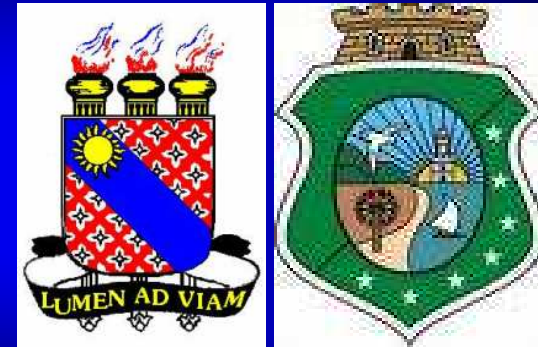


Hydrogen and Sustainable Energy Future of the State of Ceara

Universidade Estadual do Ceará
15 - 16 March 2011
Fortaleza, Brazil



Hydrogen Technologies and Activities in Brazil

Newton Pimenta
UNICAMP / CENEH

- Why to use hydrogen?
- Energy storage: $H_2 \times$ batteries
- Applications: vehicular and photovoltaic
- Hydrogen activities in Brazil
- Investments
- Conclusion





Why to use Hydrogen?

- Energy safety;
- Environment and Public Health:
 - Global warming caused by fossil fuel use (under debate);
 - Air Pollution from the industrial and transportation sectors (CO, SO_x, NO_x);
 - Harmful materials used in batteries;
- Renewable sources will be more and more important;
- Storage is necessary to regulate the offer of intermittent sources of energy;
- Batteries would be the natural candidates, but despite the advances they are: expensive, heavy, slow charging.



Why to use Hydrogen?

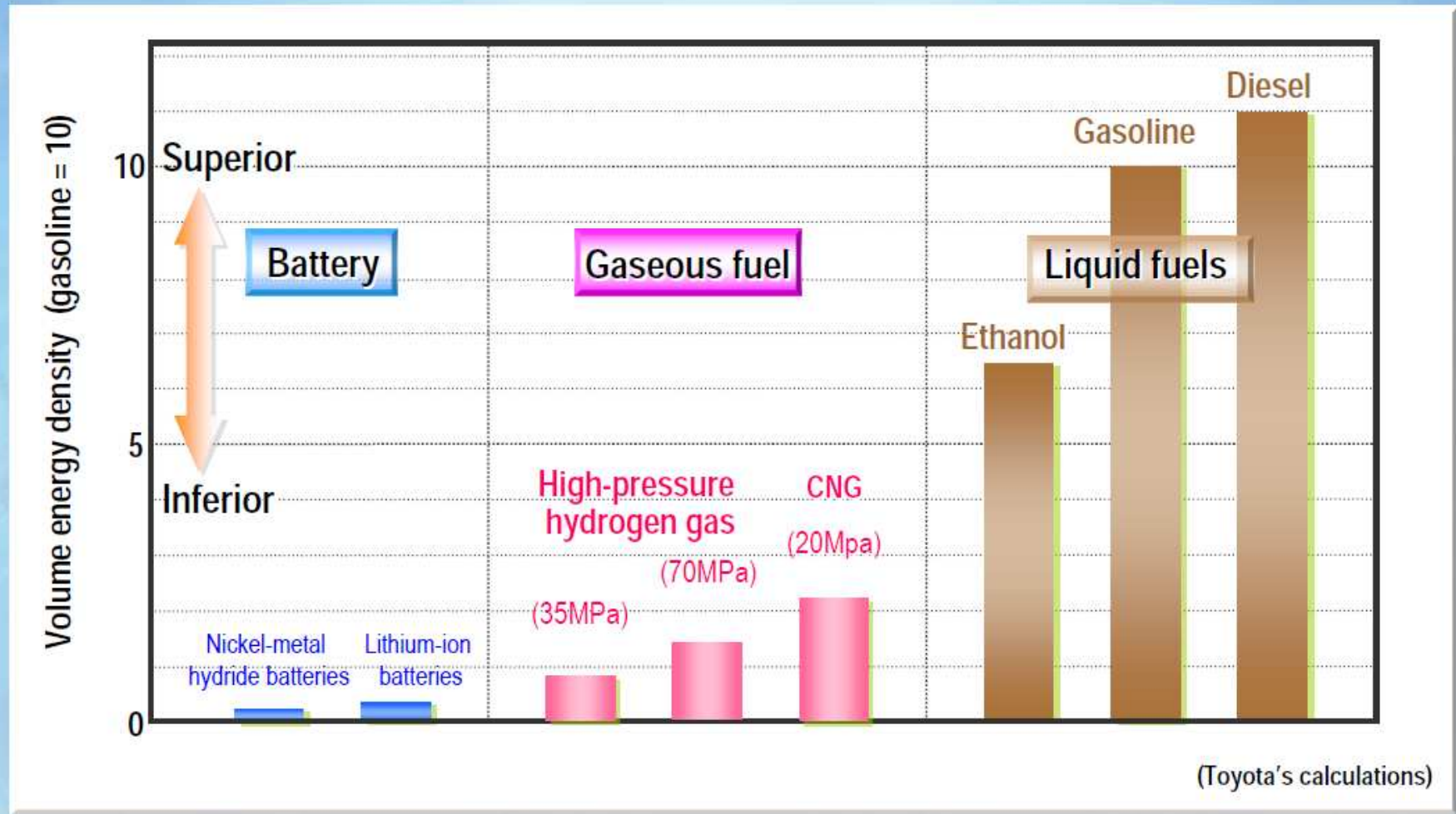
Toyota's R&D Activities for Realizing Sustainable Mobility

Takeshi Uchiyamada
Executive Vice President
Toyota Motor Corporation
December 14, 2009

TODAY for TOMORROW

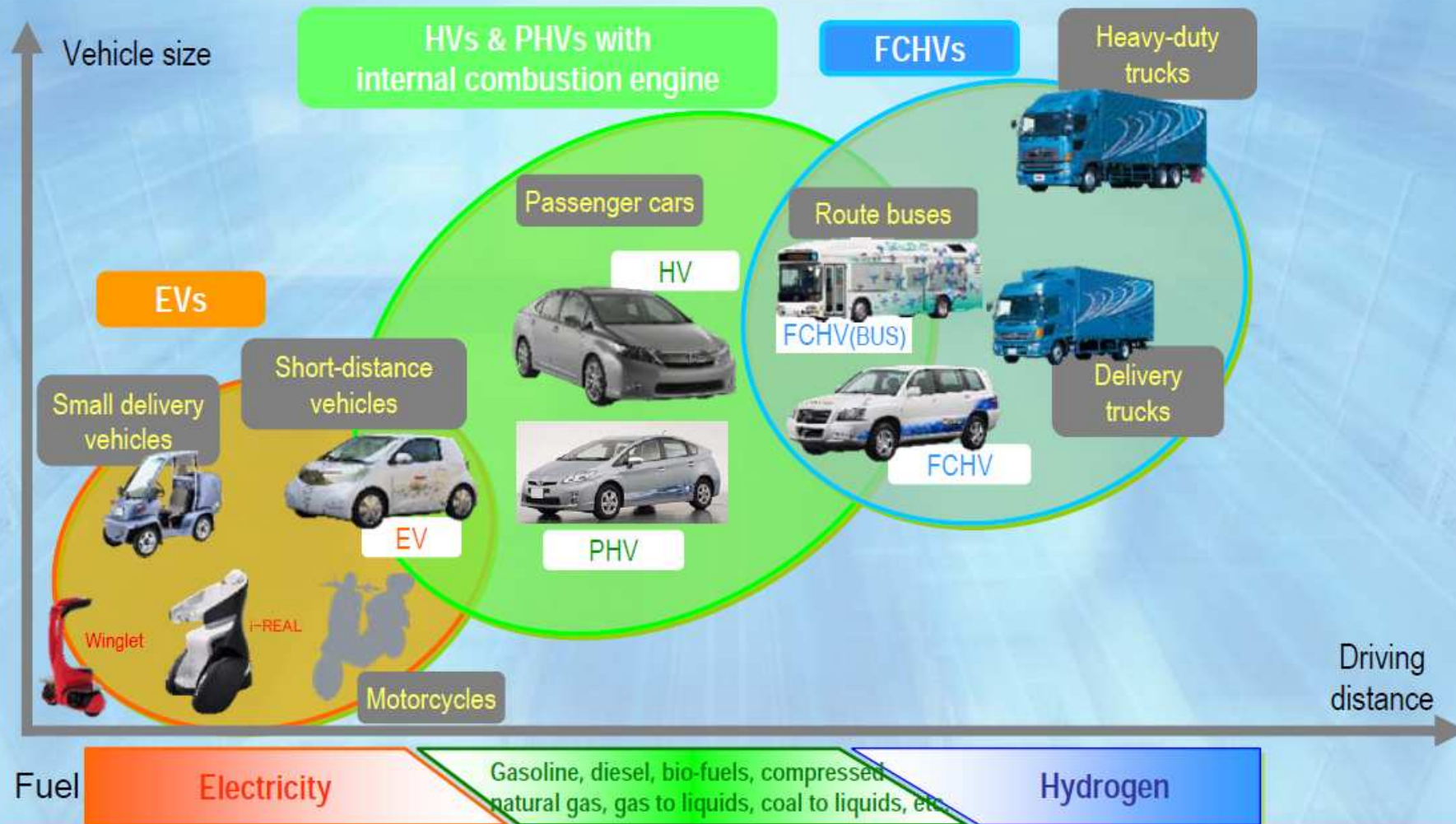
TOYOTA

Comparison of Energy Density



Energy density of Li-ion battery is 1/50 of gasoline

Response to Environmental and Energy Issues



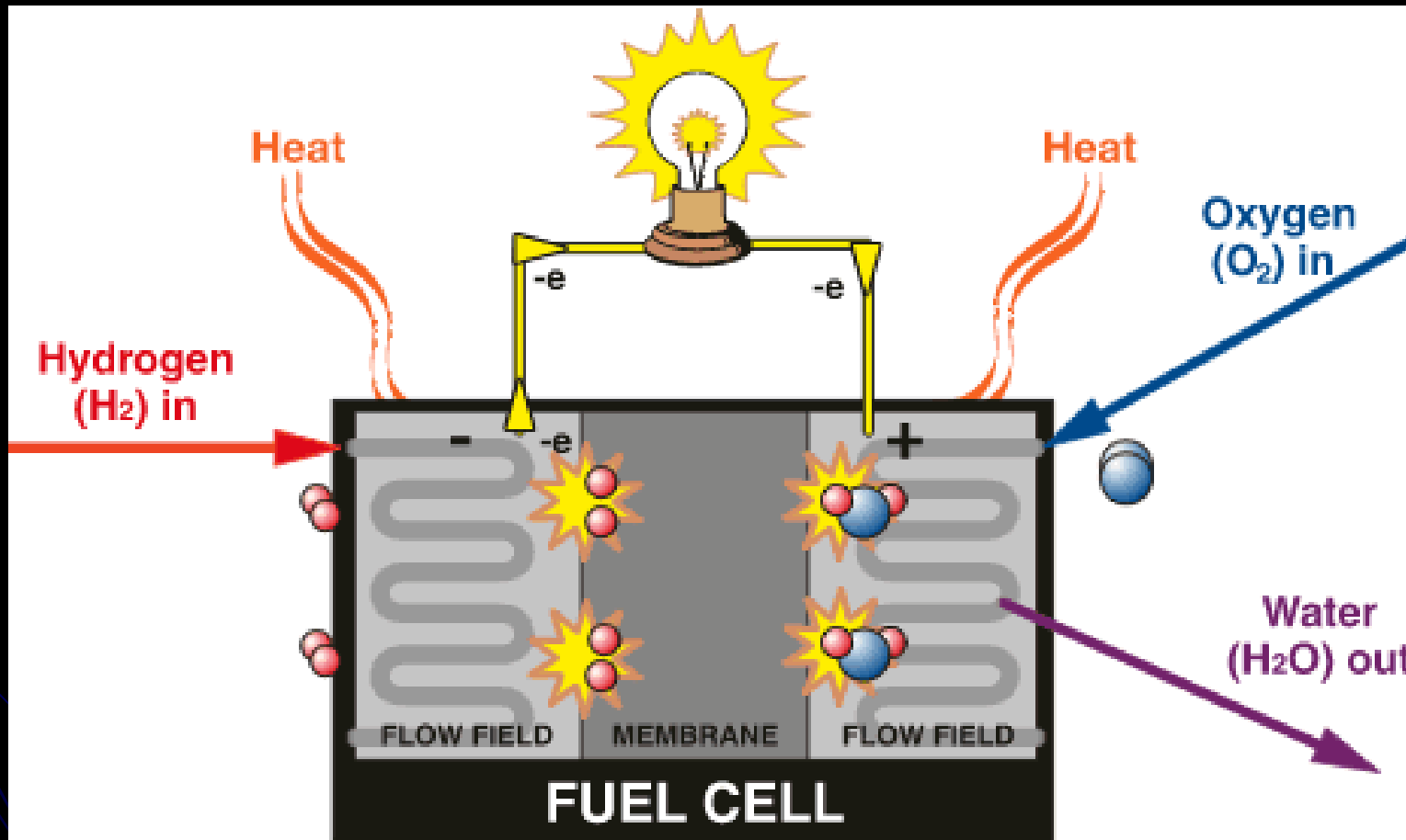
EVs: short-distance vehicles; HVs and PHVs with ICE: wide-use vehicles;
FCHVs: medium-to-large vehicles.

What is a Fuel Cell?

- Electrochemical device that converts the chemical energy of fuels (mainly H_2) directly to electricity (heat and water).
- Operating principle (reverse of electrolysis) was discovered by Willian Grove, 1839.
- Pratical applications started during the space race, with NASA – in the 1960s.



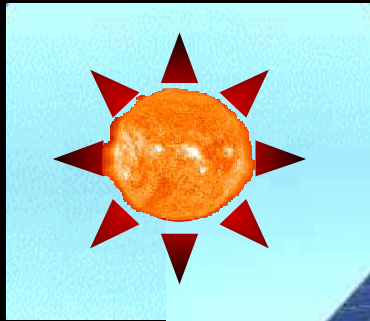
PEM Fuel Cells



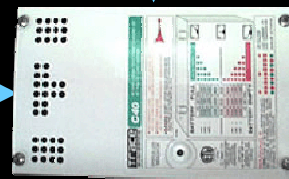
H₂ from Renewable Energies

Energy Storage: H₂ × batteries

Photovoltaic System with storage in batteries



Battery bank
max. discharge 70%
12V, 100Ah



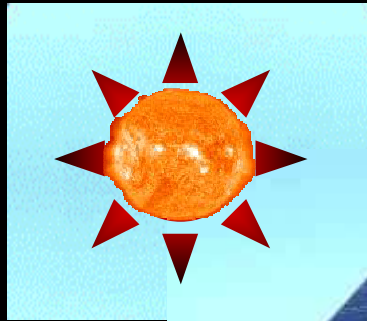
Charge control



Inverter
CC/CA



Photovoltaic System with H₂ storage



Painéis

H₂ Tank



Electrolyser

H₂



Inverter
CC/CA



PEM
Fuel Cell

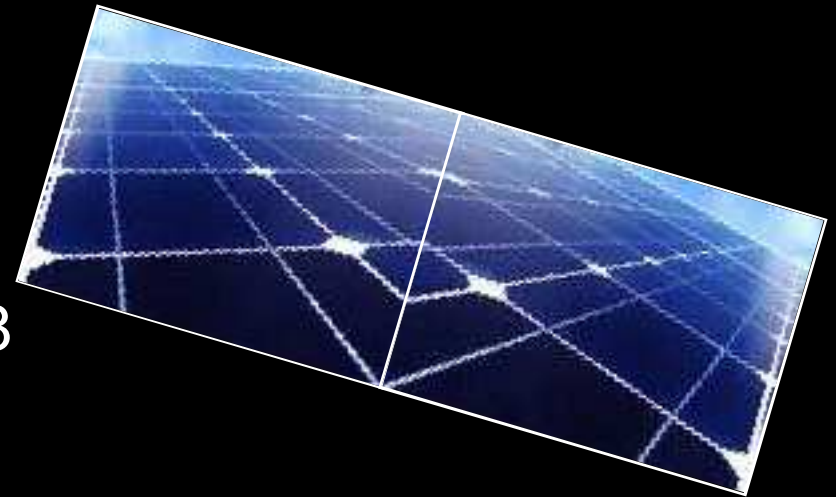


Source: Furlan, A.L., MSc. Dissertation, Unicamp, 2008

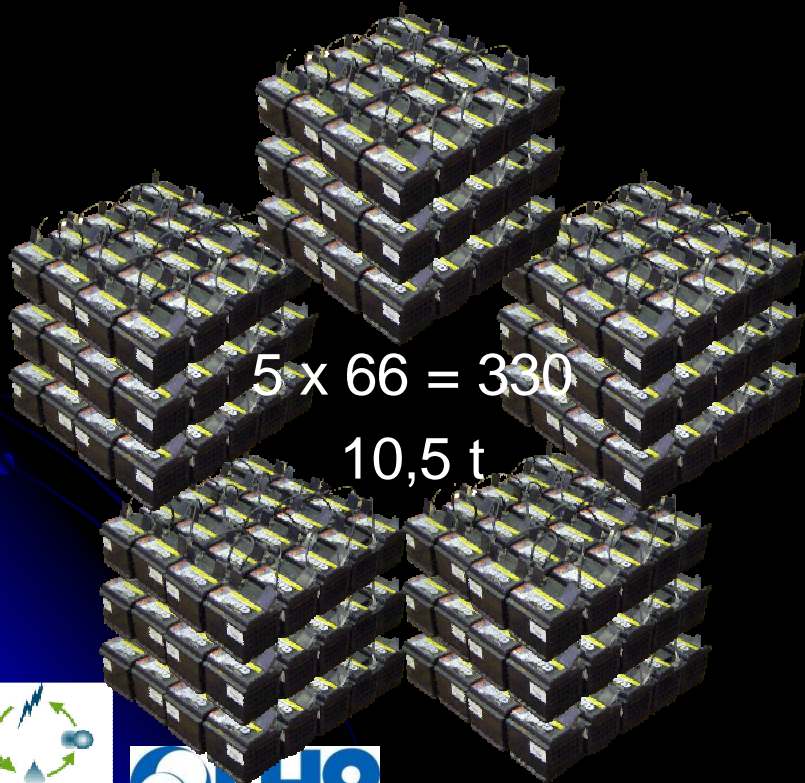
Photovoltaic System Comparison: H₂ x Batteries



24

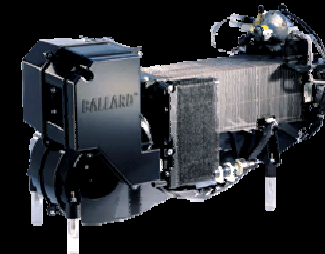


58



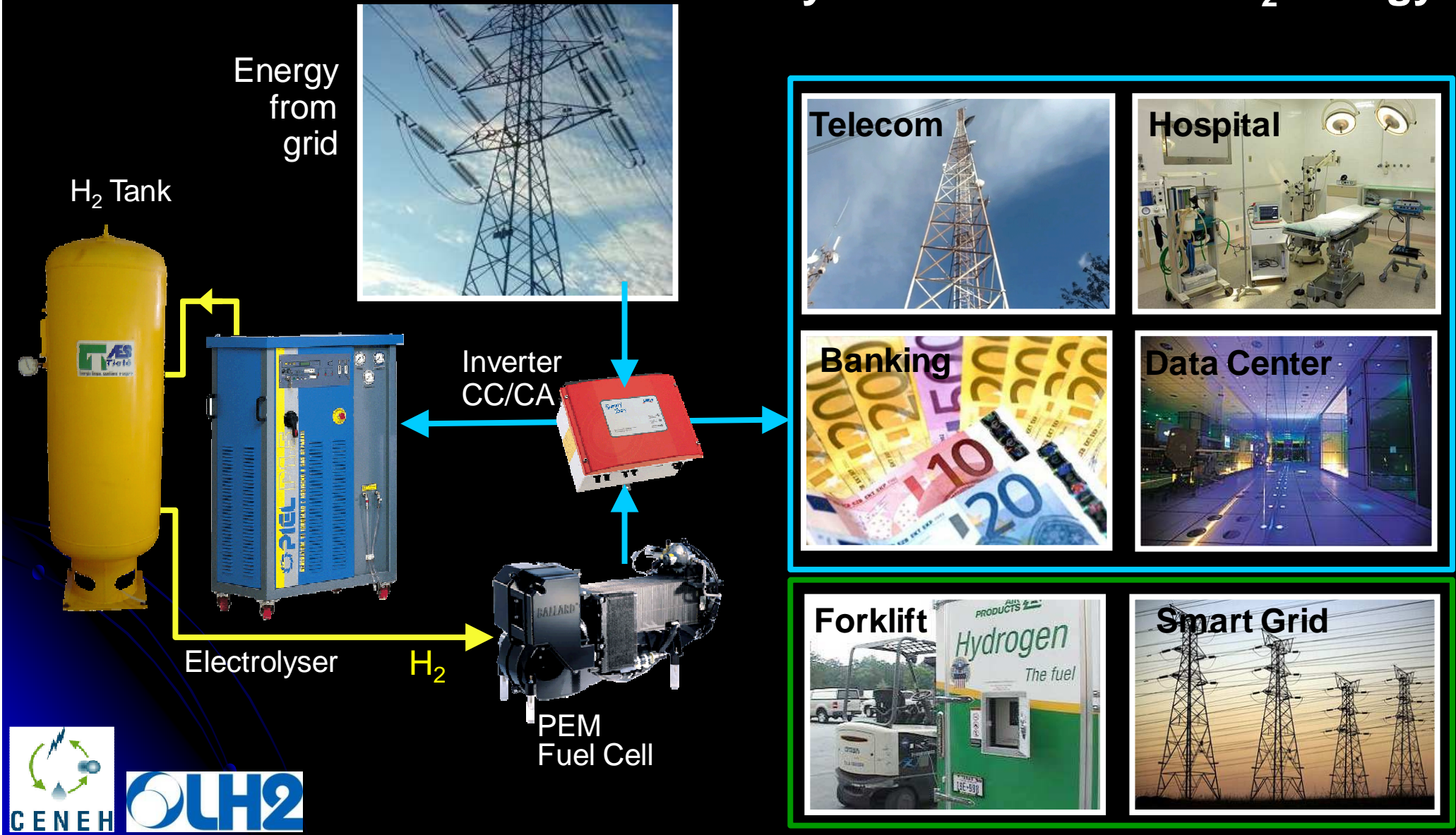
5 x 66 = 330

10,5 t

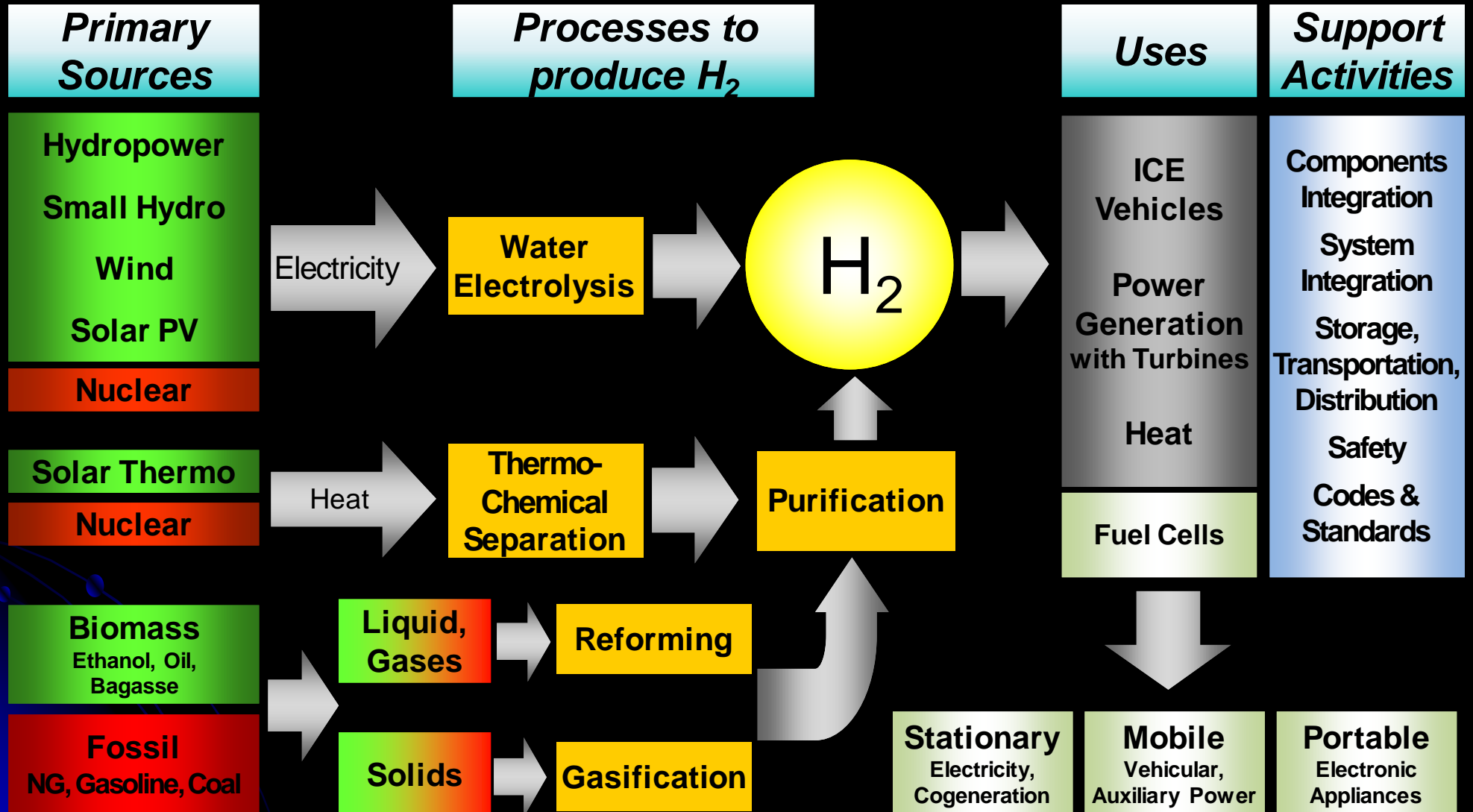


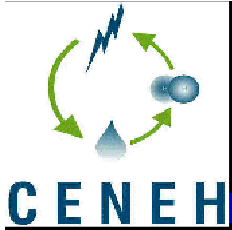
Source: Furlan, A.L., MSc. Dissertation, Unicamp, 2008

Uninterruptible power supply for essential loads and early niche markets for H₂ energy



H₂ for energy use





H₂ Cost x Environmental Impact

Hydrogen
Cost

+

-

Electrolysis with
Solar PV

Electrolysis with Wind

Electrolysis with
Hydropower

Ethanol Reforming

Biomass
Gasification

NG Reforming

-

Environmental
Impact

+

Hydrogen and Fuel Cell Activities in Brazil



Universidade Estadual de Campinas, SP

UNICAMP is the site for 3 energy centers:



- The Hydrogen Laboratory (LH2) at the *Instituto de Física "Gleb Wataghin"*



- The Interdisciplinary Center for Energy Resources Planning (NIPE)

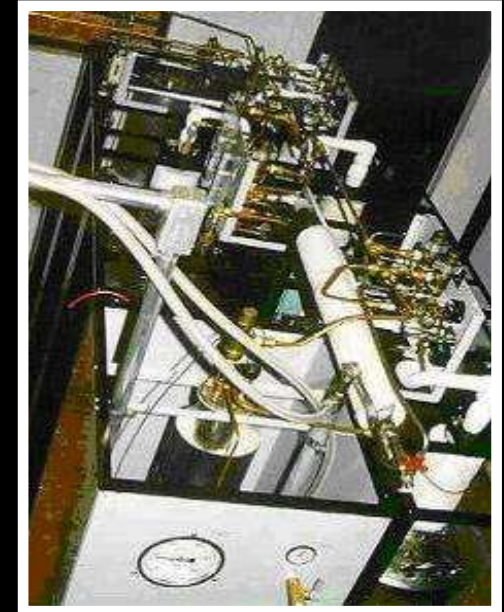
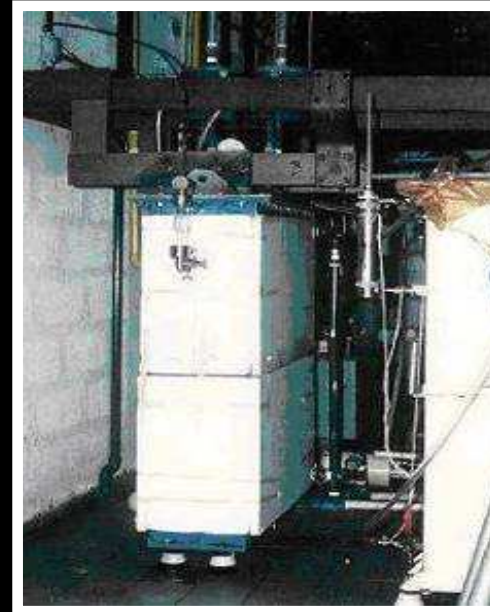


- The Brazilian Reference Center for Hydrogen Energy (CENEH)

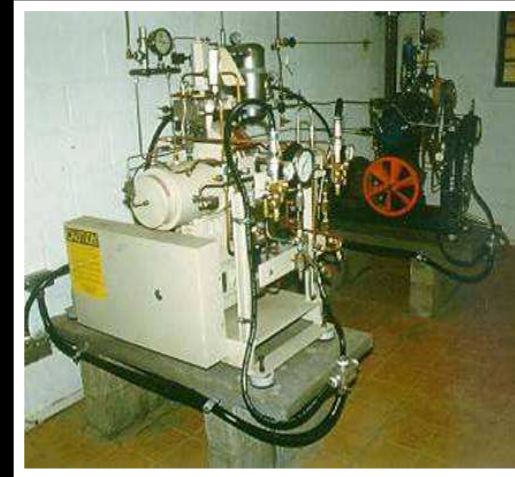
- LH2 has been working on H₂ technologies since 1975.
- Some R&D topics are:
 - Hydrogen economy
 - System integration
 - H₂ and H₂ blends for transportation
 - Alkaline water electrolysis
 - Ethanol and NG reformation
 - H₂ from renewables (wind & PV)
 - Trace gas analysis and standards
 - Safety



- Alkaline water electrolysis plant for H₂ production
- Operation: 1982 to 2000
- 2 electrolyzers: 1.5 m³/h each
- Up to 1.000 m³ per month high purity hydrogen (5.5)
- H₂ used in semiconductor manufacture research.



- Despite the small scale, the operation is quite similar that of larger plants.
- This work gave us good experience in purification and handling of compressed and high purity H₂ and other gases.
- H₂ Safety Course (and gases)



- GC trace gas analysis
- Development of gas standards for H₂ analysis in Brazil



- Analysis of high concentration gaseous mixtures (syngas)

Recent activities:

- Operation of imported commercial electrolysers
- Integration of electrolysers × photovoltaic panels
- Production and storage of H₂ for backup power and peak shaving
- Obtaining experimental data is essential for energy planning.



Project VEGA II





Hythane (*Hidrano*): H₂ + NG



The Brazilian Reference Center on Hydrogen Energy

- International Workshop on Hydrogen and Fuel Cells WICaC: 2002, 2004, 2006, 2008 and 2010
- Short courses: H₂ Safety and Fuel Cells
- R&D and Energy Policy:
 - ProH2 (MCT): 50 R&D groups
 - IPHE (MME): 17 countries
 - ABNT (ISO and IEC)



5th International Workshop on Hydrogen and Fuel Cells

- Global View: Programs and Policies
- High and Low Temperature Fuel Cells
- Codes, Standards and Safety
- Hydrogen Production
- Hydrogen Infrastructure
- Hydrogen and Fuel Cells: Education



**5th International Workshop
on Hydrogen and
Fuel Cells**



WICaC 2010

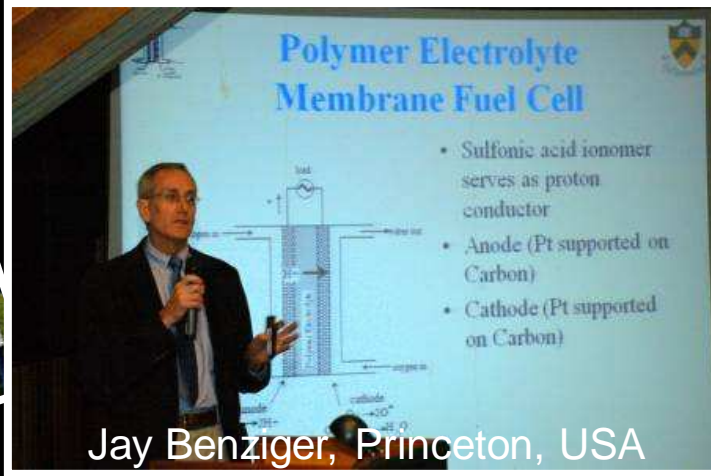
October 26 to 29 - 2010
Centro de Convenções - Unicamp
Campinas - Brazil

Sponsors:



Organization:





Short Courses in WICaC

Electrocatalysts and Membranes
Prof. Dr. Ernesto Gonzalez - USP



Polarizations in PEM Fuel Cells
Prof. Dr. Marcelo Linardi - IPEN



Hydrogen Safety

Mod.	Title
1	H ₂ Market, H ₂ Production, Fuel Cells
2	International System of Units, Ideal Gas, Real Gas
3	Safety of Gases and H ₂
4	Cylinders, connections and valves for gases and H ₂
5	Purges of Gases
6	Infrastructure for gases and H ₂
7	Accidents with H ₂
8	Standards, Codes and Regulation

➤ CCCH - Center for Fuel Cells and Hydrogen

➤ PEMFC

➤ SOFC

➤ H₂ Production

➤ SFC

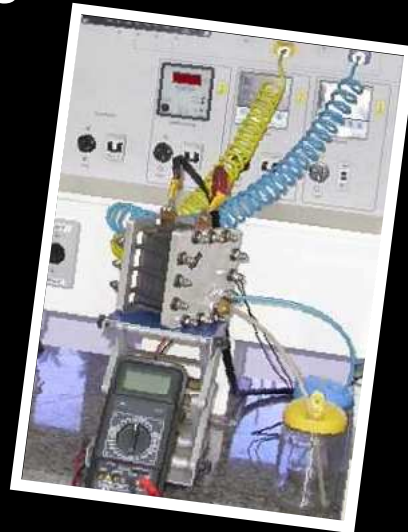
➤ CCTM - Center for Material Science and Technology

➤ Department of Ceramic Materials

➤ LIE - Laboratory of Special Feedstock

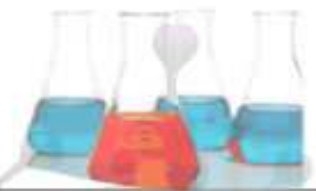
➤ LPCR - Laboratory of Ceramic Processing

➤ Characterization of Raw Materials and Material





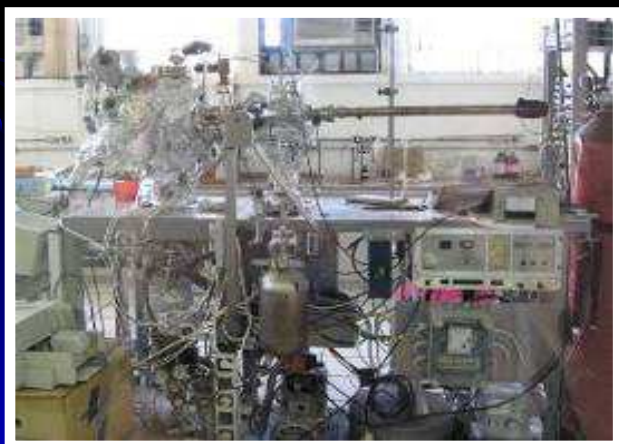
INSTITUTO DE QUÍMICA DE SÃO CARLOS
IQSC/USP



Grupo de Eletroquímica

Instituto de Química de São Carlos | IQSC
Universidade de São Paulo

- R&D on H₂ & Direct Ethanol PEMFC
- Synthesis of nanostructures
- Characterization of samples (STM, XRD, ultra high vacuum chamber)



Hytron



- Hytron is a spin off company from the LH2 at UNICAMP.
- Products and Services
 - Autothermal Reform of Ethanol
 - Autothermal Reform of NG
 - Water Electrolysers
 - Electric power generators (fuel processor and fuel cells)
 - Gas purification systems

- Ethanol Reformer:
 - In: air, ethanol, water
 - Out: H₂



- Electrocell is a PEMFC maker incubated at CIETEC/IPEN
- Products:
 - PEMFC stacks
 - PEMFC stationary systems
 - Bipolar plates
 - Bench test systems for FCs
 - Electric power conditioning
 - FC components
 - Bipolar graphite battery





- PEMFC maker, Americana, SP
- Vertical business strategy:
 - Ultra Thin Highly Conductive Bipolar Plates
 - Low Pt Membrane Electrode Assembly
 - Gasket In Place Silicone Seals & Frames
 - Low Energy Strategy Balance of Plant
 - Fully Predicted Micro Processed Integrated System





Brazilian Fuel Cell Bus



- Type: Padron (12.6 m long) / Low floor
- Capacity: 40 passengers (1 driver / 29 seated / 9 stand up / 1 for wheel-chair)
- Accessibility (wheelchair space and access ramp)
- Electronic control and diagnostic system
- Power: 230 kW
- Range: 300 km
- H₂ consumption: 15 kg / 100 km



- Air-conditioning
- Low noise level
- Zero emission



Brazilian Fuel Cell Bus: Highlights



- Hybrid technology (Bat+FC)
- Price below US\$ 1 million
- Best performance among the hydrogen buses
- Designed for regular use
- No subsidies: regular prices for components and services
- Brazilian technology has collaborated to reduce costs





COPPE
UFRJ

COPPE's Hydrogen Bus



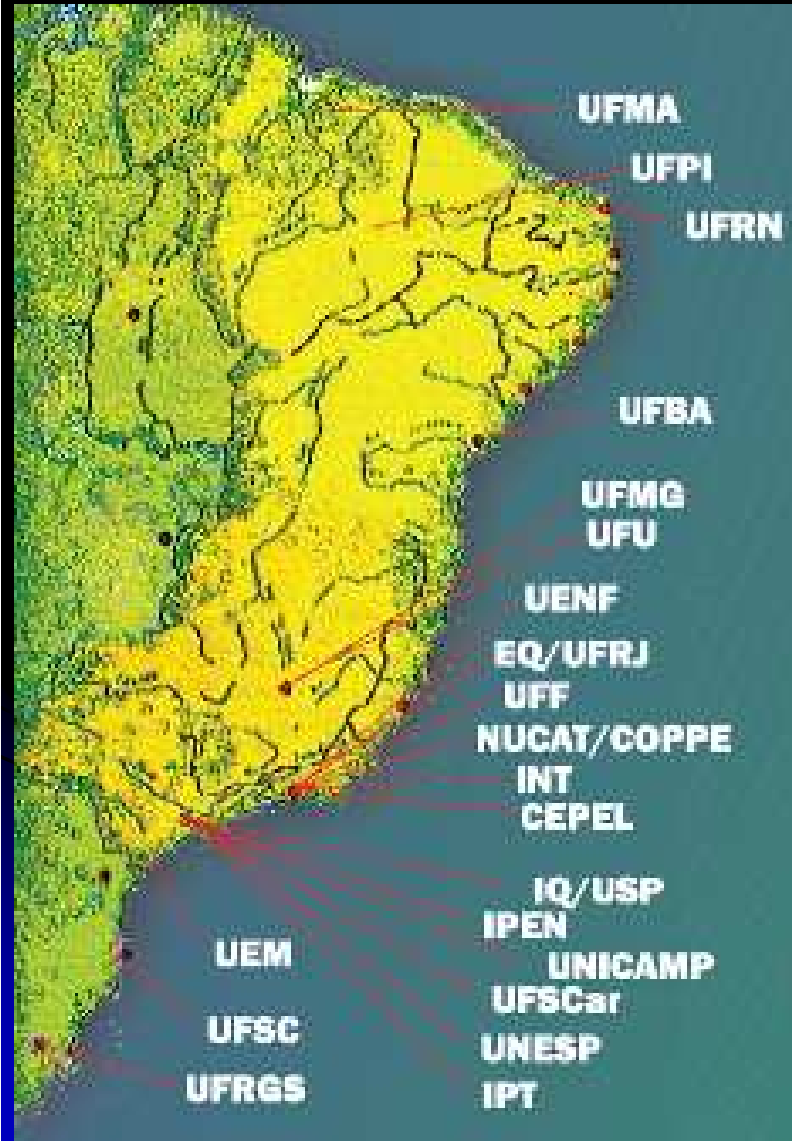
- Launch: May10
- Tests are underway

Brazilian Program for Science, Technology and Innovation for the Hydrogen Economy











- **ProH2 “Law”:** Portaria MCT nº 731, Nov. 14, 2002
 - To promote integrated and cooperative actions to support the national development of technologies for the production of hydrogen and fuel cell systems, to enable the country to be internationally competitive.
- **ProH2: 5 networks with more than 40 universities and centers:**
 - Proton Exchange Membrane Fuel Cells - PEMFC
 - Solid Oxide Fuel Cells - SOFC
 - Hydrogen Production
 - Systems, Integration and Engineering
 - Utilization and Auxiliary Activities (Safety, Codes, Standards, etc.)

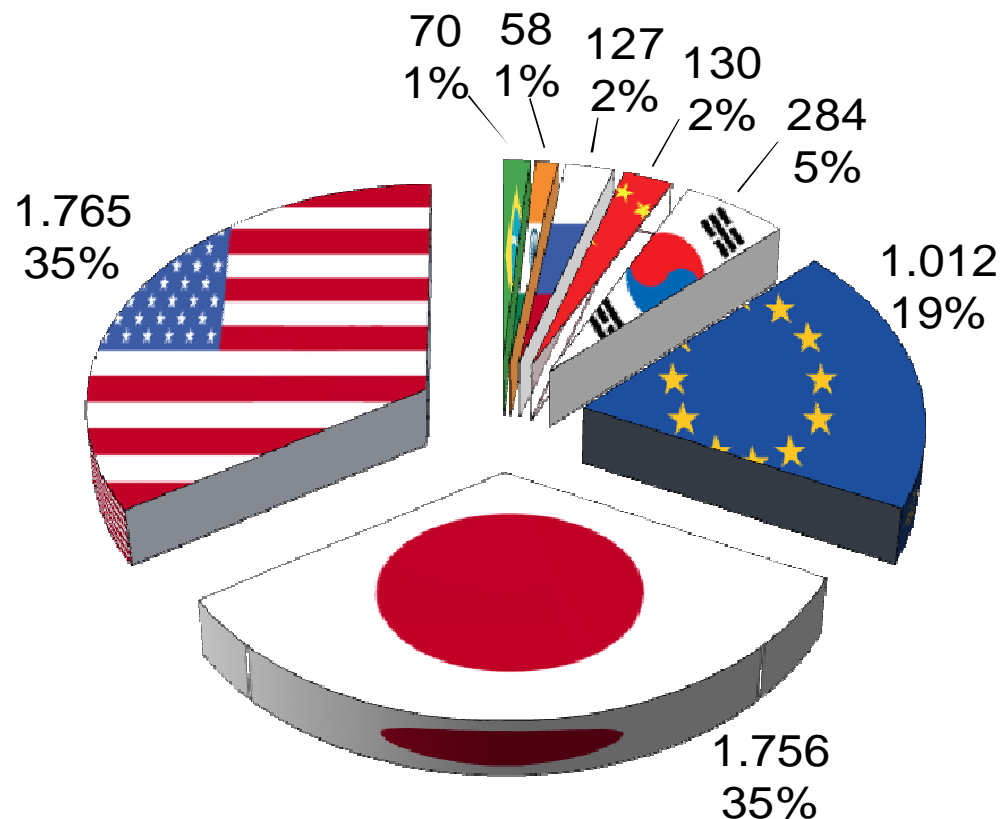
Brazilian Program for Science, Technology and Innovation for the Hydrogen Economy



- ProH2: 5 networks with more than 40 universities and R&D centers
- Brazil also counts with:
 - Other 60 R&D groups working with hydrogen technologies
 - 7 major gas companies (Linde, APCI, Air Liquide, White Martins, IBG, Gama Gases and Bann Química)
 - 3 small fuel cell companies
 - 1 small company for hydrogen production systems

Brazilian Program for Science, Technology and Innovation for the Hydrogen Economy

Country	Period	US\$ Millions	US\$ MM/yr
 Brazil	99 - 07	70	8
 India	05 - 07	58	19
 Russia	04 - 07	127	32
 China	01 - 06	130	22
 South Korea	00 - 08	284	32
 European Union	01 - 07	1,012	145
 Japan	00 - 07	1,756	220
 USA	01 - 07	1,765	252



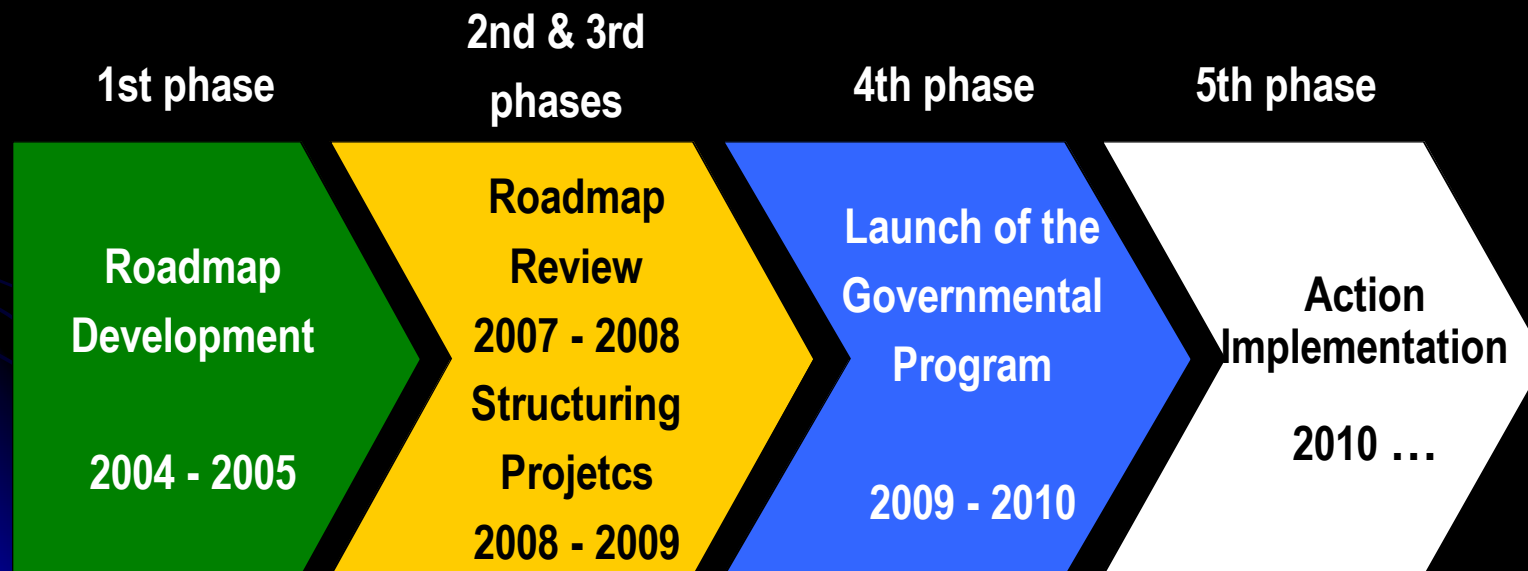
Sources:

- Matos, M.B., MSc. Dissertation, Unicamp, 2009;
- Lee, T. H., Lecture in Seoul, 2009

- Organized actions are being done with good results
- More investments are necessary
- Strategic partnerships can accelerate the results

Brazilian Program for Science, Technology and Innovation for the Hydrogen Economy

- Document of the Brazilian government (Mar. 2005);
- Coordination of the Ministry of Mines and Energy (MME);
- Objective: to point out actions and structuring projects to introduce the hydrogen in energy matrix within 2020.



Source: Roteiro para Estruturação da Economia do Hidrogênio no Brasil, Mar/ 2005



Hidrogênio Energético

Tecnologias Críticas e Sensíveis em Setores Prioritários



Uma estratégia para a Produção do Hidrogênio

Newton Pimenta, UNICAMP / CENEH

Brasília, 22 de junho de 2010

Centro de Gestão e Estudos Estratégicos
Ciência, Tecnologia e Inovação

Economia do hidrogênio
Produção do hidrogênio
Logística do hidrogênio
Sistemas de utilização

Thank you! Obrigado!



Brazilian Reference Center
on Hydrogen Energy

Hydrogen Laboratory
at Unicamp



Contact:
Newton Pimenta
nevesjr@ifi.unicamp.br