Fuel Cells for Buildings and Stationary Applications Roadmap Workshop

"By 2020, fuel cells will be intimately integrated in buildings, part of a flexible portfolio of options for meeting energy needs and/or supporting the grid."

Workshop Proceedings
April 10-11, 2002

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1.0 Introduction

A. Overview

The U.S. Department of Energy's Office of Power Technologies sponsored a two-day workshop in College Park, Maryland on April 10-11, 2002, to design a set of actions for research, development, and demonstration of fuel cell technologies for use in buildings and stationary applications. The *Fuel Cells for Buildings Roadmap Workshop* brought together researchers, government officials, and industry members to creatively develop solutions to achieve a vision for the fuel industry. The vision, developed at an earlier workshop, is stated below.

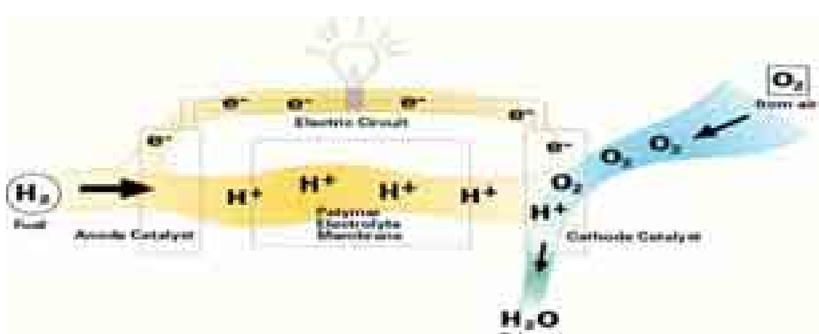
By 2020, fuel cells will be intimately integrated in buildings, part of a flexible portfolio of options for meeting energy needs and/or supporting the grid.

The *Fuel Cells for Buildings Vision Workshop* involved many of the same stakeholders as the Roadmap Workshop; during the course of the workshop, they not only outlined this vision for the fuel cells industry as it affects buildings, but they created specific, strategic goals to achieve it..

This document presents the proceedings of the *Fuel Cells for Buildings and Stationary Applications Roadmap Workshop*. These proceedings include a summary of workshop products, including the plenary presentations, and the recommendations of three breakout groups.

B. Background

The principle of the fuel cell has been known since the 19th century, when William Grove utilized four large cells, each containing hydrogen and oxygen, to produce electric power. Similar to a battery, fuel cells have an anode and a cathode separated by an electrolyte; the electrolyte is the distinguishing characteristic of the fuel cell. Hydrogen enters the anode and air enters the cathode. The hydrogen and oxygen are separated into ions and electrons, in the presence of a catalyst. Ions are conducted through the electrolyte while the electrons flow through the anode and the cathode via an external circuit. The current produced can be utilized for electricity. The ions and electrons then recombine, with water and heat as the only by-products. This unique process is practically silent, nearly eliminates emissions, and has no moving parts.



In the 1960's the alkaline fuel cell was developed for space applications. The successful demonstration of fuel cells in space led to their development for terrestrial applications in the 1970s. With the introduction of the Nafion™ material membrane by Dupont in the early 1970's, proton exchange membrane fuel cells (PEMFC) were being seriously researched for stationary and mobile applications.

The proton exchange membrane is a thin fluorinated plastic sheet that allows hydrogen ions (protons) to pass through it. The membrane is coated on both sides with highly dispersed metal alloy particles (mostly platinum) that are the active catalyst. The PEMFC operates at relatively low temperature, has high power density, and can vary its output quickly to meet shifts in power demand. It is well suited for applications where quick startup is required (e.g. transportation and power generation). The PEMFC is a leading candidate for powering the next generation of vehicles and is ideal for office, retail, hotel, education, and health building applications because of its load characteristics, impact on rate structures, and economies of scale.

The emergence of new fuel cell types, such as solid oxide fuel cells (SOFC) and molten carbonate fuel cells (MCFC) in the past decade has led to a tremendous expansion in the number of useful products and applications for buildings. For example, the SOFC operates at high temperatures, which further enhances combined cycle performance. The solid oxide system uses a hard ceramic material instead of a liquid electrolyte. The solid-state ceramic construction enables it to operate at high temperatures and allows more flexibility in fuel choice. SOFCs are capable of fuel-to-electricity efficiencies of 45-60%LHV and total system thermal efficiencies of up to 80% in combined heat and power applications.

Fuel cell systems today typically consist of a fuel processor, fuel cell stack, and power conditioner. The fuel processor, or reformer, converts hydrocarbon fuel to a mixture of hydrogen-rich gases, and depending on the type of fuel cell, can remove contaminants to provide pure hydrogen. The fuel cell stack is where the hydrogen and oxygen electrochemically combine to produce electricity. The electricity produced is direct current (DC); the power conditioner converts the DC electricity to alternating current (AC) electricity, for which most end-use technologies are designed. As a hydrogen infrastructure emerges, the need for the reformer will disappear as pure hydrogen will be available near the point of use.

The U.S. Department of Energy is working with researchers and fuel cell manufacturers to make the PEMFC commercially available for buildings and stationary applications. Fuel cells installed in such distributed power applications entail less risk and introduce a cost effective and growing market for the PEMFC until a hydrogen infrastructure is in place. Improving materials, components and subsystems, and integrating these systems with the building infrastructure, will lead to growing numbers of fuel cell installations in buildings across the country.

C. Workshop Process

The *Fuel Cells for Buildings and Stationary Applications Roadmap Workshop* began with presentations from DOE officials on current federally-funded activities involving fuel cell and hydrogen research and development. Workshop participants then worked in one of three parallel breakout groups:

- Materials
- Components and Subsystems
- Building Infrastructure

Each the three parallel sessions were professionally facilitated and resulted in specific actions and action plans that need to be taken to achieve a set of strategic goals for the fuel cells for buildings industry. These goals include:

- Lowering the installed cost
- Improving the performance and lifetime of the fuel cell system
- Creating an infrastructure to support stationary fuel cell installations

Each breakout group developed a set of top priority action items, and then created specific action plans for the top priority action items. These action plans identified the scope, specific tasks, timeframes, linkages with other programs, lead and support organizations, and immediate next steps to be taken.

2.0 Plenary Presentations

This section provides the presentations given by DOE fuel cell and hydrogen program managers during the plenary session. These presentations provided background information about the fuel cells for buildings program, as well as the fuel cells for transportation program, the hydrogen program, and the Solid State Energy Conversion Alliance (SECA) program.

A. Welcome & Overview of the Fuel Cells for Buildings Program
   Ronald Fiskum, Program Manager, Office of Power Technologies, Department of Energy

B. The Department of Energy's Fuel Cells for Transportation Program
   Nancy Garland, Program Manager, Office of Transportation Technologies, DOE

C. Hydrogen Briefing
   Neil Rossmeissl, Program Manager, Office of Hydrogen and Superconductivity, DOE

D. The Solid State Energy Conversion Alliance
   Wayne Surdoval, SECA Program Manager, National Energy Technology Laboratory, DOE

A. WELCOME & OVERVIEW OF THE FUEL CELLS FOR BUILDINGS PROGRAM

Ronald Fiskum, Program Manger, Office of Power Technologies, Department of Energy

Stationary Fuel Cells

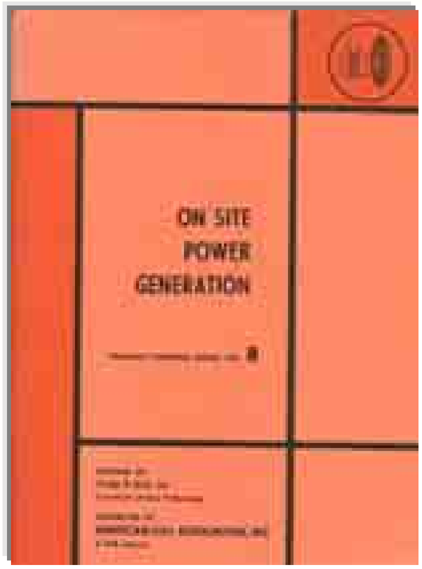
Ronald Fiskum

Energy Consumer Choice

"… one of the several promising opportunities that we're working on for consumers to manage their peak load requirements is the use of combined heat and power systems in buildings. These systems couple natural gas fired distributed generation, such as microturbines, recip engines, and fuel cells, with thermally activated cooling and humidity control equipment to meet a building's energy and indoor comfort needs. There happens to be a national test facility for these devices only 15 miles from here at the University of Maryland.   There are other examples from our existing portfolio including the integration of solar energy devices and buildings, industrial power systems, and electricity storage devices for power quality."

David Garman, Assistant Secretary
Energy Efficiency and Renewable Energy

Reminiscing & Reputation: According to AGA in September 1966



Onsite power generation offers a promising way for the gas industry to participate in the growing electric energy market. Gas energy onsite power systems can compete with purchased power in residential, commercial, and industrial applications. This ability will improve as the technology of energy conversion develops and the use of onsite power becomes better understood. Although first costs of fuel cells are not yet clearly defined, it is presently projected that production fuel cells can be built for approximately $100 per kilowatt.

Assessment

- Where it the PEM technology today?
- How close is PEM to a viable product?
- Where are the GAPs?

What the Future Holds

- What will it take to close these GAPs?
  - Programs
  - Money
  - Time
- When should we tell policy makers, wall street and the general public we are launching real products?
- What other stationary fuel cell technologies should we consider: solid oxide, alkaline, etc.?

Exciting Times

- These are exciting times for development of stationary fuel cells.
- If America will transition to a H_2 economy, it will be across a bridge of stationary fuel cells.
- Before FreedomCARs will roll across our highways, FreedomPOWER will light our buildings.
- However, it all begins today with planning.

Our Request

- Listen carefully, think strategically, be thoughtful, and work hard the next day and one half.
- Create the best and most realistic vision for a public/private partnership in stationary fuel cells.

B. The Department of Energy's Fuel Cells for Transportation Program

Nancy Garland, Program Manager,
Office of Transportation Technologies, Department of Energy

The Department of Energy
Fuel Cells for Transportation Program**

Nancy L. Garland
U.S. Department of Energy
Fuel Cells for Buildings Roadmap Workshop
April 10-11, 2002

**soon to be the Hydrogen, Fuel Cells, and Infrastructure Technologies Program

Outline

Program: Goal and Implementation
Fuel Pathways: Strategy, Energy Efficiency, Emissions, and Cost
Technical Challenges
Program Activities

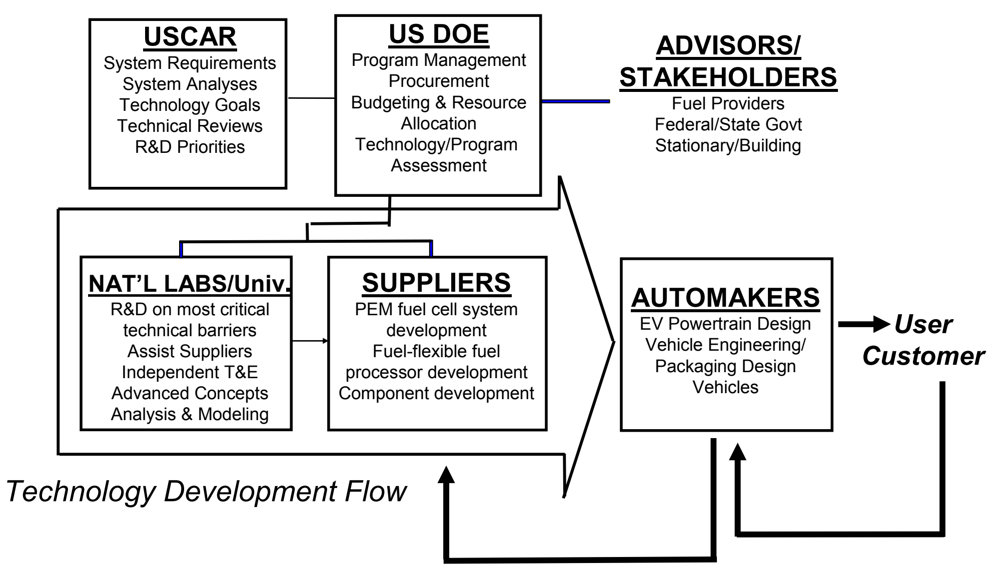
Fuel Cells for Transportation

Our goal is to develop technologies for:

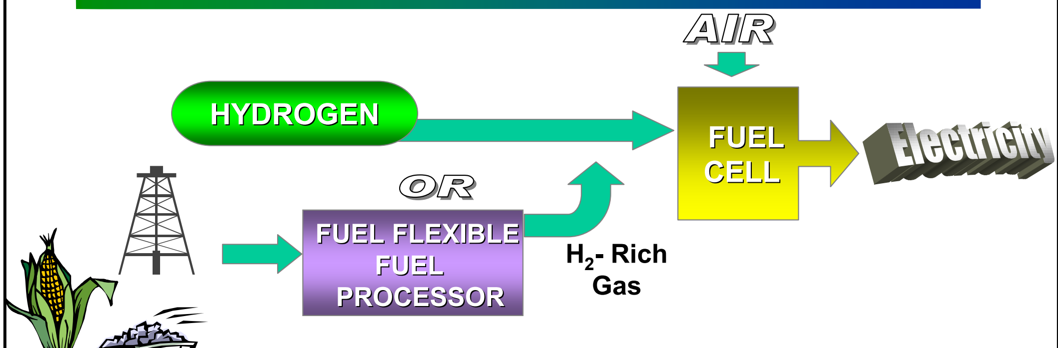
- highly efficient
- low- or zero-emission
- cost-competitive

automotive fuel cell power systems that operate on conventional and alternative fuels.

Fuel Cell Program Implementation A Strategic Partnership

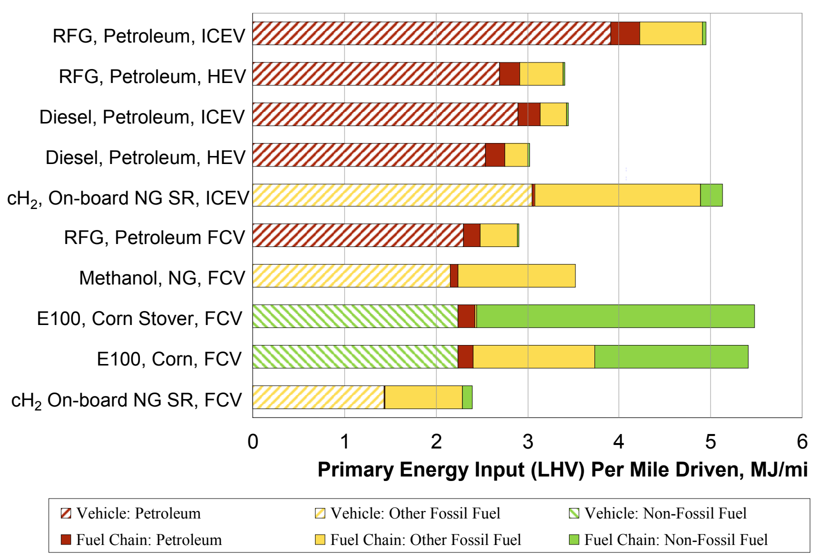


DOE Transportation Fuel Cell Program Fuel Strategy



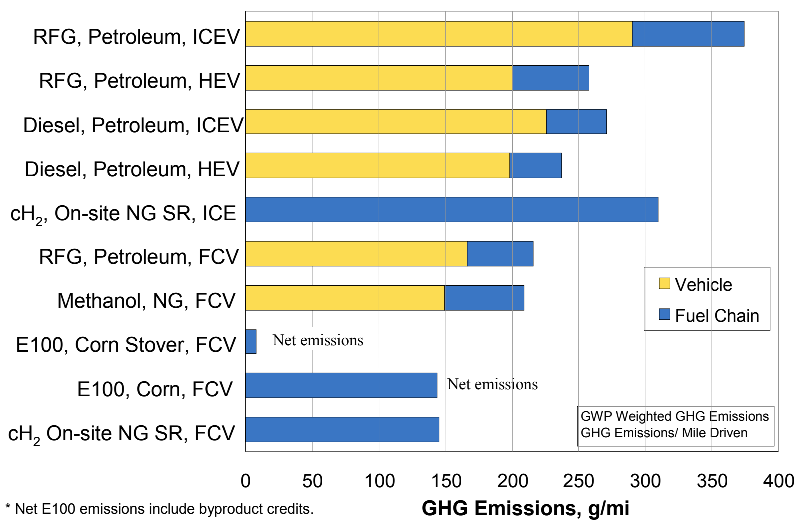
- Hydrogen can be stored and supplied directly to the fuel cell: *Storage and Infrastructure Issues*
- Hydrogen can be derived on-board from fuels such as ethanol, methanol, natural gas, gasoline or FT fuels: *Durability and Start-up Issues*

Well-to-Wheels Comparison of Fuel Pathways



Results from Phase 2 of "Fuel Choice for Fuel Cell Vehicles", ADLittle Well-to-Wheels Project for DOE, 10/01,

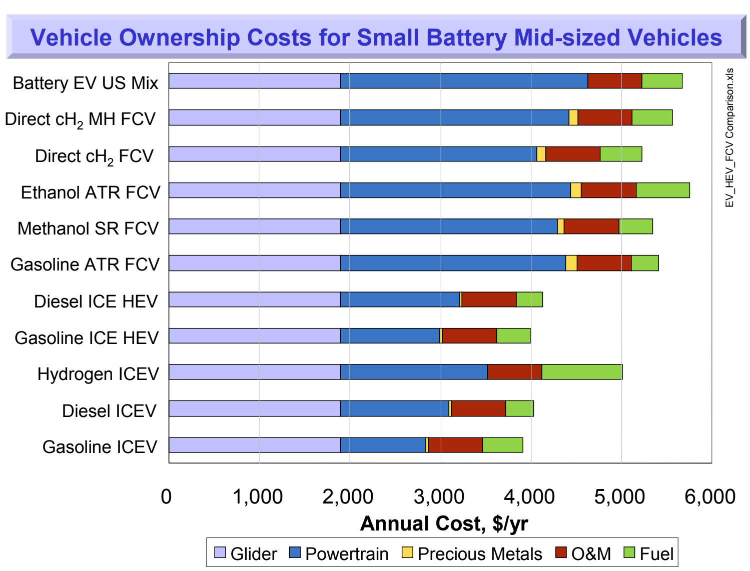
Well-to-Wheels: *Greenhouse Gases Fuel Comparison*



* Net E100 emissions include byproduct credits.

Results from Phase 2 of "Fuel Choice for Fuel Cell Vehicles", ADLittle Well-to-Wheels Project for DOE, 10/01,

Fuel cell vehicles will cost more than conventional and advanced ICE vehicles



Note: All vehicles are based on the same midsized vehicle platform with 350 mile range except the Battery EV which has only a 120 mile range.

Projected Fuel Cell Vehicle Performance
Lightweight Hybrid Vehicle

Projected Mileage, MPG_e

	Gasoline Fueled Fuel Cell	Hydrogen Fueled Fuel Cell
Urban Fuel Economy	79	101
Highway Fuel Economy	97	128
Combined	86	*111*

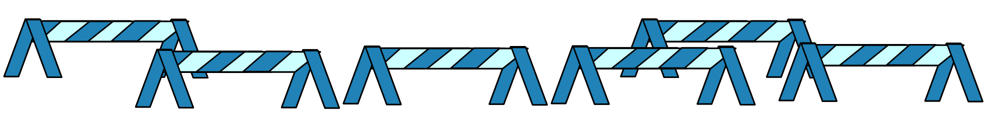
Note: Based on NREL/ADVISOR system modeling using target fuel cell efficiencies.

108 mpg_e predicted

Automotive Fuel Cells
Key Technical Challenges

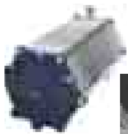
There are significant technical and economic barriers that will keep fuel cell vehicles from making significant market penetration for 10 years.

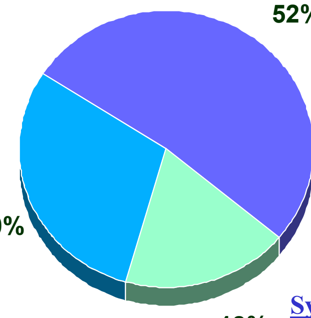
- Hydrogen Storage
- Fuel Infrastructure
- Start-Up (Fuel Processing)
- Cost/Affordability (Platinum)
- Reliability/Durability
- Air/Thermal/Water Management



Program Activities – Fuel Cells

FY 2002 Budget = $41.925M





Fuel Processing/Storage R&D

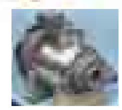
- On-/Off-board fuel processing
  - Catalyst R&D
  - Fuel Effects/Durability
  - CO/Sulfur Management
  - Microchannel Components
- Hydrogen Storage
  - Advanced Chemical Hydrides, C-Based Materials
  - Independent Test Facility

Fuel Cell Stack Subsystem

- Catalyst R&D
- High Temperature Membrane R&D
- MEA/Bipolar Plate Manufacturing Process
- Cost Reduction R&D
- Durability Studies

Systems

- System Validation
- System Modeling
- Ancillary Components (Compressors, Sensors)
- Cost Analyses
- Emissions Testing

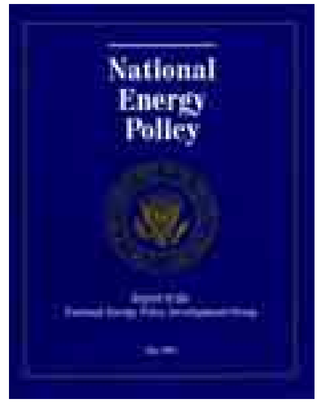


FY 2003 Request = $50M

Fuel Cells for Transportation Program Partners/Partnerships

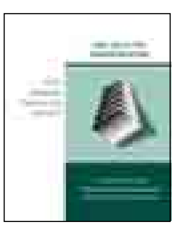
Summary

- Improving energy diversity will increase economic and energy security (supports National Energy Policy)
- Tremendous progress has been made, however major technical challenges prevent the introduction of fuel cells into the marketplace
- DOE's Office of Energy Efficiency and Renewable Energy is addressing critical technical challenges.



For Further Information

2001 Annual Progress Reports available at www.cartech.doe.gov



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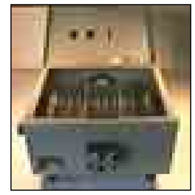
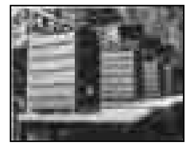
C. HYDROGEN BRIEFING

Neil Rossmeissl, Program Manager,
Office of Hydrogen and Superconductivity, Department of Energy



Fuel Cells for Buildings Roadmap Workshop



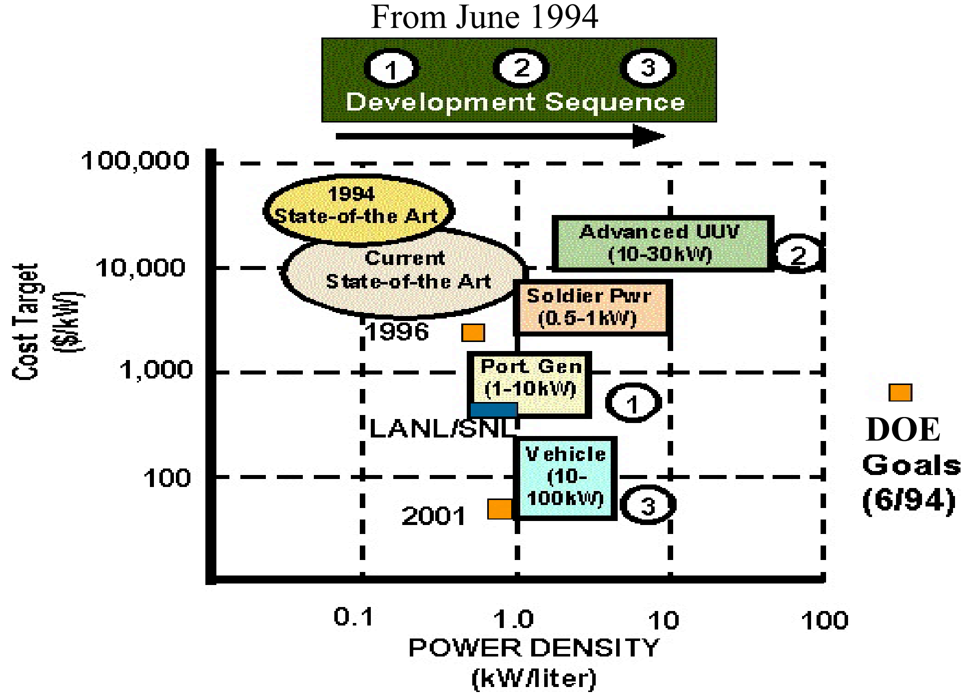
Hydrogen Briefing

Neil Rossmeissl

April 11, 2002

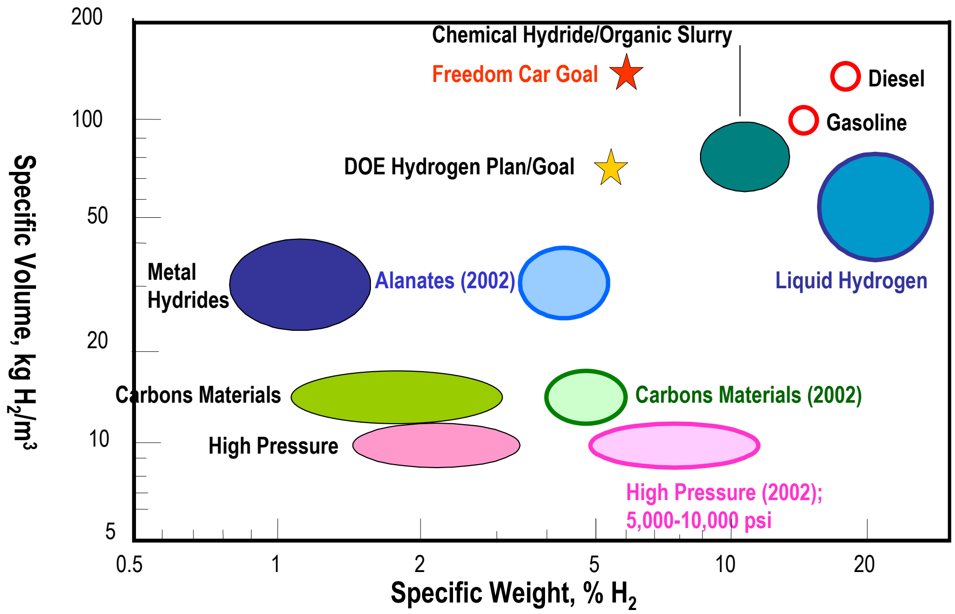
PEM FUEL CELL REQUIREMENTS

From June 1994



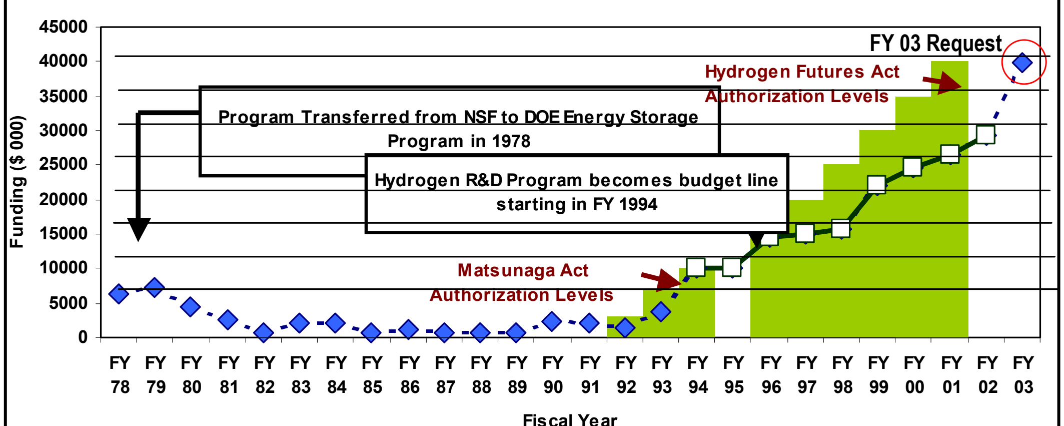
Hydrogen Storage Developments

Reference Data From the R&D Roadmap 1998



Hydrogen Program Funding Summary

Hydrogen R&D Program -- Historical Funding



Legislative Mandates

Pursuant to Matsunaga Hydrogen RD&D Act and the Hydrogen Futures Act of 1996, 2002:

Title 1 Hydrogen

"…to direct the Secretary of Energy to conduct a research, development, and demonstration program leading to the production storage, transport, and use of hydrogen for industrial, residential, transportation, and utility applications"

- **Allows demonstrations with at least 50% non-Federal cost-share**
- **Accelerates "critical" R&D**
- **Calls for fostering technology transfer**
- **Authorizes a total of $290 million in spending;**
- **Reauthorize the formation of the Hydrogen Technical Advisory Panel to review the program activities and make recommends to the Secretary on implementation and conduct of the program.**

FY 1996-2001

Reauthorization Approved in House, Senate has not acted

Legislative Mandates

Pursuant to Matsunaga Hydrogen RD&D Act and the Hydrogen Futures Act of 1996, 2002:

Title 2 Fuel Cells (amended for 2002)

"…to direct the Secretary of Energy to solicit proposals for projects to prove the feasibility of integrating fuel cells into Federal, State, and local government facilities for stationary and transportation applications."

- **Allows demonstrations with at least 50% non-Federal cost-share**
- **Accelerates "critical" R&D**
- **Calls for fostering technology transfer**
- **Authorizes a total of $130 million in spending;**
- **Not later than 120 days after the date of enactment of this section, the Secretary shall establish an interagency task force led by a Deputy Assistant Secretary of the Department of Energy and comprised of representatives, OSTP, DOT, EPA, NASA, DOD, DOC.**
- **Original authorization 1996 - 2001**
- **Reauthorization approved in House, Senate has not acted FY 2002- 2006**

Integration With Other Programs

California Fuel Cell Partnership

- Provide Hydrogen Infrastructure
- Provide Pressurized Storage Tanks

Southcoast Air Quality Management District

- Provide Hydrogen Infrastructure

Codes and Standards

- International Code Council
- National Fire Protection Association

Department of Transportation

NASA

GTI

- Fuel-maker for Hydrogen
- Infrastructure Working Group

Assistant Secretary Garman's 9 Priorities

EERE's Priorities: Hydrogen

1. Dramatically reduce or even end dependence on foreign oil
3. Increase viability and deployment of renewable energy.
4. Increase reliability and efficiency of electricity generation.
9. Lead by example through government's own actions.

Milestones and Deliverables

Install distributed refueling stations that can produce hydrogen untaxed at $1.25 per gallon equivalent.

Hydrogen storage system that can provide 6% by weight hydrogen and 250 – 400 miles of range.

Validate integrated systems into Power Parks that co-produce electricity (<$0.06/kW) and hydrogen.

Priority/Support

1. Balanced research, development and validation program to produce hydrogen from indigenous fossil and non-fossil sources.
3. Initiated a number of collaborations with Wind, CSP and DER programs using energy storage.
4. Collaborated with other EERE and FE programs on integrating fuel cells with hydrogen production
9. Last three years have developed collaborations with FE,OIT,OTT, DOT to foster major hydrogen initiatives.

Major Accomplishments

Awarded three cooperative agreements with industry teams for hydrogen refueling stations.

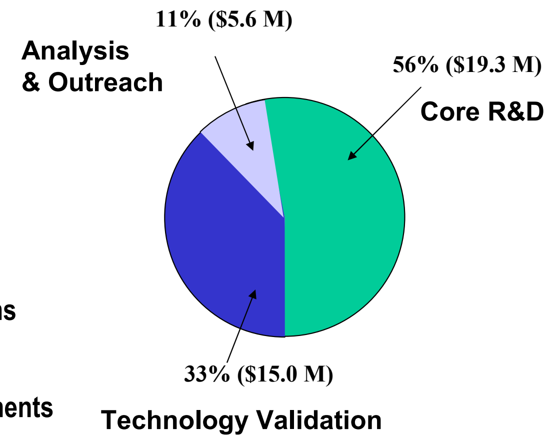
Completed certification of a 6% by weight, 5000 psi cyrogas hydrogen storage tank.

Completed 100 cycles of a 5.2 % by weight hydride tank.

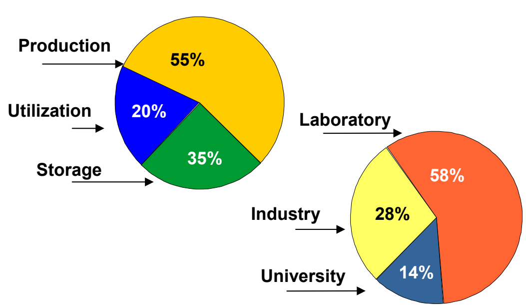
Completed testing of hydrogen production and 50kWe hydrogen fuel cell.

Hydrogen Program Structure

- **Core R&D**
  - Production
  - Storage
  - Utilization
- **Technology Validation**
  - Renewable Hydrogen Systems
  - Hydrogen Infrastructure
  - Distributed/Remote Power Systems
- **Analysis and Outreach**
  - Economic and Technical Assessments
  - Operational Database on Validation
  - Projects for Codes & Standards



Core R&D Thrust FY02



Storage: $ 7.84 M

FY 01 Milestones

Developed new method to synthesize catalyzed alanate.

Demonstrated thermal compressor at 6000 psig.

FY 02 Milestones

Validate 5.2% by weight storage on catalyzed alanate with over 1000 cycles.

Scale up thermal compressor to 15 liters/min

Production : $ 7.76 M

FY 01 Milestones

Completed construction of ITM PDU

Operated a 5 liter bioshift reactor on a slipstream of syngas.

FY02 Milestones

Operate PDU continuously at 24,000 SCFD of syngas to verify performance.

Operate the 5 liter bioshift reactor at 10 psi on a slipstream of syngas

Utilization : $ 3.74 M

FY 01 Milestones

Supported CaFCP by modeling maintenance building ventilation.

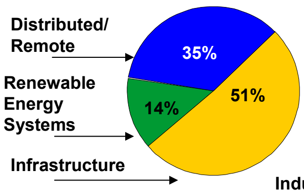
Hydrogen additions to natural gas extended the lean flammability limits cutting NO_x by 25%.

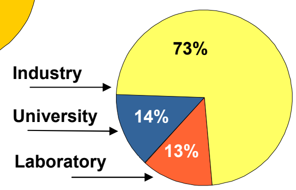
FY 02 Milestones

Demonstrate 200 W advanced PEM fuel cell for personal mobility devices.

Quantify the effect of adding up to 100% hydrogen to combustion turbine emissions.

Technology Validation Thrust FY02





Hydrogen Infrastructure ($ 6.5M)

FY01 Results
Fabricated and test components for fueling station.
Validated 5000 psi composite tanks.

FY02 Milestones
Certify pressure vessels.
Demonstrate co-production refueling station with 50 kW hydrogen fuel cell.

Renewable Energy Systems ($ 2.65 M)

FY01 Milestones
Reduced cost of hydrogen production from wind and biomass pyrolysis.

Completed electrolysis/metal hydride hydrogen scooter.

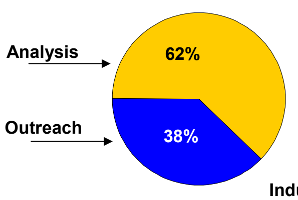
FY02 Milestones
Demonstrate utility energy storage system.
Optimize fluidized bed reformer for biomass pyrolysis
Complete electrolzyer cost reduction efforts

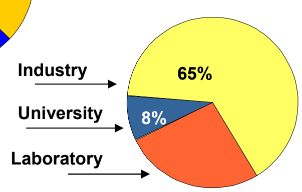
Distributed/Remote Power ($ 5.85 M)

FY01 Milestones
Determined suitability of PEM fuel cells for stationary applications.
Completed power park scenario analysis and associated component costs and efficiencies.

FY02 Milestones
Complete design of power park
Demonstrate distributed remote FC

Analysis & Outreach Thrust FY02





Outreach: ($ 2.11 M)

FY 01 Milestones

Completed hydrogen curriculum for high schools and colleges.

Complete educational module to support DER outreach program to educate state and local officials.

FY 02 Milestones

Complete a one-day educational program for NFPA on hydrogen.

Complete working script for hydrogen new age film.

Analysis: ($ 3.44 M)

FY 01 Milestones

Developed with ICC 24 amendments to the building codes.

Completed flammability tests on sheetrock for garage modeling.

FY02 Milestones

Complete the assessment of natural gas reforming using solar energy.

Support industry participation at the ICC hearing to approval the hydrogen amendments.

Codes and Standards: ($ 1.2 M)*

FY 02 Major Initiatives

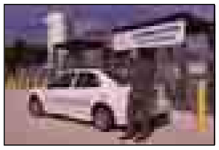
Complete educational training seminar in collaboration with NFPA on hydrogen energy and fuel cells.

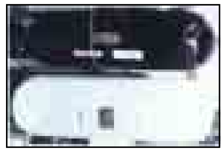
Complete amended code changes for the NFPA fuel gas and fuel cell codes.

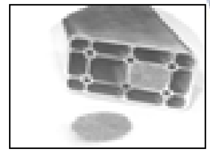
Complete hydrogen version of NGV2 tank standards.

* Note: funding is part of analysis

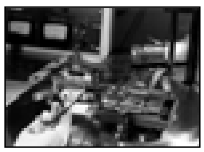
Key Events for Next Year







- ☑ Operation of Hydrogen Fueling Station
- ☑ Demonstration of Light-weight Pressurized Storage Tanks
- ☑ Demonstration of Hydride Storage System
- ☑ Demonstration of .01 Gram Carbon Nanotube Material
- ☑ Demonstration of Reversible Fuel Cell



D. THE SOLID STATE ENERGY CONVERSION ALLIANCE

Wayne Surdoval, SECA Program Manager,
National Energy Technology Laboratory, Department of Energy

The Solid State Energy Conversion Alliance

Fuel Cells for Buildings and Stationary Applications Roadmap Workshop

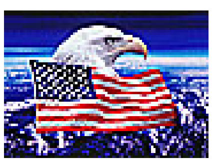
April 4, 2002

Wayne A. Surdoval

National Energy Technology Laboratory

NETL

National Benefits

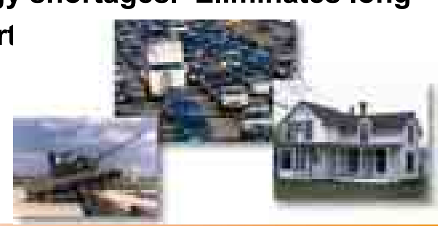


SECA

Energy Security

- Multi-fuel capability allows use of available fuels or currently cost-effective fuels including hydrogen and coal.
- In many applications doubles the efficiency of producing power from fossil fuels compared to current technologies.
  - Reduced CO_2 emissions
  - Reduced dependence on imported fuels
- Rapid response to local energy shortages. Eliminates long-lead time and economic uncert

  plants.



NETL

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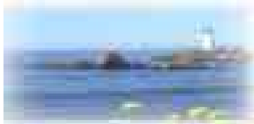

National Benefits

SECA

Environment and Health Benefits

- **Important health benefits due to the negligible emission of environmental pollutants using fossil fuels.**

Economic Choices

- **Provides a grid independent, environmentally friendly power source for use in the undisturbed, natural areas of the nation.**
- **Provides more power choices for residences and businesses. The high efficiencies of a combined heat and power (CHP) system along with a choice of fuel, power quality, grid integration or grid independence will provide citizens with choices and will significantly assist de-regulation efforts throughout the nation.**

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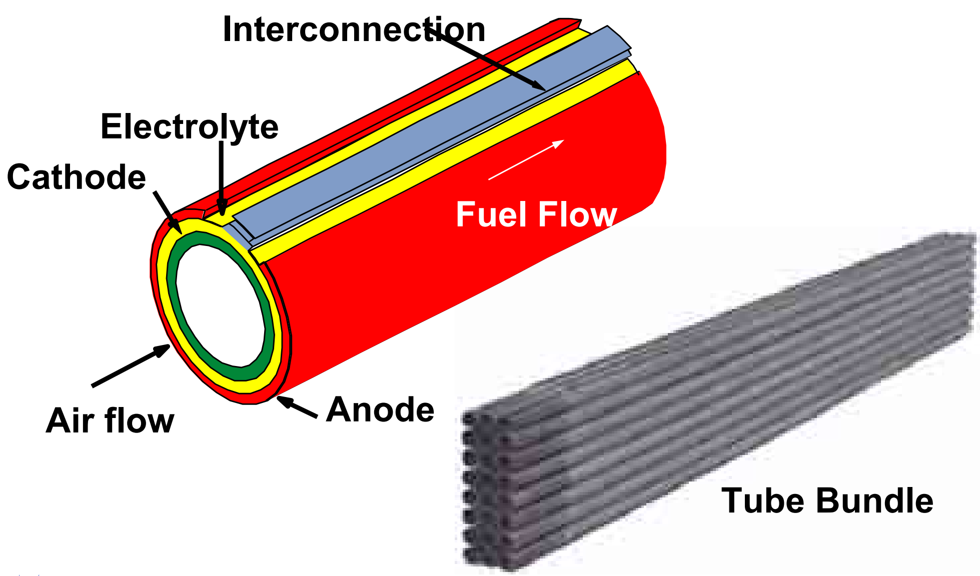
Tubular SOFC

SECA



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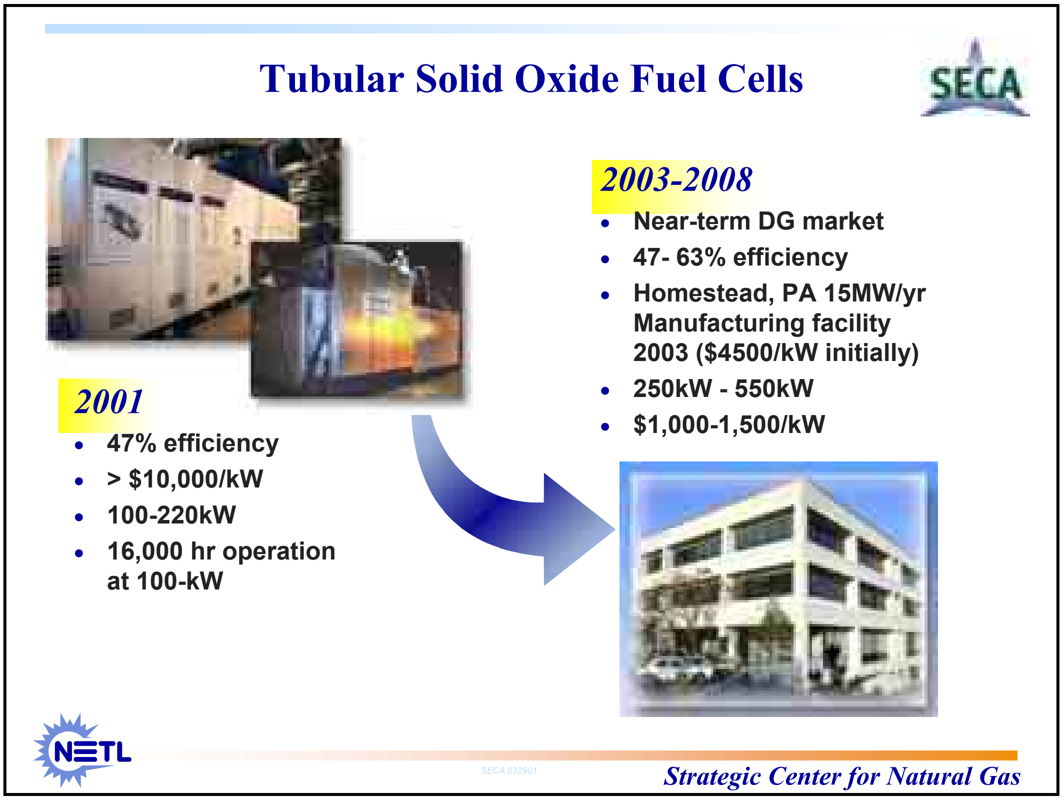
Tubular Solid Oxide Fuel Cells
SECA
2001
47% efficiency
> $10,000/kW
100-220kW
16,000 hr operation at 100-kW
2003-2008
Near-term DG market
47- 63% efficiency
Homestead, PA 15MW/yr Manufacturing facility 2003 ($4500/kW initially)
250kW - 550kW
$1,000-1,500/kW
NETL
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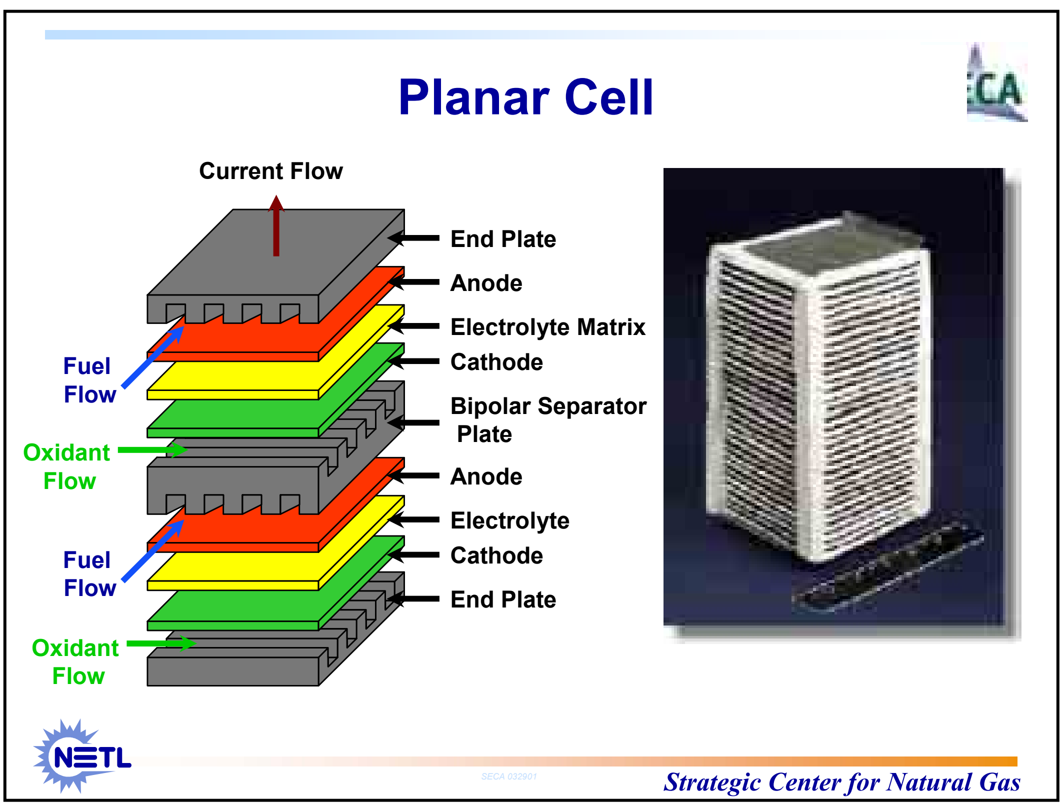
Planar Cell
Current Flow
End Plate
Anode
Electrolyte Matrix
Cathode
Bipolar Separator Plate
Anode
Electrolyte
Cathode
End Plate
Fuel Flow
Oxidant Flow
Fuel Flow
Oxidant Flow
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Automotive Auxillary Power Unit

SECA

DELPHI

Automotive Systems

NETL

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FCT 5 kWe SOFC Power System Oblique View-Open Access Panels

SECA

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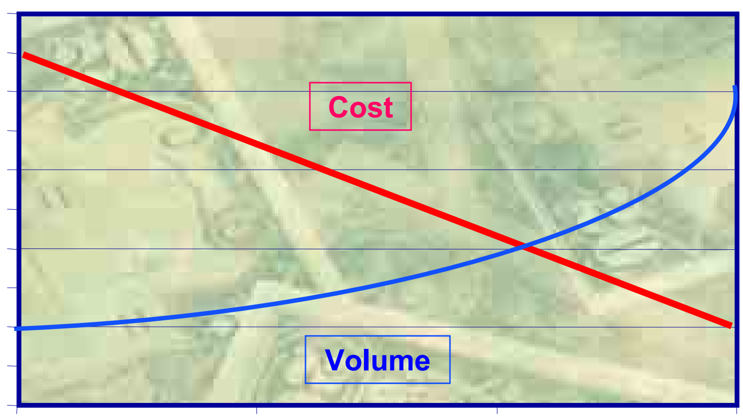
Working Definition of Hybrid Fuel Cell

- A combined-cycle power generation system containing a high-temperature fuel cell plus a
  - ✓Gas turbine
    or
  - ✓Reciprocating engine
    or
  - ✓Another fuel cell

The Vision: *Fuel Cells in 2010*



Low Cost/High Volume
$400/kW/ > 50,000 units/yr

SOFC Materials Costs

SOFC Component	Material Cost ($/kW)
Common Materials (excluding interconnects)	
Ni/ZrO_2 anode (500 microns)	11.67
ZrO_2/Y_2O_3 electrolyte (10 microns)	0.40
$LaMnO_3$ cathode (50 microns)	2.30
ss End Plates (1.25 centimeters)	0.70
Subtotal Common Materials	15.07
Ceramic Interconnect (2.5 millimeters)	137.50
Subtotal Ceramic Interconnect & Common Materials	152.57
50% Contingency	76.28
Total Material Costs Using Ceramic Interconnects	**228.85**
Metallic Interconnect (2.5 millimeters)	6.67
Subtotal Metallic Interconnect & Common Materials	21.74
50% Contingency	10.87
Total Material Costs Using Metallic Interconnects	**32.61**

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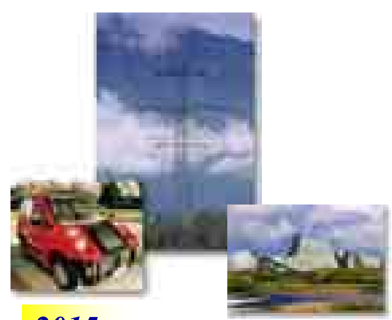
SECA Goals and Applications

2005

- **$800/kW**
  - Long-haul trucks
  - RVs
  - Military
  - Premium power

2010

- **$400/kW**
  - Residential & industrial CHP
  - Transportation auxiliary power



2015

- **Vision 21 power plants**
  - 75% efficient
- **Hybrid systems**
  - 60–70% efficient

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Technical Requirements

Cost	**$400 / kW**
Power Rating Net	**3-10 kW**
Efficiency **(AC or DC/LHV)**	**30 - 50% [APU]** **40 - 60% [Stationary]**
Fuels **(Current infrastructure)**	**Natural Gas** **Gasoline** **Diesel**
Design Lifetime	**5,000 Hours [APU]** **40,000 Hours [Stationary]**
Maintenance Interval	**> 1,000 Hours**

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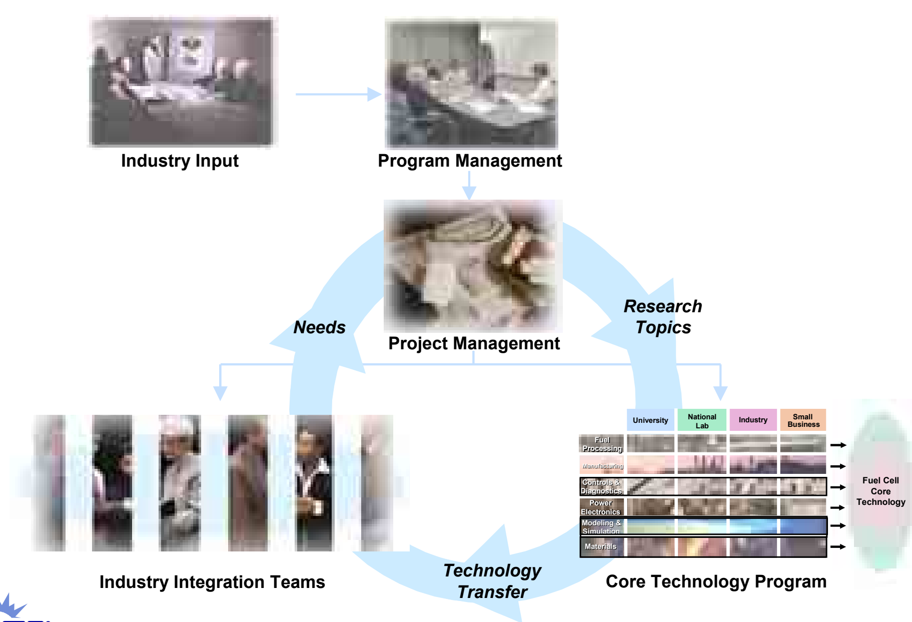
Program Structure



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INDUSTRIAL TEAMS

Honeywell (GE)	Demonstrated a unique unitized sealess radial design. Single cell performance at 700 C is near Goals
Delphi/ Battelle	Demonstrated automotive APU. Design developed by Battelle will use unique seals, anode, and cathode.
Cummins/ McDermott	McDermott has demonstrated a unique design and cost effective multi-layer manufacturing using techniques developed in the semi-conductor industry.
Siemens-Westinghouse	Siemens-Westinghouse has redesigned their technically successful tubular design to reduce stack cost.

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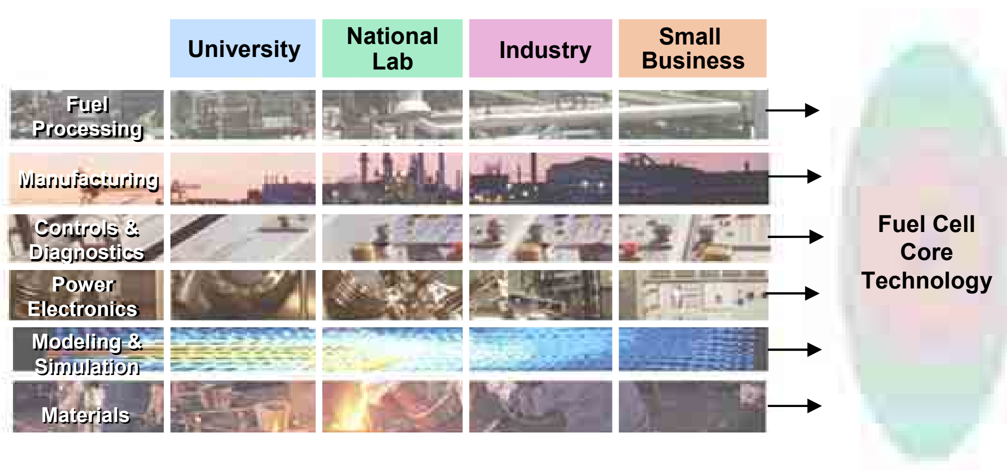
Core Technology Program

The Technology Base



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Alliance

	# of Participants	Funding Mechanism
Large Business	5	Industrial Teams 1999 PRDA 2000 Multi-Layer
Small Business	6	2000 Multi-Layer SBIR Phases I & II
Universities & Non-Profits	6	1999 PRDA UCR
National Laboratories	6	Field Work Proposals

Strategic Center for Natural Gas

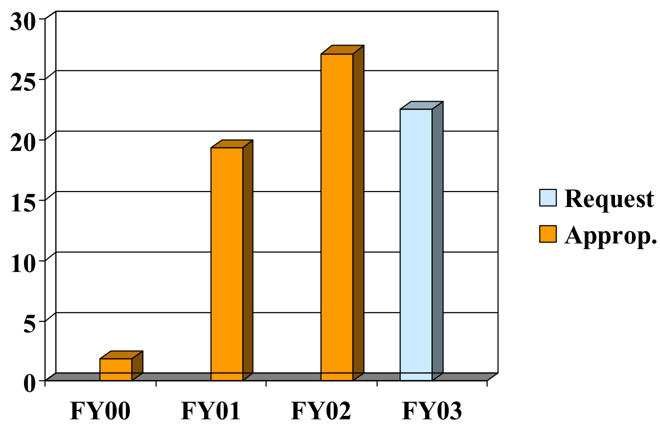
SECA Players/Efforts

Universities, National Labs, Industry

Strategic Center for Natural Gas

SECA Budget

($ - millions)



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SECA Timeline

• Industry Team Solicitation Issued	November 3, 2000
• Proposals Due	*January 3, 2003*
• SECA Core Technology Program Workshop	February 14 & 15, 2000
• 2nd Annual SECA Workshop	March 29 & 30,2001
• 2001 Industrial Teams Selected	August 2001
• Core Technology Program Review	November 2001
• Core Technology Program Solicitation Issued	January 2002
• Core Technology Program Review	*June 18 & 19, 2002*

www.netl.doe.gov/scng
www.seca.doe.gov

Strategic Center for Natural Gas

FUTURE NEEDS

Strategic Center for Natural Gas

Materials

3.0 Introduction

The materials group discussed the fuel cell stack, including high temperature membranes, water management, catalysts, and bi-polar plates. Research and development on materials used in fuel cells will lead to a more efficient, lower cost, and higher performance fuel cell power plant. The actions identified by the group are in the following four areas:

- Fundamental Research
- Applied Research
- Development
- Analysis

Table 3-1 illustrates the key actions identified by the materials breakout group. Table 3-2 displays the work breakdown structure of the high priority actions.

Participants: Materials Breakout Group

NAME	ORGANIZATION
Guoyi Fu	Millinium Chemicals
Ajay Misra	NASA Glenn Research Center
Steve Slayzak	National Renewable Energy Laboratory
Ed Taylor	Naval Air Systems Command
Sandy Dapkunes	National Institute of Standards and Technology
Bill Swift	Argonne National Laboratory
Nancy Garland	U.S. Department of Energy
Bahri Ozturk	Allegheny Ludlum
James Wang	Sandia National Laboratory
Mike Silver	American Elements
Bruce Rauhe	Houston Advanced Research Center
Bill Ernst	PlugPower
Neil Rossmeisl	U.S. Department of Energy

Facilitator: Rich Scheer, Energetics, Incorporated

3.1 Action Plans

The most critical part of the fuel cell system is the membrane. The membrane has the most influence on the operating temperature, efficiency, and lifetime of the fuel cell. Because membrane problems, such as degradation, are at the heart of fuel cell construction, operation, and maintenance, breakout group participants support the development of a central laboratory, housed at a university or national laboratory, where all membrane problems could be assessed. Once degradation problems and solutions are understood, manufacturers and researchers would be able to improve the membrane itself.

Development of high temperatures membranes will allow the fuel cell to be integrated with combined heat and power applications. By raising its operating temperature, the fuel cell could also support heating and cooling loads as well as provide electricity. High temperature membranes will give the fuel cell power plant system a high overall efficiency of 70-80%.

Improved water and thermal management are keys to efficient fuel cell operation. The fuel cell generates water, but both the fuel and air entering the fuel cell must be humidified; in addition the polymer electrolyte membrane must be hydrated. If it is not ideally hydrated, the membrane does not conduct the hydrogen ions well and electric output drops. To combat this problem, water and heat transport models should be developed on the membrane level and then synthesized for the stack level. This would result in an analytical tool that researchers and manufacturers could use to effectively model water and thermal management. Alternately, research could be conducted on different stack materials to reduce the need for water and thermal management systems.

Development of lower cost, higher activity, and increased impurity- tolerant electro-catalysts is necessary for fuel cells to be competitive, operating off the current fueling infrastructure. Platinum is currently the best catalyst for the PEMFC, but it is very expensive and sensitive to impurities in the fuel stream (CO, S, NH3). The anode catalyst needs to have an increased tolerance to impurities, while the cathode catalyst needs to stimulate more activity. Lowering the loading levels of the platinum catalyst would greatly reduce the cost of fuel cell systems. Table 3.0 illustrates the targets for tolerance to sulfur and carbon monoxide (CO) as well as targets for decreasing stoic and platinum (Pt) loading levels. Development of non-precious, high tolerant material catalysts would be a revolutionary breakthrough for low cost, fuel flexible fuel cell systems.

A life cycle cost test/model should be designed to document the durability and lifetimes of the fuel the cell systems, as well as to predict system performance. This process would be based on the “model, modify, verify” loop. The industry could adopt the FMEA (Failure Mode Effects Analysis) process, which is a pro-active engineering- quality testing method that helps identify and counter weak points in the early conception phase of product and process testing and validation.

The solid oxide fuel cell (SOFC) offers another fuel cell type for building applications. The SOFC operates at a much higher temperature then the PEMFC and is less sensitive to impurities from hydrogen- rich fuel. Developing an R&D program to lower operating temperatures, reduce materials costs, and increase power density will make the SOFC a viable energy solution for buildings.

Table 3.0 Tolerance Targets for the Anode and Cathode

Anode		**Cathode**	
2003		**2003**	
Sulfur	10 ppb	Stoiciometry	1.5
CO	20 ppm	OP	.6V
Stoiciometry	1.2	**2005**	
Pt-Loading	.2 mg/cm^2	Stoiciometry	1.35
2005		OP	.5V
Sulfur	.5 ppm	**2012**	
CO	200 ppm	Stoiciometry	1.2
Stoiciometry	1.15	OP	.3V
Pt- Loading	.15		
2012			
Sulfur	1 ppm		
CO	500 ppm		
Stoiciometry	1.1		
Pt-Loading	.1		

TABLE 3-1. KEY ACTIONS- MATERIALS

Fundamental Research (Chemistry/Physics)	Applied Research	Development	Analysis	Other
• Tolerance to impurities – CO Tolerant anode catalyst • Develop improved understanding of membrane degradation mechanisms • Higher electrical performance catalysts • Water transport models for advanced materials • Develop and verify models for electroclyte/GDL/catalyst interaction • Longer-life reformer catalysts	• Develop more efficient and lower cost catalysts • Develop improved membranes for high temperature operations (120-150ºC) • Develop improved bi-polar plates • Develop improved techniques for water and thermal management	• Develop advanced materials and designs for mass production and cost reductions • Develop lower temperature firing and operating ceramic layers (SOFC) • Develop, design, and test skid test bed for CHP	• Re-assess CHP requirements versus fuel cell technology • Develop life cycle cost model and use to evaluate materials and fuel cells designs – Test methods for durability and lifetimes – Life prediction methods – Document durability and reliability – Identify failure modes	• R&D in reformers working with various fuels • Include water management with heat and power in CHP systems

TABLE 3-2. ACTION PLANS - MATERIALS

Actions	Scope	Tasks/ Deliverables	Start and End Dates	Linkages	Lead and Supporting Organizations	Immediate Next Steps
• Techniques for water and thermal management • Models for water transport in advanced material	• R&D of stack materials /design to reduce need for thermal /water management subsystems	• Membrane-level water/ heat transport models • Stack-level water/ heat transport models • Develop prototype materials/designs • Bench-scale model validation experiments	• Models- year 1 • Prototypes – year 2 • Validation- year 3 • Integration- year 4-5	• Fuel Cell Components and Systems – Water and thermal management subsystems	• Models- Business, government, universities • Prototypes- Business, government • Validation- government, universities	• Program Plan • Partnerships – Roles – Funding
• Models for electrolyte, GDL, catalyst interactions	• Long-term research	• University - Training and Education "Center of Excellence" • National Labs- Collaboration • Industry- Evaluation, guidance, wants • Deliverable- Verified, useful models	• Start now and continue throughout program life		• Lead- Academia • Supporting- National labs and industry	• Identify problem areas • Establish national program
• Understand and remedy membrane (MEA) degradation mechanisms	• Analysis of membranes and catalysts, all contribute, assess life expectancy	• Assess envelop materials properties for modeling • Adequate life membranes with predictive performance economics • Real-time, broad-spectrum sub- ppm, impurity sensor	• Now- 2004	• Materials development companies – i.e. Dupont	• Industry provides criteria • DOE funds universities and labs • Industry funds own work • Government provides lab and p???	• Setup virtual lab test systems
• Membranes for high temperature operation	• Ionic transfer models • Materials development	• Material synthesis • Evaluation of materials • Fabricate	• Materials- 1 years • Membrane- 2-3 years	• PEM development projects in transportation and buildings	• National Labs, industry, government	• Fund program/initial study

Actions	Scope	Tasks/ Deliverables	Start and End Dates	Linkages	Lead and Supporting Organizations	Immediate Next Steps
	• Integrate into stack with test	membrane • Evaluate membrane • Integrate with stack • Deliverable- workable membrane of 170-200		• Space vehicles		
• More efficient and lower cost catalysts • Impurity tolerant materials – E.g. co-tolerant catalysts • Higher electrical performance catalysts – Cathode electrochemistry cover potential	• Develop lower cost, higher activity, increased impurity tolerant electro catalysts	• Anode catalysts with increased tolerance to impurities (CO, S, NH3) • Cathode catalysts with increased activity • Non-precious metal catalysts • Deliverables (Anode) – Sulfur 10 ppb – CO 20 – Stoic 1.2 – Pt-loading .2 – Sulfur .5 ppm – CO 200 – Stoic 1.15 – Pt-loading .15 – Sulfur 1 ppm – CO 500 – Stoic 1.1 – Pt-loading .1 • Deliverables (cathode) – Stoic 1.5 – OP .6V – Stoic 1.35 – OP .5V – Stoic 1.2 – OP .3V	• 2003 • 2005 • 2012 • 2003 • 2005 • 2012	• FreedomCAR • DARPA • ONR	• Lead: National labs • Supporting: Universities and Industry	• Develop RFP
• Develop packaging alloys compatible	• Life cycle package issues	• Interface with stack producers	• Start immediately	• Maintain a frictionless feedback	• Oak Ridge and other National labs	•

Actions	Scope	Tasks/ Deliverables	Start and End Dates	Linkages	Lead and Supporting Organizations	Immediate Next Steps
with lifecycle expectations of balance of fuel cell • SOFC – Lower operating temp – Pychloric formation – Lower cost processes to produce materials – Increased power density	• Gas composition and as to composition • Temp range, cycling • Humidity • WT./Thickness limitations • Cost expectations • Material compatibility			loop with industrial teams	• 4 industrial teams • EU participants • Other entrepreneurial developers	
• Life-cycle cost testing/ modeling – Predictions – Durability – Life times – Document results	• Set up “model, modify, verify” loop	• Adopt FMEA process • Establish performance/ durability test standards – SAE for transportation • Establish standard materials characterization methods • Correlate real-time w/ accelerated life tests (critical to FMEA • Iterate between test results and models • Compare/verify model assumptions and accuracy • Institute material changes (from model) and verify with standard test bed (cost and performance)	• Now – 2008	• SECA • ATP • Auto (SAE, Industry) • Standards organizations	• DOE • National labs • Universities • Industry • DOD, HUD	• Convene workshop on modeling methods, characterizations, and measurement techniques to determine scope of work

Components and Subsystems

4.0 Introduction

The components and subsystems group discussed methods for improving fuel cell performance and reducing system costs. Fuel processing issues and opportunities were also discussed, as was research, development, and demonstration actions that should be taken to achieve the fuel cell vision.

PEM fuel cells ideally operate on pure hydrogen, since processed hydrogen contains sulfur and CO that can hinder fuel cell performance. Until hydrogen becomes a mainstream fuel, fuel cells need to operate cost effectively on various fuels (e.g. natural gas, #2 oil, diesel fuel, etc.)

The components and subsystems group organized the key actions into four categories:

- Research and Development on subsystems
- Fuel Processing
- Analysis
- Demonstrations

A complete list of actions is shown in Table 4-1. The complete action plans for the top priority actions is displayed in Table 4-2.

Participants: Components and Subsystems Breakout Group

NAME	ORGANIZATION
Graydon Whidden	Catalytica Energy
Brian Engleman	Catalytica Energy
Doug Wheeler	UTC Fuel Cells
Fred Kemp	CTC
Sean Field	Naval Air Systems Command
Stanley Chen	U.S. Department of Energy
Greg Jackson	DCH Enable
John Turner	National Renewable Energy Laboratory
Nick Josefik	CERL
Doyle Miller	MesoFuel
Ravi Kumar	GE Power Systems
Conghua Wang	Sarnoff
Tom Butcher	Brookhaven National Laboratory
Allan Williams	Georgia Tech
Patrick Davis	U.S Department of Energy
Wayne Surdoval	National Energy Technology Laboratory
Pinakin Patel	FuelCell Energy
Marla Perez-Davis	NASA Glen Research Center
Jill Jonkouski	U.S. Department of Energy
Jennifer Schafer	Plug Power

Facilitator: Dan Brewer, Energetics, Incorporated

4.1 Action Plans

A top research and development priority, therefore, is development of a low cost, fuel flexible fuel processor for a 50 kilowatt fuel cell. Development of this processor will lead to defined performance and cost targets for fuel cell components (catalyst and heat exchangers) as well as the entire processor. Successful development of a fuel processor will also demonstrate its commercial potential.

Creating an RD&D program to remove sulfur from the fuel stream is critical to producing an effective hydrogen- rich gas. The first step in this process is to compare different options for sulfur removal. These options include liquid or gaseous sulfur removal in the fuel cell power plant or removal of sulfur at the beginning of the fuel stream. For example, sulfur is added to natural gas as an odorant for safety; developing alternative odorants can remove sulfur from the natural gas fuel stream. The fuel cells for buildings industry should consider incorporating the Department of Defense's success in reforming liquid fuels for military applications.

A comprehensive RD&D program on fuel cell life should be designed to allow researchers and manufacturers to understand the inhibitors of a long- lasting fuel cell. A matrix that links water and thermal management issues to membrane degradation would help clarify membrane degradation problems and solutions. Research should also be pursued on processed hydrogen fuel lifetimes, reliability, efficiency, and cost. These linkages would guide researchers on the substances that need to be removed from the fuel stream. A national research laboratory could work with manufacturers on identifying stack and critical system component failure mechanisms, among other issues.

An RD&D program to reduce costs and integrate systems would aid the commercialization of the PEMFC. Such a program would consist of three phases, each lasting three years in duration. The first phase would identify integration options for the system, resulting in an exhaustive list of viable options for system integration. The second phase would involve performance of a cost benefit analysis on each of the options. Finally, the best options from the cost benefit analysis would be verified through system testing. The result would be a "Best Practices Guide" for manufacturers to use in reducing costs.

The phosphoric acid fuel cell (PAFC) has been installed in buildings across the nation. Fuel cell and building designers and construction managers have already tackled many of the challenges that lie ahead for the fuel cell for buildings industry. By gathering data and reviewing experiences of PAFCs in building applications, the fuel cell industry can build upon, and not repeat, work that has already be done.

Demonstrations of fuel cell projects managed by early adopters (government, premium power applications, and universities) will show off the benefits of using fuel cells for on-site power generation. These demonstration projects would include interactive controls to anticipate and manage load swings, reformers with CO2 sequestration, and combined heat and power (CHP) applications for low-temperature PEM.

TABLE 4-1. KEY ACTIONS- COMPONENTS AND SUBSYSTEMS

◆ = VOTE FOR PRIORITY TOPIC

Research and Development on subsystems	Fuel Processing	Analysis	Demonstrations	Other
• Develop R&D program initiative to reduce costs and integrate systems ◆◆◆◆◆◆◆◆◆ • Water management – Reformer – PEM ◆◆◆◆ • How to deal with H2 recycle in the fuel cell system ◆◆ • R&D on PEM membrane especially high temperature PEM ◆ • Development of low cost, highly reliable air management systems – Air cleanup – O2 concentration ◆ • Develop efficient power conditioning systems ◆ • Development of fuel cell specific sensors for stack and reformer operation • Develop test procedure to determine seasonal system performance	• Low cost, fuel flexible, fuel processor – Natural gas – #2 oil – diesel fuel ◆◆◆◆◆◆◆◆◆◆ • Purity of Hydrogen- effects lifetime, reliability, and efficiency and cost ◆◆◆◆◆◆ • Develop test to characterize and analyze fuel options ◆◆ • Low cost sulfur removal ◆◆ • Novel, low cost processes for H2 separation membranes ◆ • Low cost heat exchangers in reformers • Long -lasting catalyst compatible with fuel cell materials and fuel processing • R&D on pressurized fuels	• Begin a comprehensive program on fuel cell life ◆◆◆◆◆◆◆◆◆◆ • Determine optimized system arrangements using combinations of technologies- e.g. fuel cell combinations, energy storage, fuels. ◆◆◆ • Establish clear performance characteristics for consistent evaluation of fuel cells ◆◆ • Develop standardized non-proprietary models of integrated systems/subsystems ◆ • Economic analysis on fuels ◆ • Feasibility of CO2 sequestration • Thermal integration and management • Define standard fuel cell safety system	• Develop large scale demo program for stationary fuel cell systems – Reformers and CO2 sequestration ◆◆◆◆◆◆◆◆◆ • Controls to anticipate and mange load swings ◆◆	• Use and build on PAFC building history ◆◆◆◆ • Develop reliability standards ◆◆ • Interconnect standards for heat utilization ◆ • Exploit synergy with high temperature fuel cells for early market entry ◆ • Work on “rules of the road” for utilities and others to site fuel cell systems ◆ • Leverage DoD work in power conditioning and fuel processing • Initiate national design competition for fuel cell based building systems

TABLE 4-2. ACTION PLANS- COMPONENTS AND SUBSYSTEMS

Action	Scope	Tasks	Start and End Dates	Linkages with other programs	Lead and Support Organizations	Immediate Next Steps
• Low cost, fuel flexible, fuel processor (50 kW FC) – Natural gas – #2 Oil – Gasoline	• Development and demonstration of prototype hardware with commercial potential	• Reformer component integration costs • Liquid fuel processing • Mass manufacturing • Catalysts and heat exchanger costs • Efficiency and O&M costs	• 2003-2006 • 2003-2006 • 2006-2010 • 2003-2004 • 2003-2008	• SECA • IEA • DOE- Hydrogen and Transportation programs • National labs • State agencies • DOD- Reforming of liquid fuels	• DOE • DOD	• Define targets for performance/costs • RFP
• RD&D on sulfur removal	• Develop liquid or gaseous sulfur removal	• Alternative odorants for natural gas • System study comparing options for sulfur • Define cost targets • Sorbent replacement targets • Understand fuel cell degradation	• 2003-2004 • 2003-2004 • 2003-2004 • 2003-2004 • 2003-2006	• SECA • IEA • DOE- Hydrogen and Transportation programs • National labs • State agencies • DOD- Reforming of liquid fuels	• Industry • National Labs • Universities	• System study comparing options
• Begin a comprehensive program on fuel cell life	• Membrane failure mechanism	• Set up national lab user facility to work on stack and critical system components		• Link water management and membrane life (impurities/ water recovery)	• Fuel cell companies • DOE • National Labs	
• R&D on water management	• Analysis of water/ humidity issues: stack, reformer, building needs- with analytical tool	• Develop analytical tool			• DOE • Industry	• Run solicitation
• Develop R&D program to reduce costs and integrate systems	• Identify and explore opportunities for cost reduction	• List integration options • Cost/Benefit analysis • Select and verify	• 3 phases of 3 year duration	• CERL- DOD/Army • Other energy generation ventures • Stimulate volume production	• DOE/State agencies • DOD/Industry/ EPA	• Get money
• Use and build on PAFC – Building history	• Review experience of PAFC in building and apply to PEM	• Gather data • Review DOE/Army/CERL	• 10/02-10/03 • 10/02-10/03	• SECA program • Fossil energy program	• DOE/EERE (lead) • DOE/ Fossil energy • DOD Army CERL	• Get funding • Contact correct people

Action	Scope	Tasks	Start and End Dates	Linkages with other programs	Lead and Support Organizations	Immediate Next Steps
	effort	program • Lessons learned on PAFC- cost and performance • Relate results to PEM development	• 3/03-3/04 • 3/04-6/04		• Industry support	
• Large scale demonstration program for stationary fuel cell systems – Reformers and CO2 sequestration	• Multiple demos managed by early adaptors	• Install multiple units in early adaptors – Government – Premium power – Universities at power levels 1. 100 – 200 kW 2. 5 – 10 kW • Demonstrate controls to anticipate and manage load swings • Demonstrate CHP for low temperature PEM	• 4Q/03 – 2010	• DOD • DOE Transportation and power parks • Demo- multiple fuels	• DOE (lead) • Manufacturers • Universities • National labs • Industry • Government	

Building Infrastructure

5.0 Introduction

Participants in the Fuel Cell Building Infrastructure group discussed a number of key actions that need to be taken to achieve the vision for fuel cells as used in buildings and stationary applications. The group represented diverse interests, including architecture and engineering, fuel cell manufacturers and system designers, state and federal government, national research laboratories, fuel cell advocates and associations, and utilities.

Because of the group's diverse interests and expertise, action plans spanned the many technical, institutional, policy, and education challenges facing commercial application of fuel cell technology in buildings and stationary applications. Key actions were discussed in the areas of:

- Marketing
- Policy Initiatives
- Demonstrations
- Integration Technology: Components and Products
- Education, Training, and Outreach
- Codes and Standards

A complete picture of these actions is displayed in Table 5-1. Table 5-2 illustrates the specific action plans for the top priority actions.

Participants: Building Infrastructure Breakout Group

NAME	ORGANIZATION
Syed Faruq Ahmed	Burt Hill Kosar Rittelmann
Sunil Cherian	Sixth Dimension
Mark Davis	NIST
Mario Farrugia	NEDO
Jose Figueroa	NETL
Bernadette Geyer	U.S. Fuel Cell Council
Shawn Herrera	U.S. DOE
Steve Hortin	U.S. DOE- Atlanta Regional Office
Keith Kline	ORNL
Anita Liang	NASA Glenn Research Center
Eric Lightner	U.S. DOE
Joseph Pierre	Siemens Westinghouse
Kristen Rannels	Sentech
Terres Ronneberg	Capital E
Walter Runte	Gas Technology Institute
Larry Simpson	Connected Energy
David Sutula	Gas Appliances Manufacturing Association
Richard Sweetser	Exergy Partners
Paul Wang	Concurrent Technologies
Sam Wong	M.C. Dean
Mary Rose de Valladares	DCH Technology

Facilitator: Jan Brinch, Energetics, Incorporated

5.1 Action Plans

The top priority action that needs to take place is development of a series of demonstration projects of fuel cells in actual building environments. Building sectors that would be most appropriate for such demonstration projects include universities and federal facilities, including defense sites. The demonstration projects would be designed to showcase not only the technology, but the economic viability of fuel cells in buildings, as well as the manner in which fuel cells can be integrated with other energy options (e.g., solar, CHP) in distributed applications. Demonstration projects utilizing existing fuel cell technologies should be initiated in the short to medium time range; advanced fuel cell technologies should be showcased further into the future.

There are numerous other programs, in both the public and private sectors, with which this fuel cell demonstration program should be integrated, including the DOE Climate Change Program, the EPA Environmental Technology Verification Program, the Distributed Energy Resources program, Rebuild America, etc. Many organizations would be interested in participating, including EPA, the Gas Technology Institute, the National Hydrogen Association, etc. The first steps in designing a demonstration program are to find a "champion" for such an activity, engage fuel cell manufacturers, and develop a budgeted line-item in the federal budget for cost-shared funding.

Education, training, and outreach needs to be conducted as well; in fact, demonstration projects provide a natural venue for such activity. This effort needs to include public outreach; state and local government official training; technician training; short term utility education programs; education, training, and certifications programs for tradespersons, including finance, insurance, and real estate professionals; training for building designers, operators, and managers through professional organizations, including the American Institute of Architects, ASHRAE, the building code organizations, etc.; and educational programs for teachers and students in grades K-12, as well as college and post graduate students. An assessment of existing educational materials must be conducted first, and additional materials then developed to "fit" each of these groups, including case studies, technical and policy materials, and market studies. Numerous other programs and organizations should be brought into this process, including the National Association of Technical Colleges, professional organizations such as IEEE, American Chemical Society, the National Institute of Standards and Technology, the National Science Foundation, etc.

In the policy arena, effort needs to be made to develop a legislative and regulatory climate that allows generation of energy on-site using fuel cells and allows integration with the grid. State regulatory commissions should be encouraged to open retail energy markets that support net metering and interconnection opportunities for fuel cell powered buildings. Incentives for fuel cell use in new real estate developments should also be considered, in much the same way as new all-gas or electric developments receive hook-up incentives. Policy changes are long-term, but should begin as soon as possible, and involve many organizations, including IEEE, the Federal Energy Regulatory Commission, the National Association of State Energy Officials, the National Association of Regulatory Utility Commissions, and others. The first step in this process is to clearly articulate the issues of concern, and identify a public-private coalition of organizations and institutions to support these issues.

Demonstration projects, education and outreach programs, and policy initiatives must be combined with market and cost-benefit data gathering and analysis. Baseline fuel cell operation and performance data from buildings and stationary applications can then be compared with operational data collected on-site, to show real-world performance. Once credible data is obtained, market research can be conducted and used to generate commercial interest in fuel cells for this buildings sector. An inventory of existing sites should be conducted to develop a database and to characterize fuel cell technology and markets at these sites. This is a short to mid term activity, one that coordinates well with other market assessment activities underway at the national laboratories. The first step in taking action on this issue is to request that all federally-funded technology characterizations include fuel cells.

Other key actions involve development of building codes and standards that include fuel cell components and systems, so that buildings utilizing this technology can be permitted and built in a timely fashion. Existing fire, safety, and construction codes need to be updated, and officials educated as soon as possible, with the assistance of the national code organizations, mechanical and electrical professional associations, and fuel cell trade associations, such as the U.S. Fuel Cell Council.

Development of a building infrastructure that utilizes fuel cells in both the near and far term will require attention to all of these actions, as well as to the materials, and component and systems actions identified above. Research, development, and demonstration are required to move fuel cell components and systems out of the laboratory and into buildings and stationary applications. The U.S. Department of Energy, in partnership with both other public as well as private and non-profit stakeholders, is at the forefront of this effort. The actions identified at the Fuel Cells for Buildings and Stationary Applications will, if implemented, provide the impetus needed

TABLE 5-1. KEY ACTIONS- BUILDING INFRASTRUCTURE

◆ = VOTE FOR PRIORITY TOPIC

MARKETING	POLICY INITIATIVES	DEMONSTRATIONS	INTEGRATION TECHNOLOGY: COMPONENTS AND PRODUCTS	EDUCATION, TRAINING, AND OUTREACH	CODES AND STANDARDS
• Market baseline data for fuel cells ♦♦♦♦♦♦♦♦ – Develop value propositions that will lead to commercial success in the future – Set up data base to show fuel cell performance, operation and maintenance cost data for building operators • Identify early building systems applications – Mission critical architecture – Biomedical research – Air quality stressed areas ♦♦♦♦♦♦♦ • Develop commercialization strategies ♦♦♦♦♦♦ – Design and build fuel cell systems on GSA buildings • Build a transparent performance/maintenance information system ♦ – Ease third party finance and insurance • Create a database of government facility CHP	• Work towards a legislative/regulatory climate that accepts fuel cells in buildings integrated with the grid ♦♦♦♦♦♦♦♦♦ – Encourage state PUCs to open retail energy markets – Work toard passage of net metering and interconnection bills in all states – Support "President's" cap and trade monitoring emissions cost – Create incentives for fuel cell use in new real estate developments, including pre-certification of fuel cells – Require companies to include value of FCS as part of their least-cost planning • Define/create incentives for early adopters ♦♦♦♦♦♦♦ • Federal and state • Quantify and value all benefits ♦♦♦♦♦♦ – Environmental – Non-energy – Public policy goals,	• Gain exposure through demonstration building projects ♦♦♦♦♦♦♦♦♦♦♦♦ – Conduct university fuel cell building projects/contests – Demonstrate projects in federal facilities (FEMP network) – Demonstrate economic viability of fuel switching – Apply "lessons" from CERL-DOD and DOE (passive solar, A/E activities) – Facilitate/demonstrate procedure for building partners to access $$ – Demonstrate dispatchable buildings – Install fuel cell system at the White House – Perform R&D on integrated H_2 parks for stationary/building applications – Participate in international demonstrations–use IEA, EIHP • Demonstrations fuel projects ♦♦ – Demonstration fuel projects H_2 – Reformate gas, liquid	• Develop "command and control" systems for the operation of fuel cells in buildings including interaction with the grid ♦♦♦♦♦♦ • Survey experiences of PAFC installations on building integration issues ♦ • Design buildings with integrated fuel cell systems – Design economies can result – Building performance improves – Helps environment • Develop and publicize interconnect specifications (both physical and C&C) between gensets and heating/cooling equipment	• Develop an education program that includes ♦♦♦♦♦♦♦♦♦♦♦ – Public outreach – State and local government official education – Technician training – Short term utility programs – Efforts to allay fears about H_2 – Education for trades (finance, insurance, real estate – Related work – Educational materials: case studies and outreach materials – Economic incentives for fuel cell industry – EC/EZ, EDA infrastructure, Brownfields – Efforts to draw building owners into the process – Educational tours of fuel cell installations (4 Times Square has fuel cells open to public view) – FEMP technology verifications and reports on fuel cells – Market fuel cell potential – Introduce design/build/operate concept to building	• Develop codes and standards for fuel cell use in buildings ♦♦♦♦♦♦♦ – Address safety issues/develop applicable – Develop test process and rating methodology allowing consumers to make economic decisions – Train local code enforcement officials – Differentiate end use for codes and standards development

MARKETING	POLICY INITIATIVES	DEMONSTRATIONS	INTEGRATION TECHNOLOGY: COMPONENTS AND PRODUCTS	EDUCATION , TRAINING, AND OUTREACH	CODES AND STANDARDS
needs and applications	e.g., CAA, EPACT			owners and developers	
• Target demand for the production capacity developed/developing – Conduct market study – Design financing schemes – Create utility/supplier incentives – Target specific buildings (e.g., office, hospitals, etc.) – Consolidate information on FC systems available for building demonstration projects – Conduct survey of builders for incentives and barriers to using fuel cells	• Work toward national legislation exempting certified fuel cells from air permits (following California actions) ♦♦ – Foster "H_2 economy" culture at the consumer level through tax relief for trendsetters and trail blazers • Support empowerment of public/private partnerships to educate and promote fuel cells in buildings – Include policy/ appropriations component in partnership			– Facilitate teacher/ educator training and distribution of educational materials – Institute a student contest program in building designs to incorporate fuel cells as a primary source of energy for buildings – Establish college/graduate level curricula in fuel cell technology/engineering – Educate/work with building design professionals through their organizations (AIA/ASHRAE, APPA, BOMA, etc.) – Inventory existing information/ materials • Develop training and certification program for technicians and operators ♦♦♦♦♦ • Spark popular imagination—paint a compelling picture of what success looks like ♦ • Implement weekly news reports on fuel cells	

TABLE 5-2. ACTION PLANS- BUILDING INFRASTRUCTURE

ACTION DESCRIPTION	KEY DELIVERABLES	START AND END DATES SHORT-TERM—2005 MID-TERM—2005-2010 LONG-TERM—2010-2020	LINKAGES WITH OTHER ACTIONS/PROGRAMS	LEAD AND SUPPORT ORGANIZATIONS	IMMEDIATE NEXT STEPS
• Gain exposure through demonstration projects	• Identify buildings/fuel cell concepts • Identify applications • Funding plan • Lessons learned • Apply to mainstream communications strategy	• S-M: Existing technology • L: Advanced Technology	• NEP • Garman priorities • DOE Climate Change Program • EPA Environmental Technology verification program • DER • FEMP • FE • Rebuild America • SEP • Buildings program • State renewable energy funds	• Public-private partnerships • DOE • DOD • SENG • EPA • DPCA • GTI • PTI • Hydro/FC • FEMP • NAHB • NHA • AIA • NRECA • BTS	• Find champion • Collaborative by 9/02 • Engage manufacturers/ private sector • Identify applications and sites • RFP process • Develop technology transfer plan with lessons learned
• Conduct Education, training and outreach program	• Inventory existing assets • Plan for targeted education • Success stories—lessons learned • Integrated education and outreach program	• S-M-L • ASHRAE Class • Ongoing certification	• Assoc of physical plant admin • See above • National Association of Tech Colleges • Professional organizations (IEEE) AmChem, NIST, NSTA) • FEMP training schools • University courses • NSF • National Labs • AIA • Engineering schools	• FC advocates • FC power association (FCPA) • US FCC • ABET (Accred Board for Engineering Technology) • Houston technology center – Austin group • "Incubators" focus on energy	• Participate in NHA coalition building • Explore involvement of DOE/Biz group (John Sullivan) – marketing/outreach
• Undertake legislative and regulatory actions	• Utility interconnection standards • Congressional work • Incentives	• S-M-L • ASAP	• Reauthorize CAA • Federal and state agencies	• Regional NEMW; NESCOM • IEEE • FERC • NASEO • EPA • Air quality management districts	• Identify the message • Identify the carriers • Identify and respond to current Hill activity, "situation assessment" • Develop public-private lobby coalition

ACTION DESCRIPTION	KEY DELIVERABLES	START AND END DATES SHORT-TERM—2005 MID-TERM—2005-2010 LONG-TERM—2010-2020	LINKAGES WITH OTHER ACTIONS/PROGRAMS	LEAD AND SUPPORT ORGANIZATIONS	IMMEDIATE NEXT STEPS
				• NARUC • All trade associations • IEC • NRECA • STAPPA • ALAPCO	
• Market base line for fuel cells–value of non-economic benefits	• “Models” • Inventory of existing sites • Database • Characterize technology and markets	• Short-term • By 2005	• All organizations	• Market research organizations • NREL - Market conditions • ORNL – Market conditions at federal facilities	• Ask DOE to add fuel cells to technology characterizations • Bring in USFCC and others
• Codes and standards for fuel cells in buildings	• Update codes • Educate officials • Educate our own people (Capitol Hill) Industry outreach	• Short-term • Ongoing	• ANSI, CSA • IEEE • ASME • IEC • NFPA • UL USFCC • NIST	• USFCC • PNNL • PTI • National labs • NES	• Come to fuel cell summit (USFCC working group on codes and standards)
• Targeted marketing and outreach	• Identify early adopters • Share information • Create incentives • Design assistance • Public relations plan	• Short-term	• CA self generation incentive • DOD climate change “buy down” • Regulatory commission public goods programs • State incentives for renewables • State environmental programs	• AIA • ASME • IEEE • ASHRAE	• Monitor Interconnect standards developed–IEEE • Identify lab support
• Develop command and control systems for fuel cells in buildings	• Develop open protocols • Develop standard architecture • Survey existing architect	• Short- and Medium-term	• DER communications and controls equipment/systems • Bandwidth R&D	• DOE-DER	• Track DOE efforts • Support budget

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