

Sustainable Development

A sustainable technology

Fuel cell:
the most promising alternative to substitute the internal combustion engine



power to change the world®

A sustainable development

Biomass:
a renewable source for the production of energy



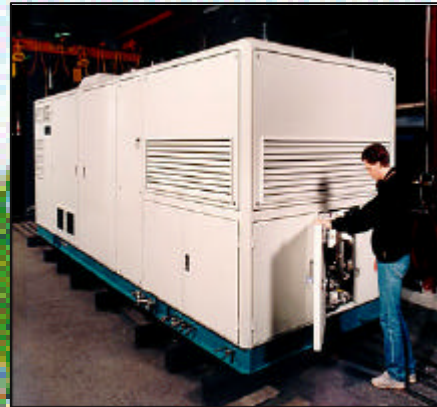
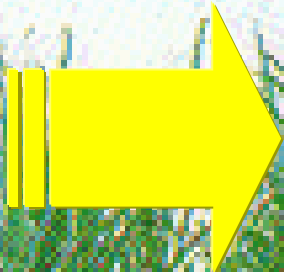
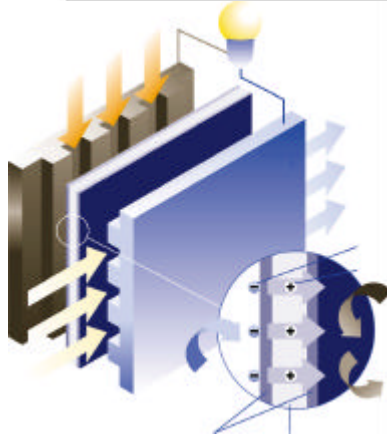
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A sustainable country

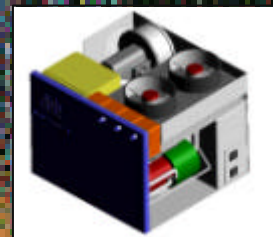
Brazil:
its history and tradition in the use of biomass



Fuel Cells open several new markets for ethanol



Automotive
Stationary Power Generation
Computers
Aerospace
Auxiliary Power Generation (APU)
Maritime
Trains (Emergency System)

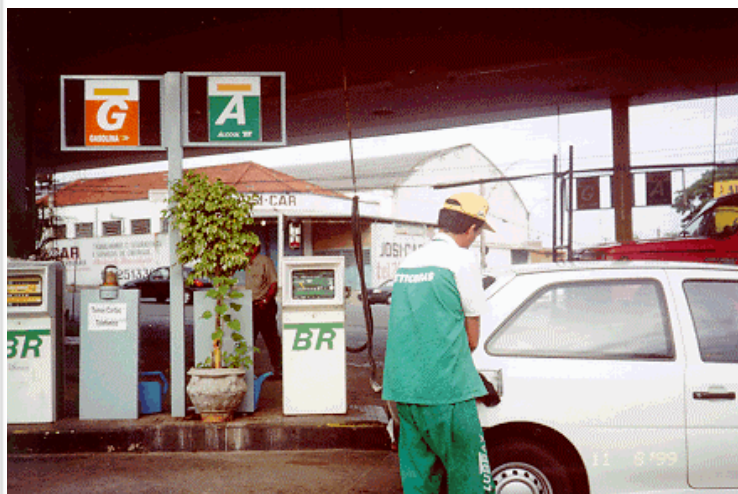


Why Ethanol for Fuel Cell?

Advantages of EtOH (in comparison to Nafta/Gasoline):

- well defined and pure single component fuel
- lower top-temperatures in the CPO-Reactor
- higher H₂-concentration in the reformat
- lower CO-concentration ⇒ smaller shift units

The Production of Hydrogen from Ethanol for Fuel Cells



Phase 1

Evaluation of Ethanol Quality
Market Research

Phase 2

Ethanol Reformer Test Bedding
Production of hydrogen from Ethanol

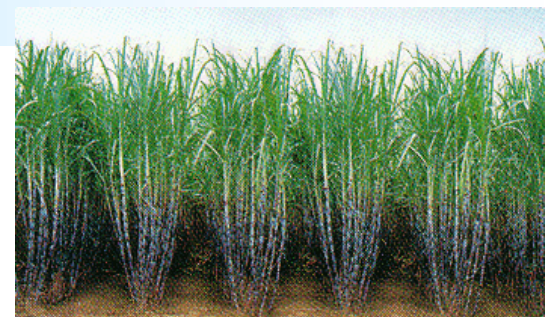
Phase 3

Complete Test Bedding
Fuel Cell Ethanol System
Evaluation for potential applications

Objective

To combine the Brazilian know-how of the use of ethanol as a fuel and the know-how of a on-board ethanol reformer technology

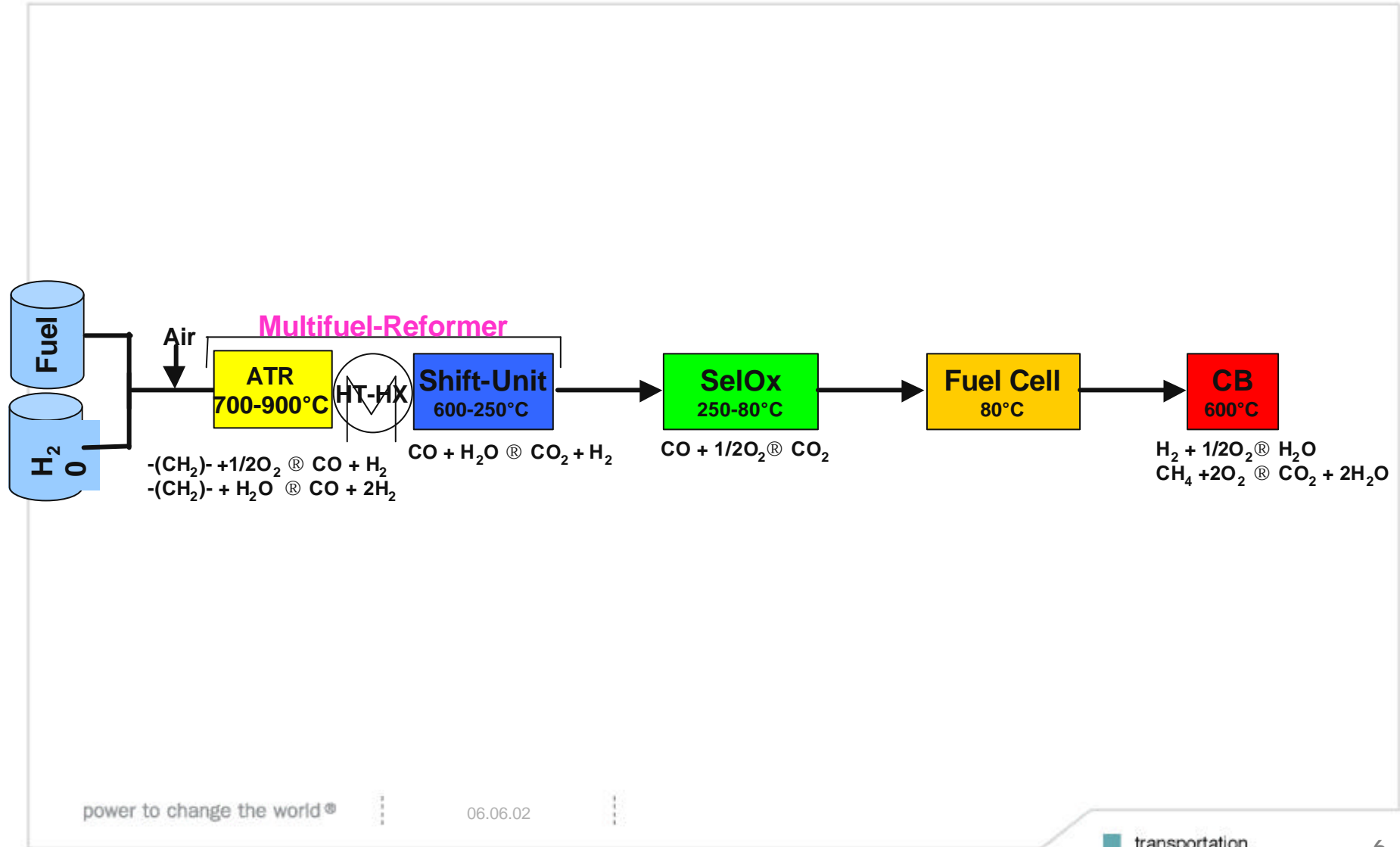
Ministry of Development, Industry and Foreign Trade
Ministry of Science and Technology
FINEP
INT - National Technology Institute
UNICA
Ballard Power Systems
OMG Germany and Brazil
BASF Aktiengesellschaft



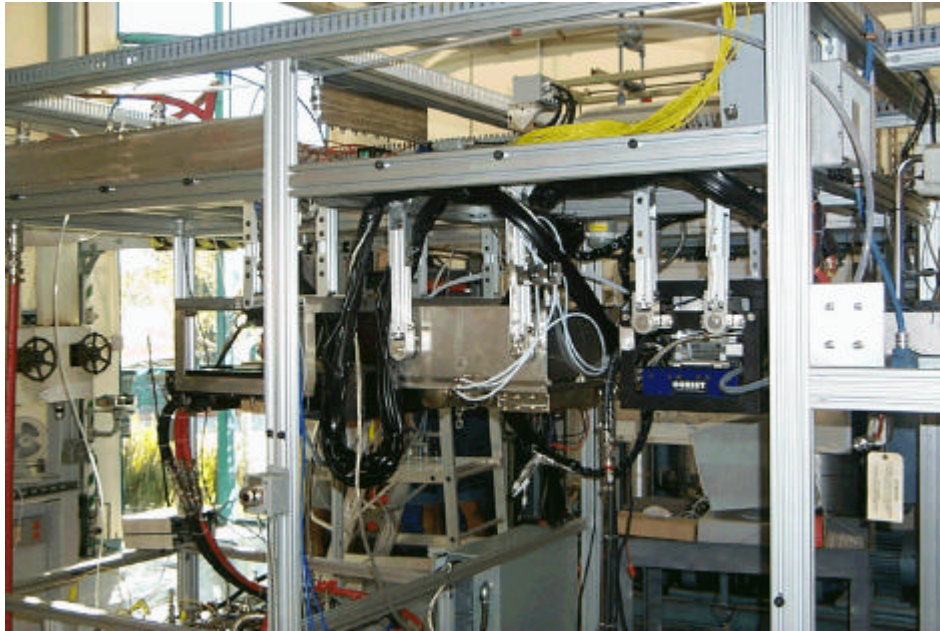
Objectives of the Project:

- ➔ **To evaluate physical and chemical characteristics of ethanol and presence of contaminants throughout the production and distribution cycle**
- ➔ **To evaluate and optimise the performance, durability and other important features of “multi-fuel reformers” for ethanol use**
- ➔ **To establish the minimum specification requirements of ethanol fuel for reformer application**
- ➔ **To establish the technical, economic, and policy bases for the development and commercial application of the ethanol powered fuel cell technology in the Brazilian automotive sector and, if feasible, for other complementary applications**

Autothermic Multi-fuel Reformer



Example of a Test Bench for automotive system optimization tests



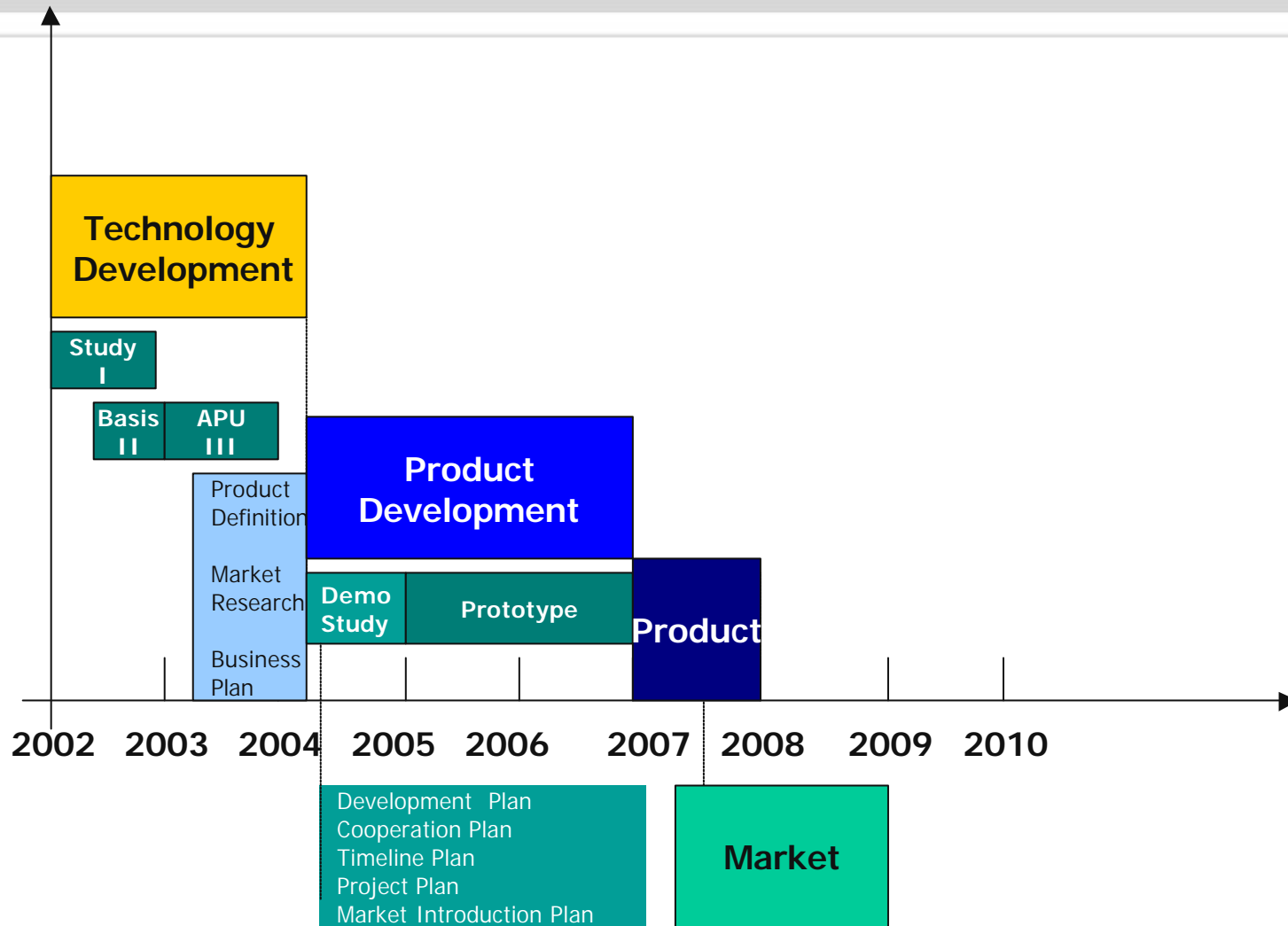
ME-75-5 Motor 75 kW PEMFC

- Client : Ford Motor Company
- Power: 75 kW
- Methanol Reformer
- Selective Oxidation Cleanup
- Ballard Mk 9 Stack Technology
- Exhibited at the Detroit Auto Show

Packaging in the vehicle



Project Overall Schedule



The competitors are not sleeping

BALLARD®

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THE ENERGY INDEPENDENT

Companies Team Up to Develop Ethanol Fuel Cell

El Staff Report

Illinois-based Caterpillar Inc. and Williams Bio-Energy, of Pekin, are among several partners in a \$2.5 million, ethanol-powered fuel cell project now underway.

CATERPILLAR

Williams Bio-Energy

NUVERA
FUEL CELL

Through the development of this fuel cell, private companies are taking the initiative to show that ethanol is more than a clean-burning fuel for cars - it is fuel to provide electrical power for buildings. The joint venture will benefit not only the companies involved, but the environment and the farmers who supply the raw material for ethanol. The U.S. Department of Energy will contribute \$800,000 to the project from an \$85 million pool of clean energy research grants unveiled in late June. The state of Illinois will provide \$550,000 and Nuvera Fuel Cells of Cambridge, Mass., will kick in \$670,000. Caterpillar

will contribute \$390,000 while Williams adds \$100,000.

"We're very excited about the project. It's clean power and it's renewable," said Caterpillar spokesman Carl Volz. "We're a leader in the distribution of power-generation and (ethanol-powered) fuel cells fit very well with that."

Volz said the fuel cell is just one of the alternative fuel ideas Caterpillar is looking into, along with clean diesel and natural gas. What makes this particular fuel cell concept different from others is the use of ethanol as fuel. Industry analysts believe ethanol represents the most acceptable source of hydrogen for fuel cells because it is renewable, domestically produced, easy to reform into hydrogen and can utilize the existing fuel distribution network.

"No other potential fuel source can claim that," said Monte Shaw of the Renewable Fuels Association.

The project gives ethanol producers a chance to stake out what are being called "the alternative energy markets of the future."

Up until now, most experimental work on fuel cells has involved gasoline or natural gas because that research was largely supported by oil companies, according to Gary Welch, technical support manager for Williams Bio-Energy.

"(Now) Hydrogen will be derived from ethanol, producing the power and byproducts of carbon dioxide and water. It's a zero emissions system," Welch said.

Once developed, the fuel cell will provide all the power for the Williams security office, which operates on the company's own power grid. "If any additional power that's generated is left over, it'll go into our grid," he said.

And while the ethanol fuel cell project uses a stationary power source, there may be additional transportation uses in the future, most industry experts agree.

RFA - Renewable Fuel Association

Renewable Ethanol Reduces Greenhouse Gas Emissions

- Greenhouse Gas, Regulated Emissions and Energy in Transportation (GREET) full-fuel-cycle analysis model developed by Argonne National Laboratory
- *"Use of a unit of ethanol, regardless of the blend mix, achieves large petroleum use and GHG emissions benefits."*
- Analysis demonstrates 35-46% reductions in greenhouse gas emissions and 50-60% reductions in fossil energy use
- For copy of report, contact Michael Wang, Argonne, (630) 252-2819

Distribution/Infrastructure

- Ethanol is blended with gasoline as an octane enhancer and oxygenate
- Ethanol distribution to terminal level complete; available in all 50 states
- Deliveries by rail, barge, truck; tests have shown pipeline shipments can be made successfully; CEQA filings indicate some refiners will ship ethanol on certain segments of their pipeline
- Gasoline industry has experience handling and blending ethanol

Environmental Benefits


- Environmentally friendly fuel:
 - Biodegradable
 - Non-toxic
 - Does not pose a threat to water, soil or public health, according to California Environmental Policy Council
- Renewable

Benefits of Ethanol as Fuel Source

- **High Energy Density**
- **Reduces Greenhouse Gas Emissions**
- **Non-toxic**
- **Simple Molecular Structure**
- **Distribution Exists**
- **Blendable with Gasoline**
- **Growing Industry; next generation (agriculture residues, wood, cellulose)**

RFA Renewable Fuel Association





Summary

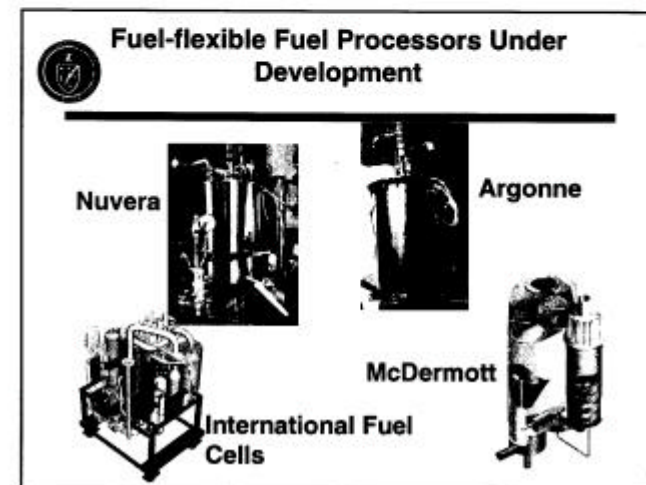
- The Renewable Fuels Association, as the U.S. ethanol industry's trade association, is committed to extensive involvement in all fuel ethanol related issues.

- We stand ready to initiate similar efforts for the use of ethanol as a reformer fuel for fuel cell applications should that opportunity arise.

United States
Department of Energy

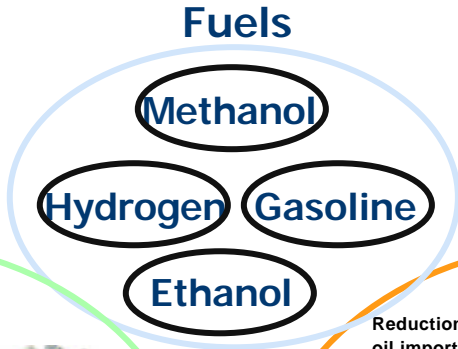
Current Projects and Funding by Budget Category

Systems	Fuel Processing	Stack Subsystem Components
<ul style="list-style-type: none"> • Plug Power/Nuvera • International Fuel Cells • Energy Partners, Honeywell • A.D. Little (Cost Analysis) • ANL (System Analysis) 	<ul style="list-style-type: none"> • Nuvera • Hydrogen Burner • McDermott • Honeywell • ADL/Acurex • ANL, LANL, PNNL 	<ul style="list-style-type: none"> • Energy Partners, AlliedSignal, IFC, Plug Power • Gas Technology Institute • 3M, SwRI/Gore, Foster-Miller • Vairex, A.D. Little, AlliedSignal, Merit • LANL, LBNL, NRL, JPL
FY01: \$7.6M	FY01: \$21.5M	FY01: \$12.4M

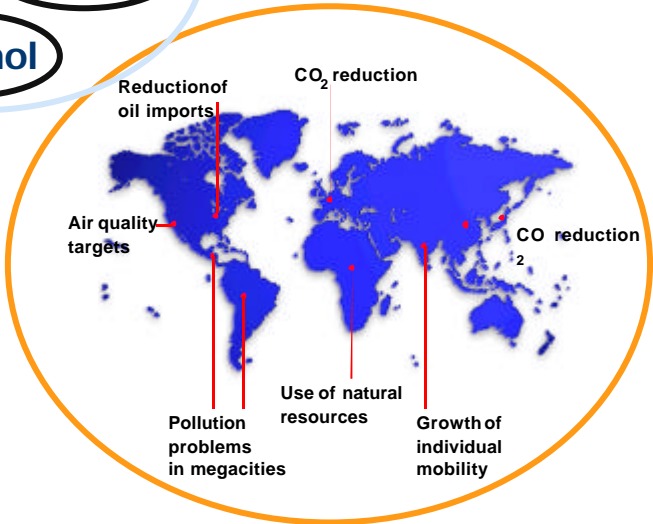


The most suitable fuel varies for different regions and applications

Applications



World Regions



Hydrogen

- + fuel for fleet applications
 - + markets with ZEV legislation
 - + best "well to wheel" efficiency
 - + fossil and regenerative production options
- power to change the world®

Methanol

- + fuel for private use
- + liquid, easy handling
- + fossil and regenerative production options
- + Direct Methanol Fuel Cell as future option

Gasoline

- + fuel for APUs (Auxiliary Power Units)
- + existing infrastructure
- + easy on-board storage

Ethanol

- + fuel for ALL APPLICATIONS
- + existing infrastructure in Brazil
- + easy on-board storage
- + liquid, easy handling
- + regenerative production options

Time is a key factor in the introduction of new technologies

The Fuel Cell technology has been developed in Europe, North America and Japan and in the future will substitute the internal combustion engine for automotive, stationary and other applications. The high investment already done by the automotive industry shows that there is no return.

The commercialization starts with the demonstration projects from 2001-2003 and small pre-commercial series in 2004.

The countries, where development and demonstrations projects are taking place, are getting social, economic and environmental benefits, such as:

- a comprehensive improvement of urban transportation,
- building the national industry,
- man power training and capacity-building,
- technology transfer and creation of new business opportunities,
- dissemination and exchange of of learning experience,
- a major push to the accelerated development of clean technologies,
- creation of new jobs,
- development of know-how, which will be exported to other countries.

The time is now for the developing countries to join the OECD countries in the fuel cell development and in the efforts to reduce CO₂ and local pollution.