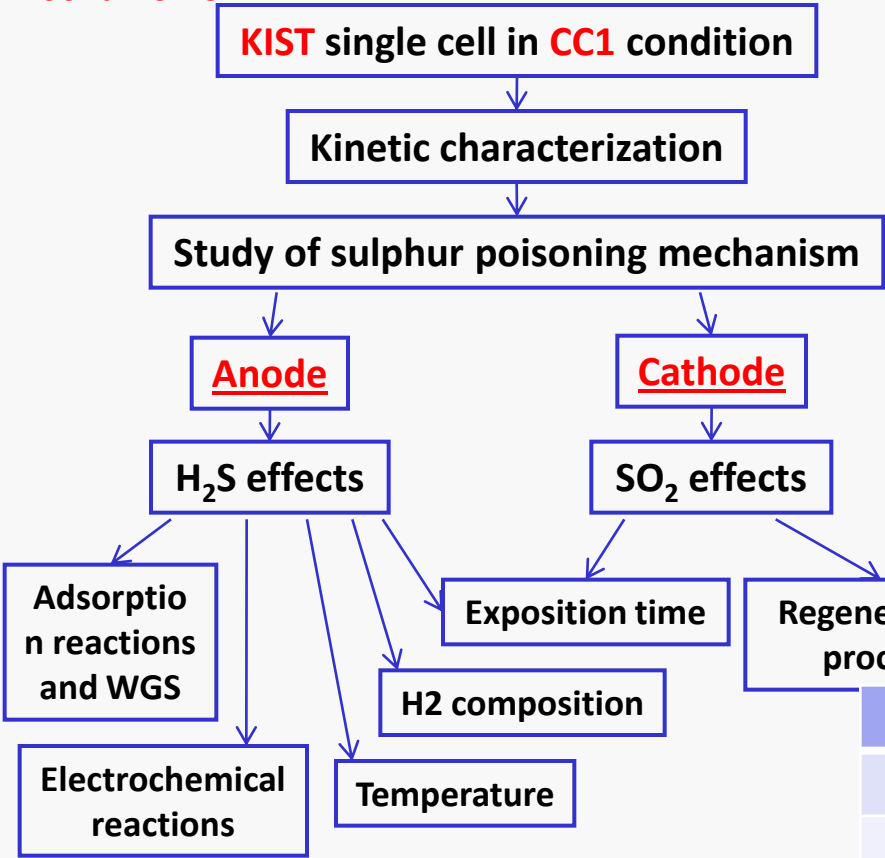
The collaboration between the Center for Fuel Cell Research at KIST and High-Temperature Fuel Cell Project at ENEA will be the most promising implement for MCFC powered by bio-fuel.



This research program will be the most systematic comprehensive program in the world to develop sulfur-tolerant and coke-resistant electrodes for high-temperature fuel cell (HT FC).

# GRL: Purposes of the work - 2010

Study the performance decay of KIST single cell under anode  $H_2S$  and cathode  $SO_2$  poisoning under real plant condition (CC1), trying to **separate the effect of the different reactions involved in poisoning mechanisms**



Anode		Cathode	
$H_2$ (%)	40.1	$N_2$ (%)	87.6
CO (%)	3.9	$O_2$ (%)	9.4
$CO_2$ (%)	7.1	$CO_2$ (%)	3.0
$H_2O$ (%)	48.9		
Flow(ccm)	258.0	Flow(ccm)	5394.7