Fuel Cell Operation at Sub-Freezing Temperatures

DOE Program/Targets and Workshop Objectives

Nancy Garland
DOE Hydrogen Program

Sub-Freezing Temperature Effects on Fuel Cells
Workshop
Phoenix AZ
February 1-2, 2005
Outline

- Hydrogen Fuel Initiative

- The Hydrogen, Fuel Cells, and Infrastructure Technologies Program

- Technical Targets

- DOE Fuel Cell & Hydrogen Activities

- Workshop Objectives
Hydrogen Fuel Initiative

- Presidential Initiative commits $1.7 Billion over 5 years
  - $1.2 Billion for hydrogen and fuel cells (Million in new money)
  - $0.5 Billion for hybrid and vehicle technologies
- Enables commercialization decision by 2015
- Fuel cell vehicles in showroom and hydrogen at fuel stations by 2020
The program’s mission is to research, develop, and validate fuel cell and hydrogen production, delivery, and storage technologies for transportation and stationary applications.

The program aims to have hydrogen from diverse domestic resources used in a clean, safe, reliable, and affordable manner in fuel cell vehicles, centralized power stations, and distributed combined heat and power applications.
## DOE Hydrogen Program Budget

### MAJOR LINE ITEMS

<table>
<thead>
<tr>
<th></th>
<th>FY 04 Appropriations ($000)</th>
<th>FY 05 Request ($000)</th>
<th>FY 05 Appropriations* ($000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production &amp; Delivery R&amp;D (EE)</td>
<td>$22,564</td>
<td>$25,325</td>
<td>$14,363</td>
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<tr>
<td>Storage R&amp;D (EE)</td>
<td>$29,432</td>
<td>$30,000</td>
<td>$23,830</td>
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<tr>
<td>Safety, Codes &amp; Standards, and Utilization (EE)</td>
<td>$5,904</td>
<td>$18,000</td>
<td>$6,061</td>
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<tr>
<td>Infrastructure Validation (EE)</td>
<td>$18,379</td>
<td>$15,000</td>
<td>$9,573</td>
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<tr>
<td>Systems Analysis (EE)</td>
<td>$5,712</td>
<td>$7,000</td>
<td>$3,444</td>
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<tr>
<td>Earmarks (EE)</td>
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<td></td>
<td>$37,301</td>
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### EERE Hydrogen Technology Subtotal– (EWD)

<table>
<thead>
<tr>
<th></th>
<th>$81,991</th>
<th>$95,325</th>
<th>$94,572</th>
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<tr>
<td>NE Hydrogen Subtotal – (EWD)</td>
<td>$6,400</td>
<td>$9,000</td>
<td>$8,929</td>
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<tr>
<td>FE Hydrogen Subtotal – (Interior)</td>
<td>$4,900</td>
<td>$16,000</td>
<td>$17,085</td>
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<tr>
<td>SC – (EWD)</td>
<td>$0**</td>
<td>$29,200</td>
<td>$29,183</td>
</tr>
<tr>
<td>DOT</td>
<td></td>
<td></td>
<td>$544</td>
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</table>

### Hydrogen Technology Total

|                                    | $93,791                       | $149,525             | $150,525                    |

* Subject to approval; includes $37M of earmarked projects. Eliminates education.
**Excludes $8M of baseline activities not counted as part of initiative
## DOE PEM Fuel Cell Program Budget

<table>
<thead>
<tr>
<th>KEY ACTIVITY</th>
<th>FY 04 Appropriations ($000)</th>
<th>FY 05 Request ($000)</th>
<th>FY 05 Appropriations ($000)</th>
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</thead>
<tbody>
<tr>
<td>Transportation Systems</td>
<td>$7,506</td>
<td>$7,600</td>
<td>$7,495</td>
</tr>
<tr>
<td>Distributed Energy Systems</td>
<td>$7,408</td>
<td>$7,500</td>
<td>$6,902</td>
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<tr>
<td>Fuel Processor R&amp;D</td>
<td>$14,815</td>
<td>$13,858</td>
<td>$9,721</td>
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<tr>
<td>Stack Component R&amp;D</td>
<td>$25,186</td>
<td>$30,000</td>
<td>$32,541</td>
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<tr>
<td>Technology Validation</td>
<td>$9,877</td>
<td>$18,000</td>
<td>$17,750</td>
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<tr>
<td>Technical Prog. Mgmt. Support</td>
<td>$395</td>
<td>$542</td>
<td>$535</td>
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| Fuel Cell Technology Total   | $65,187                      | $77,500              | $74,944                     |
FY 05 EERE Fuel Cell Activities

Fuel Processor R&D $9,721K
- LPG or propane fuel processing technology for stationary applications
- Fuel processor catalysts

Distributed Energy Systems $6,902K
- High efficiency PEMFC power systems as an alternative to grid-based electricity for buildings

Transportation Systems $7,495K
- System analysis
- System sensors
- Compact humidifiers/heat exchangers
- Auxiliary power in trucks
- Portable power applications
- Full scale compressors

Stack Component R&D $32,541K
- Membranes that operate at high temperature and low RH, with lower cost and improved durability and tolerance to feed gas impurities
- Improved understanding of proton conduction and membrane degradation
  - Cost reduction using non-precious metal catalysts and ultra-low platinum loading

Technical/Program Management Support $535K
- Program, strategic & operating plans

Technology Validation $17,750K
- First and second generation fuel cell vehicles
- Validate performance and durability of fuel cell systems
DOE Hydrogen, Fuel Cells and Infrastructure Technologies Program Staff

Steve Chalk, Program Manager
JoAnn Milliken – Chief Engineer
Fred Joseck – Technology Analyst
Lindsay Roland (On detail) – Policy/Int'l Support

Technology Validation Manager - Sigmund Gronich
Education - Christy Cooper
Safety, Codes/Standards - Patrick Davis
Safety Engineer – Antonio Ruiz

Hydrogen Production Team
Pete Devlin, Team Leader
Arlene Anderson
Chris Bordeaux
(detailed to IP)
Roxanne Danz
Matt Kauffffman
Mark Paster

Hydrogen Storage Team
Sunita Satyapal, Team Leader
Tony Bouza
John Petrovic (LANL)
Carole Read

Fuel Cell Team
Valri Lightner, Team Leader
Kathi Epping
John Garbak
Nancy Garland
Donna Ho
Amy Manheim
### Technical Targets: 80-kW<sub>e</sub> (net) Integrated Transportation Fuel Cell Power Systems Operating on Direct Hydrogen

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Units</th>
<th>2004 Status</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
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<tbody>
<tr>
<td>Energy efficiency @ 25% rated power</td>
<td>%</td>
<td>59</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Energy efficiency @ rated power</td>
<td>%</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Power density</td>
<td>W/L</td>
<td>450</td>
<td>500</td>
<td>650</td>
<td>650</td>
</tr>
<tr>
<td>Specific power</td>
<td>W/kg</td>
<td>420</td>
<td>500</td>
<td>650</td>
<td>650</td>
</tr>
<tr>
<td>Cost</td>
<td>$/kW&lt;sub&gt;e&lt;/sub&gt;</td>
<td>120</td>
<td>125</td>
<td>45</td>
<td>30</td>
</tr>
<tr>
<td>Transient response (time from 10% to 90% rated power)</td>
<td>s</td>
<td>&lt;1.5</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Durability</td>
<td>hours</td>
<td>~1000</td>
<td>2000</td>
<td>5000</td>
<td>5000</td>
</tr>
</tbody>
</table>

**Cold start-up time to 90% rated power**
- @ -20°C ambient temperature: s 120 60 30 30
- @ +20°C ambient temperature: s 60 30 15 15

**Survivability**
- °C: -20 -30 -40 -40
Financial Assistance Awards: over $425 million ($675 with cost share)

- **Hydrogen production and delivery** technologies
- **Hydrogen storage** “Centers of Excellence” and materials development
- Demonstrate and validate fuel cell vehicle and infrastructure technologies under real-world conditions
- **Fuel cells for consumer electronics** and other applications

Research, Development and Demonstration Plan:

- NRC recommendations
- New systems analysis and system integration functions

On-board Fuel Processing R&D Go/No-Go Decision:

- Technical evaluation of status, progress, and potential
- Independent review panel recommended R&D discontinued

Workshops:

- *Hydrogen Production (4)*: hydrogen separations and purification, water electrolysis by utilities, renewable electrolysis, and hydrogen production via direct fermentation
- **Codes & Standards**: understand and organize fuel purity codes & standards efforts
- **Systems Analysis**: identify and better coordinate systems analysis efforts

IPHE: scoping papers approved; joint projects to kick-off in ‘05

IATF (through OSTP): new web site - www.hydrogen.gov
Workshop on Fuel Cell Operation at Sub-Freezing Temperatures

- Transportation (and stationary) fuel cells need to operate in environments where ambient temperatures will fall below 0°C. Surprisingly little data exist to quantify the effects of sub-freezing temperatures on fuel cell operations.

- The goal of this workshop is to identify and prioritize the technical barriers associated with freezing or sub-freezing temperatures and to develop an RD&D plan to overcome these barriers.

- Results of this workshop will most likely be a topic in an FY 2006 solicitation to be released by the DOE’s OHFCIT.
The focus of this workshop is prediction of the likely effects of freezing temperatures on fuel cell operation and identification of technology tasks to mitigate these effects.

This is a working meeting - not an information meeting. We ask that everybody open up and contribute.

System level targets must be considered.
Thanks!!!

Workshop Organizing Committee

• Bryan Pivovar (LANL)
• Larry Blair (consultant to DOE)
• Doug Wheeler (consultant to NREL)
• Keith Wipke (NREL)
HYDROGEN POSTURE PLAN

AN INTEGRATED RESEARCH, DEVELOPMENT, AND DEMONSTRATION PLAN

February 2004

United States Department of Energy

www.eere.energy.gov/hydrogenandfuelcells
Tuesday, February 1, 2005

8:30  Welcome– Workshop Expectations
      Nancy Garland, DOE

8:45  Glenn Skala, General Motors

9:10  Jeremy Meyers, UTC Fuel Cells

9:35  Ballard Contribution presented by Larry Blair, DOE consultant

9:55  Richard Gaylord, Plug Power

10:15 Break

10:30 Tom Zawodzinski, CWRU

10:50 Phil Ross, LBNL

11:10 Bryan Pivovar, LANL

11:30 Rajesh Ahluwalia, ANL

11:50 Lunch

12:45 Open Discussion Moderated by Doug Wheeler (NREL consultant)

1:45 Breakout Group Assignments and instructions – Shawna McQueen, Energetics

2:00 Breakout Groups (Effects)

3:00 Break

3:20 Breakout Groups (Challenges)

4:30 Reconvene/Discuss break out group findings

Wednesday, February 2, 2005

8:00 Breakout Groups (Research Directions)

10:00 Break

10:15 Breakout Groups (Top 10 Analysis)

11:15 Reconvene/ Wrap-up/ Next Steps

12:15 Adjourn