The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific
and Cultural Organization

International Atomic
Energy Agency

Workshop on "Physics for Renewable Energy"
October 17 - 29, 2005

301/1679-21

"The Activity of the ITAE"

S. Freni
CNR - Institute for Advanced Energy Technologies
'Nicola Giordano' (CNR-ITAE)
Messina, Italy

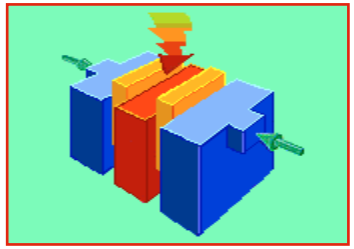
The activity of the Institute for Advanced Energy Technologies "Nicola Giordano"

Dr Salvatore Freni

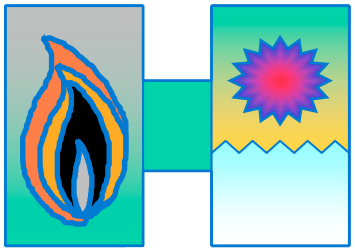
Workshop on 'PHYSICS FOR RENEWABLE ENERGY'

Institute for Advanced Energy technologies, " Nicola Giordano"

Research Topics

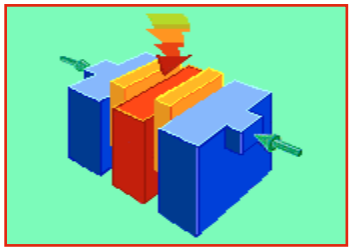


Systems for direct electricity production



Fuel production systems from traditional and renewable energy source

Systems for energy storage and transportation



Systems for direct production of electricity

Electrochemical Processes
Fuel Cells

Polymer electrolite Fuel Cell (PEFC)
Transportation applications
Stationary power
Portable power

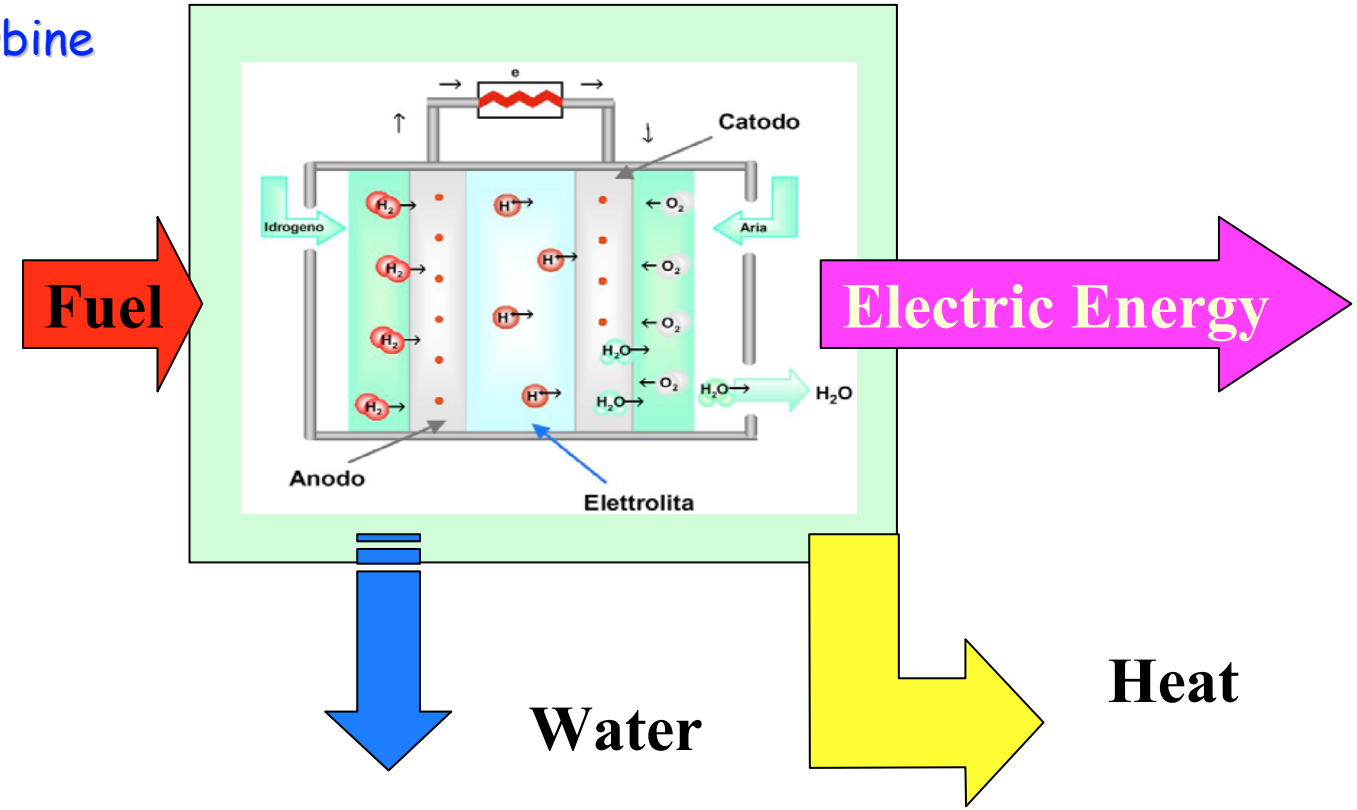
Direct Alchol Fuel Cell (DAFC)
Transportation applications
Portable power
Stationary power

Molten Carbonate Fuel Cell (MCFC)
Stationary power

Solid Oxide Fuel Cell (SOFC)
Stationary power
Transportation applications

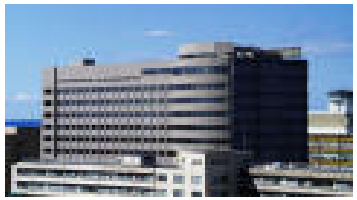
Hydrogen utilization in Fuel Cell

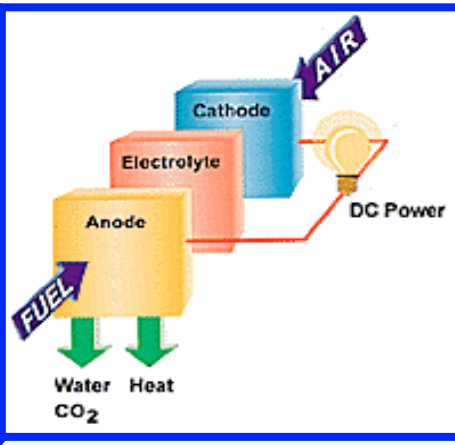
- Friendly environmental impact
- High electric efficiency independently to the size
- Production of heat usable for co-generation cycles
- Integration with gas turbine
- Fuel flexibility



FC applications

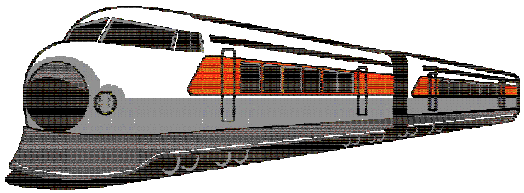
Stationary



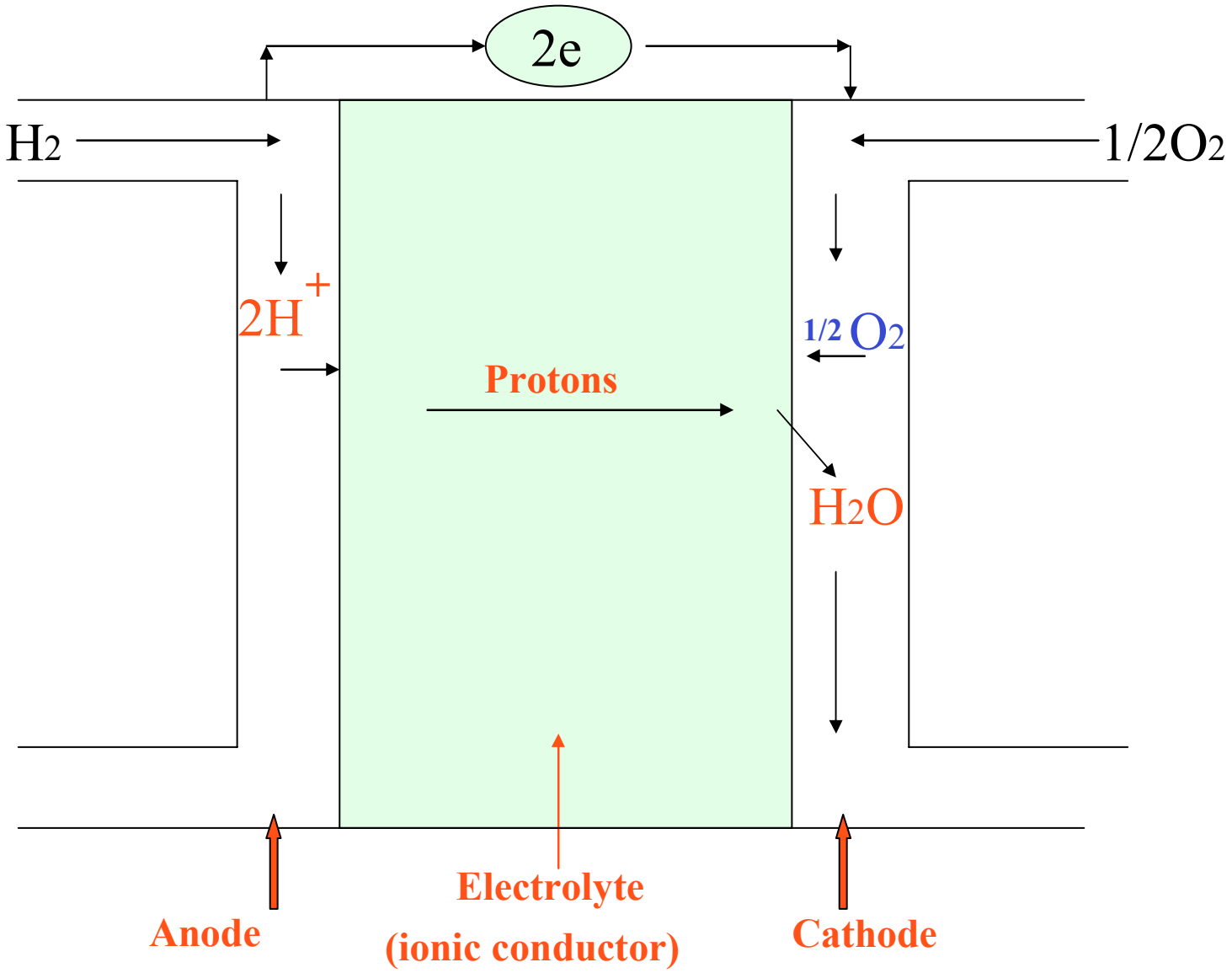


Portable

Transport



Fuel Cells


2e
H2
1/2O2
2H+
1/2 O2
Protons
H2O
Anode
Electrolyte
(ionic conductor)
Cathode

Types of Fuel Cells

Alkaline Fuel Cell (AFC)

Electrolyte: acqueous solution of KOH (85%)
Anode: 80%Pt/20%Pd supported on Ni net
Cathode: 90%Au/10%Pt supported on Ni net
Temperature: 250 °C

Phosphoric Acid Fuel Cell (PAFC)

Electrolyte: Phosphoric Acid (≅ 100%) supported on SiC
Anode: Pt/active carbon supported on carbon paper
Cathode: Pt/active carbon supported on carbon paper
Temperature: 180 °C

Types of Fuel Cells

Polymer Electrolyte Fuel Cell (PEFC)

Electrolyte: polymeric membrane (Nafion)
Anode: Pt/active carbon supported on carbon paper
Cathode: Pt/active carbon supported on carbon paper
Temperatue: < 120 °C

Molten Carbonate Fuel Cell (MCFC)

Electrolyte: mixture of Li/K carbonates
Anode: 90%Ni/10%Cr
Cathode: Ni Oxide (prelithiated)
Temperature: 650 °C

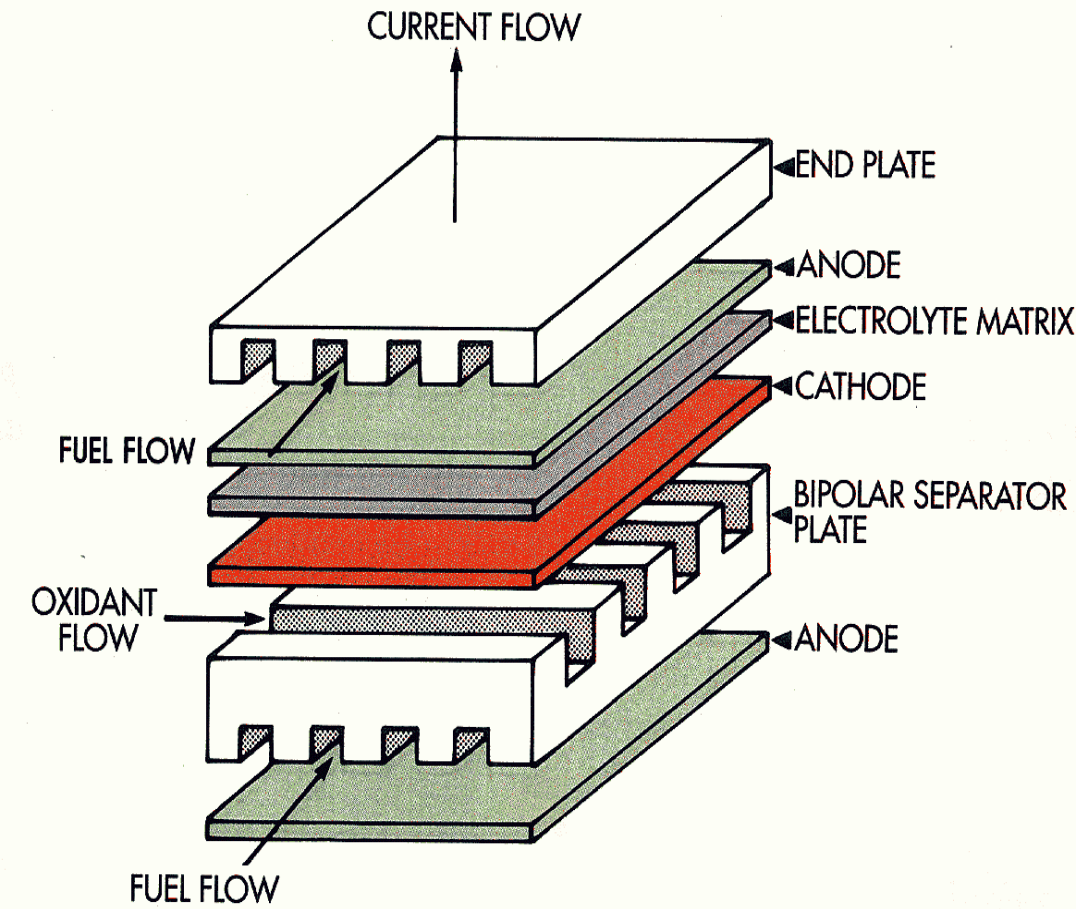
Solide Oxide Fuel Cell (SOFC)

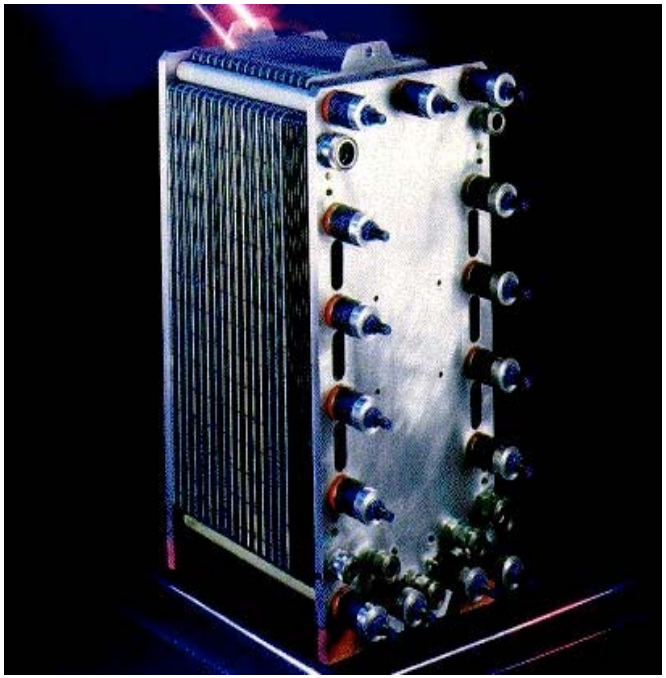
Electrolyte: Zr oxide stabilized by Y2O3
Anode: Co-ZrO2 cermet or Ni-ZrO2
Cathode: LaMnO3 dopped by Sr
Temperature: 650 -1000 °C

Electrochemical Reactions in Fuel Cells

Fuel Cell	Anode Reaction	Cathode Reaction
PEFC-PAFC	$H_2 \rightarrow 2H^+ + 2e^-$	$\frac{1}{2} O_2 + 2H^+ + 2e^- \rightarrow H_2O$
AFC	$H_2 + 2(OH)^- \rightarrow 2H_2O + 2e^-$	$\frac{1}{2} O_2 + H_2O + 2e^- \rightarrow 2(OH)^-$
MCFC	$H_2 + CO_3^= \rightarrow H_2O + CO_2 + 2e^-$ $CO + CO_3^= \rightarrow 2CO_2 + 2e^-$	$\frac{1}{2} O_2 + CO_2 + 2e^- \rightarrow CO_3^=$
SOFC	$H_2 + O^= \rightarrow H_2O + 2e^-$ $CO + O^= \rightarrow CO_2 + 2e^-$ $CH_4 + 4O^= \rightarrow 2H_2O + CO_2 + 8e^-$	$\frac{1}{2} O_2 + 2e^- \rightarrow O^=$

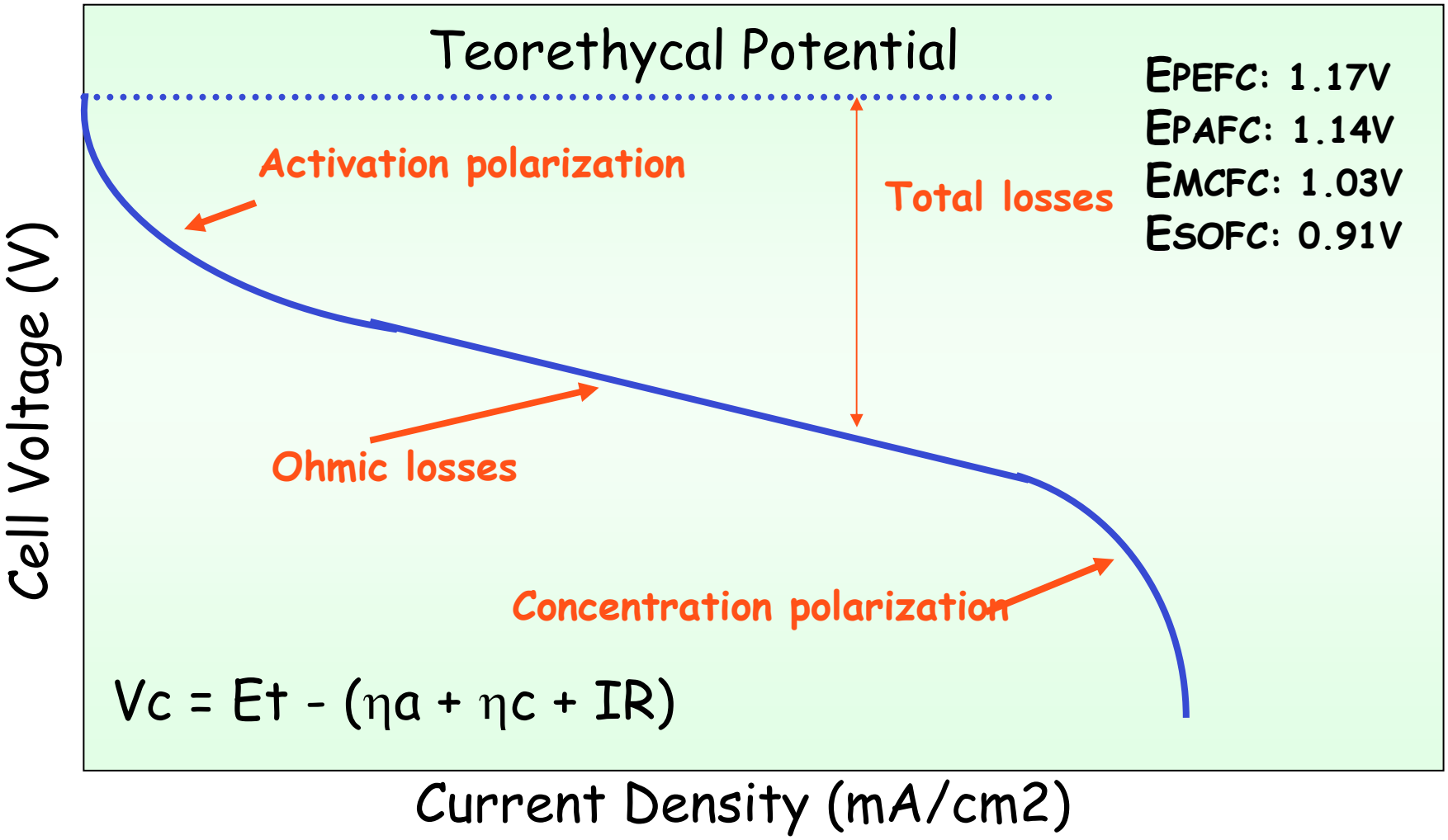
Fuel cells stack



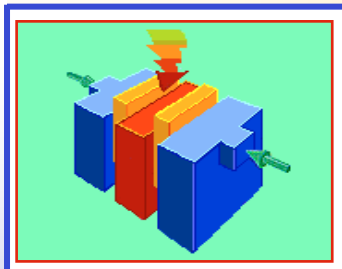


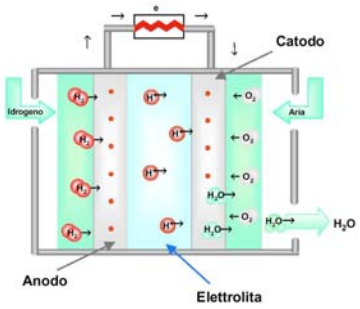
Polarization curve

$$Et = (-\Delta Go/nF) + (RT/nF) \ln [Creag]/ [Creac]$$

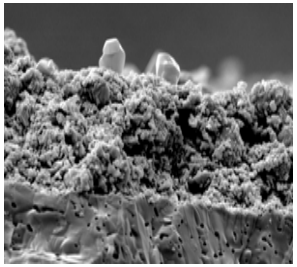


SOFC MCFC
PEFC DAFC

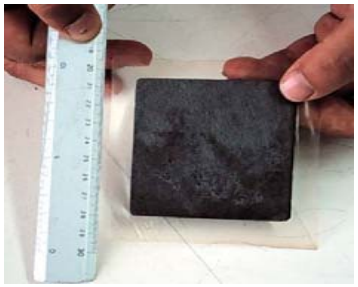




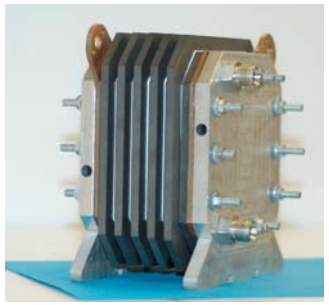
Process



New electrodes



components



systems

Prototypes

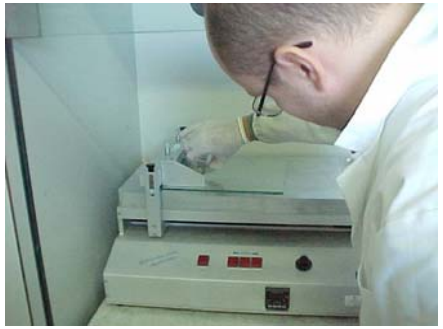
Test systems

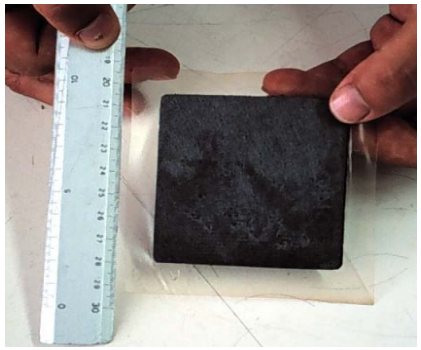
SOFC MCFC
PEFC DAFC

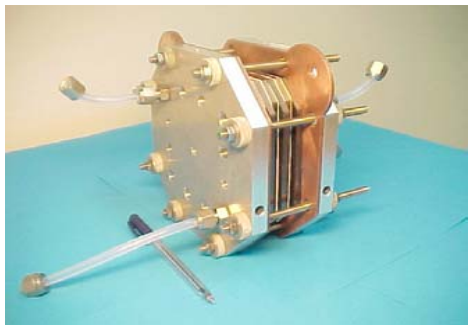
Activities

Start 1992

- development of materials and components (electrocatalysts, electrodes, membranes)
- Electrodes/membrane assembly
- Realization and test of single cells and stacks







Aim

- Increasing of the specific power
- Enlarging the range of temperature
- Improvement of CO tolerance

Main Collaborations

Enea , Nuvera Fuel Cells,CRF, Pirelli Labs

Activity

- Development of a pilot plant for PEFC gas diffusion electrodes production in semi-industrial scale

Spray automatic System : 0,6 m^2/hr of electrode

Aim

- Production and commercialization

Equivalent power: 8 kW/day

Collaborations

Ponte di Archimede S.p.A.

SOFC MCFC PEFC DAFC

Start 1992

Main aims:

- development of DAFC technology for transportation and portable (power max 5 kW)
- Direct electrochemical oxidation of organic molecules with low molecular weight (methanol, CO, ethanol)
- Design of moncells and stacks

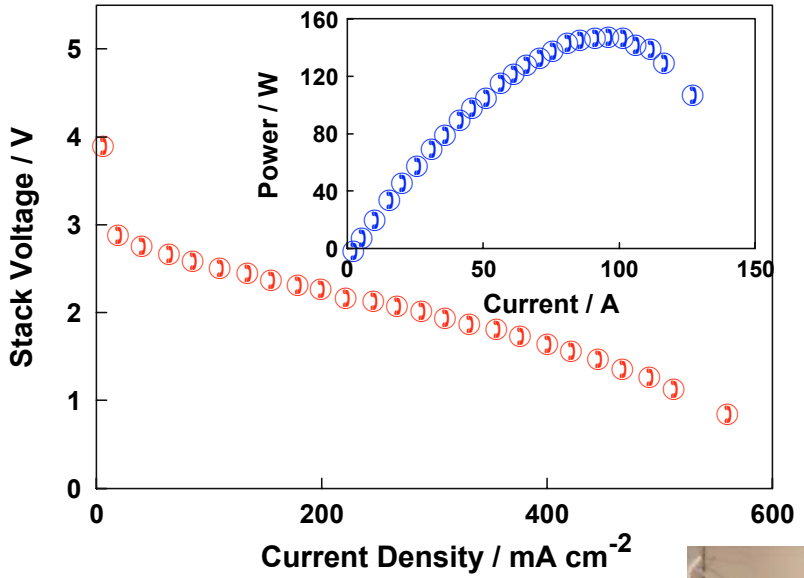
- Components development: electrocatalysts, electrodes, electrolytes
- Electrochemical test single cell and stack
- Structural, chemical and morphological analysis of materials

SOFC MCFC PEFC DAFC

Development of large area MEAs and stack

150 W DMFC stack

225 cm² MEA



T=110°C
Fuel:1M methanol
Oxidant: air

Caracteristics: 5 cells
active area 225 cm²
elettrolyte Nafion 117
anode: 85 % Pt-Ru/C
cathode: 85% Pt/C

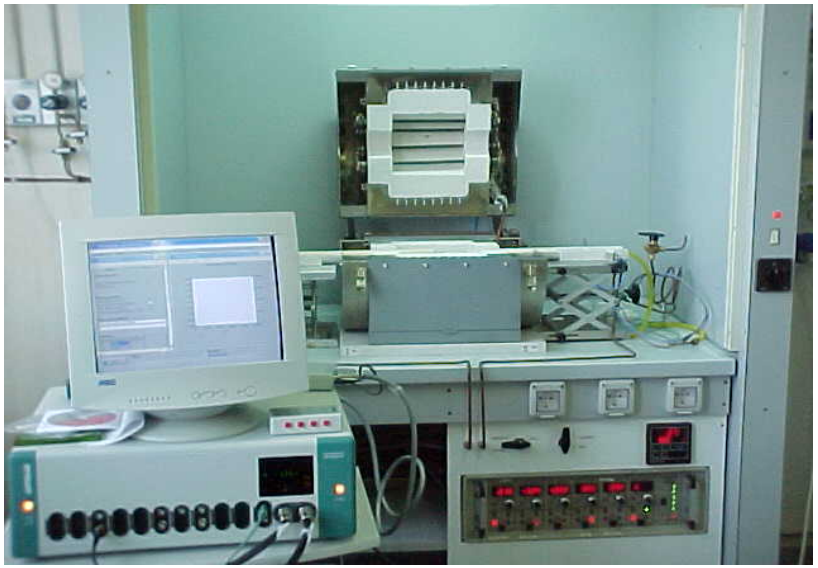
Plant and characterization : Thomson (France)
Stack : Nuvera Fuel Cells (Italy)
Electrodes and MEAs: CNR-ITAE (Italy)-LCR (France)
Catalysts: CNR-ITAE (Italia)

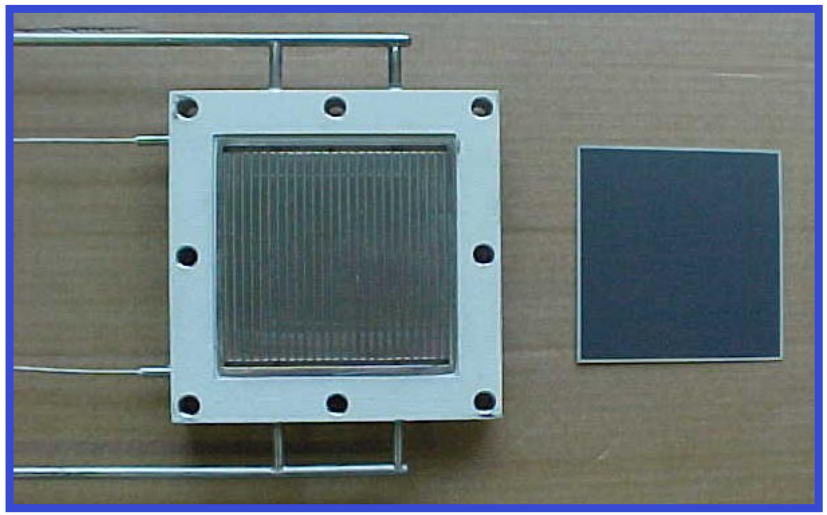
SOFC MCFC PEFC DAFC

Start 1990

Activities

- development of thin film electrolytes for IT
- development of flexible fuel catalysts
- test of single cells





Aim

- Decrease of working temperature 500°C – 750°C
- Increase lifetime and catalyst activity
- Increase power density

Main Collaborations

Pirelli, Eniricerche, I.E.N.I.-CNR

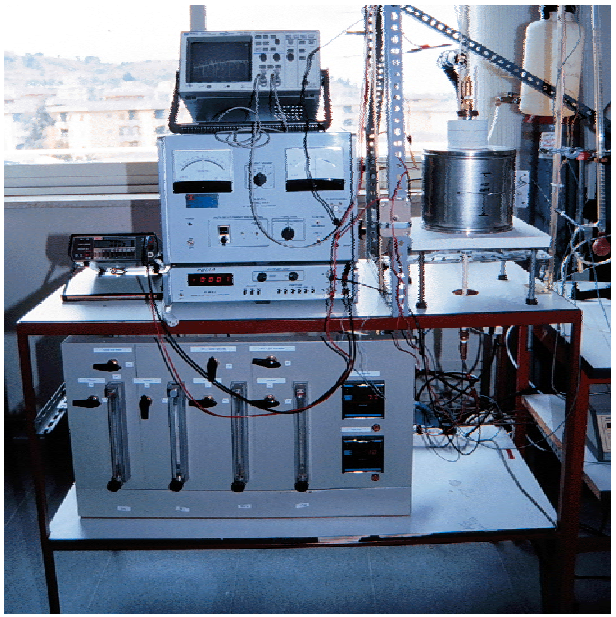
ITAE's activity on MCFC

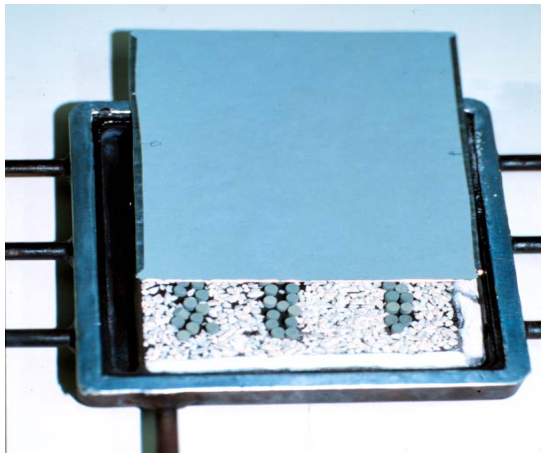
Start 1984

SOFC **MCFC** PEFC DAFC

Activities

- Optimisation of electrolyte composition
- Development of multifuel processors





100 cm² MCFC cell

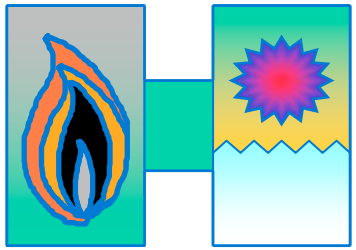
Direct internal reforming

Aim

- Realization of compact reformers with high performance
- Increasing of the components life-time
- Realization of a multifuel MCFC cell

Main Collaborations

Ansaldo, ENEA, University of Perugia



Fuel production systems from traditional and renewable energy source

Processes for hydrogen production

- **Hydrogen production from fossil fuel** *for fuel cell systems*
- **Hydrogen production from renewable energy** *from vegetable biomass to be used in FC and other systems*
- **Systems for CO_2 separation**

Process for liquid fuel production

- **Conversion technology** *of natural gas in liquid fuel as energy vector*

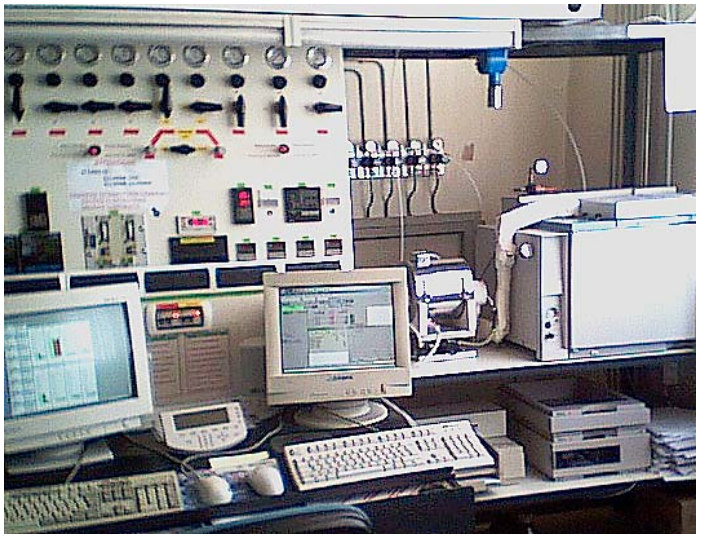
Hydrogen Production From fossil fuels

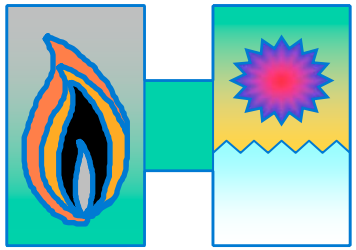
Activities

- Screening of commercial catalysts
- Development of new catalysts
- Tests on laboratory scale
- Design, realization and tests of prototipes

Aim

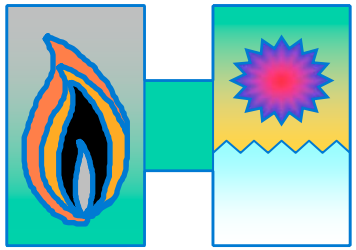
- Development of processes and systems for transportation (on-board and off-board) and stationary application
- Processes: Partial oxidation (POX), Autothermal Reforming (ATR), CO clean-up (PROX, Adsorber/Desorber)
- Fuels: Natural gas, Propane, GPL, Methanol, Ethanol, Virgin Nafta, FT Benzine





Hydrogen Production From renewable

- Autothermal Reforming of Biofuels (i.e. bioethanol)
- Catalytic gassification of vegetal biomass



Processes for liquid fuel production

Conversion technology of natural gas in liquid fuel

Aim

Development of advanced innovative catalytic systems for production of: :

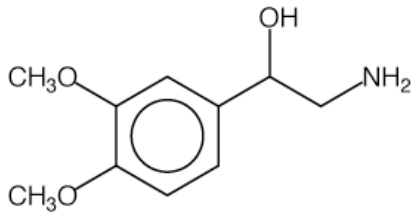
Liquid fuel without sulfur and aromatics

Transportation

Linear hydrocarbons

Synthetic diesel - DME

Diesel Engine – H2 production



Systems for energy storage and transportation

Storage and rational use of thermal energy

Air conditioning systems
adsorption heat pump
without CFC or HCFC
for buildings and vehicles

Processes for storage and transportation of energy vectors

Storage of hydrogen and liquid fuels
to apply in FC systems
transportation, stationary and portable power

Processes for electricity storage

Supercapacitors
for transportation and portable power

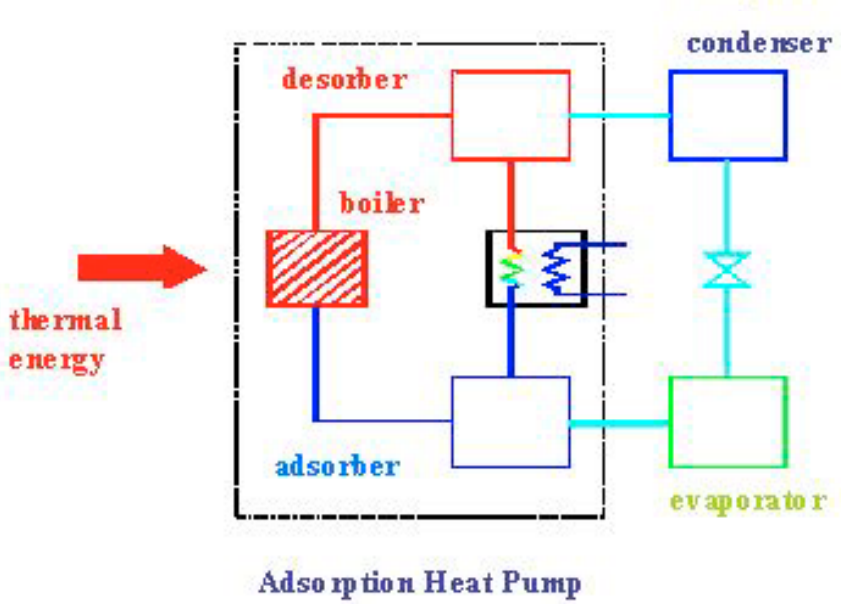
Storage of thermal energy

Adsorbent materials

Zeolite, silica gel, active carbons

Adsorbate vapours

Water, methanol, ammonia



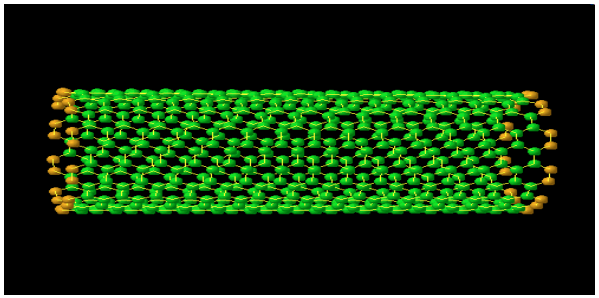
Advantages

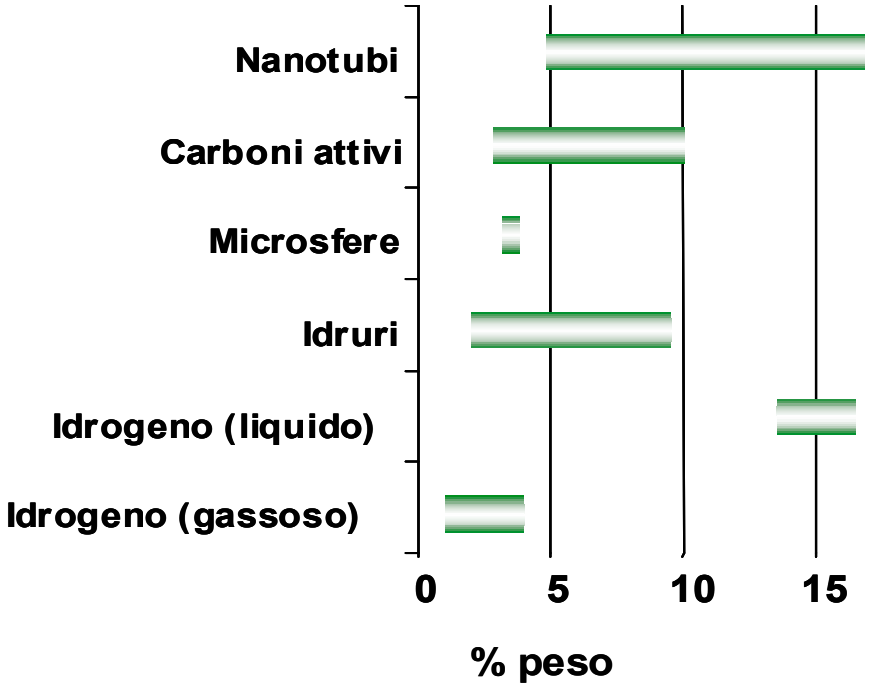
- environmental friendly refrigerants
- medium-low temperature heat (100-200°C) as primary energy
- no moving parts
- High energy efficiency

Hydrogen Storage

H_2

metal hydrides / carbon nanotubes





Instruments for materials characterization

SEM

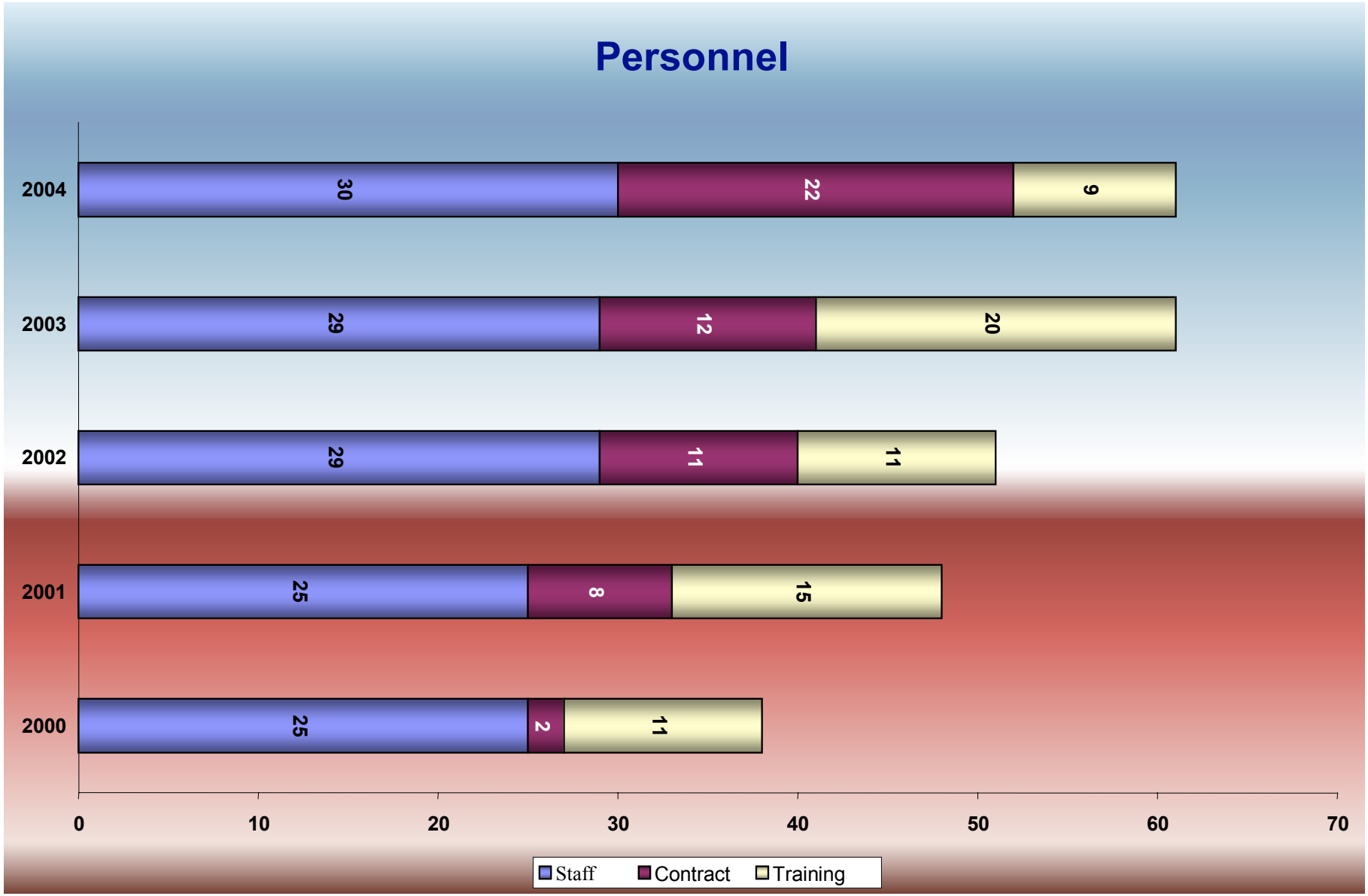
XPS

TEM

Staff

45 Researchers
12 Technicians
4 Admistration

The building is 3200 m^2,
800 m^2 of offices,
1200 m^2 of laboratories, plus
conference hall and other sevices


Personnel
2004
2003
2002
2001
2000
30
22
9
29
12
20
29
11
11
25
8
15
25
2
11
0
10
20
30
40
50
60
70
Staff
Contract
Training

Training projects

Scholarship concerning working project
6 units

Scholarship for: "High-level formation for design and experimental activity on electric propulsion systems with fuel cells."
10 units

PHD
3 units (n.2 from Messina Univ. + n1 from Rome Univ.)

Internship from university
14 units

Collaborations

Collaborations	Nat. and Internat. Programs	Research Contracts	Agreement and Bilateral Coop.
Industries	EDF, FuMA-Tech, Ponte Archimede, SAES Getter, ST micr., Ansaldo Ric, Enitecnologie, Johnson Mat.,	Pirelli, Solvay, Sirtis Ansaldo F.C., CRF, Nuvera, De Nora Eudosia,	Daimler Crysler Toyota, Arcotronics Repsol, Giano
Universities Research Inst., Local Govern.	CNAM, CNRS, Aachen Univ., ECN, Ins. F. Petrol, Univ. Thes., Univ. Warwick, Uni Roma (Sapienza, Torv.), UniMe, Uni RC, Uni CT, Uni PG	Industrial Department of Sicilian Region, City of Messina, Univ. Palermo, Univ. Milano, ENEA	Kirst, Kosef (Corea) Indonesia Ins. Sci. IHTE, Is. Borescow (Russia), IGT, Princeton Univ (USA), Univ. Bolivia
Other CNR Institutes	IENI Padova e sez. Pavia, Ist. Motori, Ist. Combustione, ISTEC Faenza, IMM Catania, IPCF sez. Messina, IFAC Firenze		

Collaborations