Economic Analysis of Stationary PEM Fuel Cell Systems

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Battelle Memorial Institute

May 26, 2004

This presentation does not contain any proprietary or confidential information
Team

Battelle Memorial Institute is the Prime Contractor

- Darrell Paul, Project Manager, Battelle -- Columbus
- Harry Stone, Economist and Principal Investigator, Battelle – Cincinnati
- Steve Millett, Futurist, Battelle – Columbus
- Gretchen Hund, Stakeholder Involvement, Battelle – Seattle
- Kathya Mahadevan, Technical and Market Analyst, Battelle – Columbus

Input from PEM fuel cell stakeholders is critical to the success of the program.

Subcontractors will be used on an as-needed basis and per DOE’s direction.
Objectives

To develop an understanding of the economic, technology, and marketplace drivers needed for commercialization of stationary PEM fuel cell systems out to the year 2015.

The action plan will:

• Evaluate high potential stationary PEMFC applications;
• Identify critical success factors required for commercialization;
• Develop a technical targets table for each application (cost, reliability, size, response, emissions, electric load versus time, etc.); and
• Educate stakeholders and raise awareness of national programs.
Benefits

• Identifies factors likely to provide leverage in PEM fuel cell commercialization over the next 10 years.

• Informs policy and investment strategies to the benefit of government and private industry interests.

• Identifies potential points for public/private cooperation and consensus.

• Establishes realistic expectations: What will have to happen to reach these targets?
Budget

Since this is not a technology development project, there is no contractor cofunding. All funds are DOE’s.

<table>
<thead>
<tr>
<th>FY</th>
<th>$Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY 04</td>
<td>500,000</td>
</tr>
<tr>
<td>FY 05</td>
<td>887,933</td>
</tr>
<tr>
<td>FY 06</td>
<td>1,065,520</td>
</tr>
<tr>
<td>FY 07</td>
<td>710,347</td>
</tr>
<tr>
<td>Total</td>
<td>3,163,800</td>
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<table>
<thead>
<tr>
<th>Qtr</th>
<th>$ Total</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>250,000</td>
</tr>
<tr>
<td>2</td>
<td>190,000</td>
</tr>
<tr>
<td>3</td>
<td>60,000</td>
</tr>
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</table>

Cumulative Expenditures: Economic Analysis of PEM Fuel Cell Systems

Cumulative Expenditures, $1,000

0 500 1000 1500 2000 2500 3000 3500

FY04 FY05 FY06 FY07
DOE Technical Barriers for Stationary PEM FC
(These are explained in DOE’s Hydrogen, Fuel Cell, and Infrastructure Technologies Multi-Year Research, Development and Demonstration Plan: Planned activities for 2003-2010)

Transportation Barriers A, B, C, and D do not apply.

Distributed Generation Systems Barriers:
- E. Durability
- F. Heat Utilization
- G. Power Electronics
- H. Startup Time

Fuel-Flexible Fuel Processor Barriers:
- I. Fuel Proc. Startup/Transient
- J. Durability
- K. Emissions/Environment
- L. H₂ Quality / CO Cleanup
- M. Fuel Proc. Sys Integration/Efficiency
- N. Cost

Fuel Cell Component Barriers:
- O. Stack Mat. & Manf. Cost
- P. Durability
- Q. Electrode Performance
- R. Thermal & Water Manage
### DOE Technical Targets For Stationary Fuel Cell Systems in 2010 (Also from DOE’s Multiyear Plan)

The first number listed is for small (3-25 kW) PEMFC systems and the second number is for large (50-250kW); single numbers are for both systems.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Small/PK (3-25 kW)</th>
<th>Large/PK (50-250 kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost per kW</td>
<td>$1000 / $750</td>
<td>$1000 / $750</td>
</tr>
<tr>
<td>Elec. Efficiency</td>
<td>35 / 40%</td>
<td>35 / 40%</td>
</tr>
<tr>
<td>CHP Efficiency</td>
<td>80%</td>
<td>80%</td>
</tr>
<tr>
<td>Transient Response</td>
<td>&lt; 3 msec</td>
<td>&lt; 3 msec</td>
</tr>
<tr>
<td>Durability</td>
<td>40,000 hours</td>
<td>40,000 hours</td>
</tr>
<tr>
<td>Cold Startup</td>
<td>5 / 10 Min.</td>
<td>5 / 10 Min.</td>
</tr>
<tr>
<td>Survivability</td>
<td>-35 to +40 C</td>
<td>-35 to +40 C</td>
</tr>
<tr>
<td>Noise @ 1 m</td>
<td>65 / 55 dba</td>
<td>65 / 55 dba</td>
</tr>
</tbody>
</table>

- < 9 / 1.5 g/1000kWh combined NO$_x$, CO, SO$_x$, hydrocarbon, and particulate emissions.
Approach

Task 1. Tech / Market / Econ Studies
- Technology Evaluations
- Market Evaluations
- Economic Evaluations
- Contingent Analyses

Task 2. Scenario Analyses to 2015
- Scenarios Using IFS Methodology
- Cross Impact Analyses
- Factors for Success
- Policy Implications

Task 3. Stakeholder Involvement
- Identify Stakeholders:
  - Government
  - Industry Associations
  - Groups
  - National Labs
  - Academia
  - Others
- Get Input & Feedback on Analyses

Task 4. Information Dissemination
Project Safety

• Safety (and perceived safety) is a barrier to fuel cell commercialization.

• Safety codes and standards regulating the storage and use of H₂ is a barrier to fuel cell commercialization.
## Schedule (milestones and deliverables next viewgraph)

<table>
<thead>
<tr>
<th>Task Description</th>
<th>FY2004</th>
<th>FY2005</th>
<th>FY2006</th>
<th>FY2007</th>
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<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<tr>
<td>Task 1. Tech / Market / Econ Analyses</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1 Technology Evaluations</td>
<td>1a</td>
<td>1b</td>
<td>A</td>
<td>2a</td>
</tr>
<tr>
<td>1.2 Market Analysis</td>
<td>3</td>
<td>4</td>
<td>A</td>
<td>5</td>
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<tr>
<td>1.3 Basic Economic Analysis</td>
<td>6</td>
<td>7</td>
<td>A</td>
<td>8</td>
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<td>1.4 Enhanced Economic Analysis</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
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<td>Task 2. Scenario Analysis</td>
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<td>2.1 Expert Focus Groups</td>
<td>13a</td>
<td>13b</td>
<td></td>
<td></td>
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<tr>
<td>2.2 Cross-Impact Analysis</td>
<td>14a</td>
<td>14b</td>
<td></td>
<td></td>
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<tr>
<td>2.3 PEMFC Scenarios</td>
<td></td>
<td></td>
<td>C</td>
<td>D</td>
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<td>Task 3. Stakeholder Involvement</td>
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<td>3.1 Stakeholder Interviews</td>
<td>15</td>
<td>16</td>
<td>E</td>
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<tr>
<td>3.2 Stakeholder Focus Groups/Mtgs</td>
<td>17a</td>
<td>17c</td>
<td>E</td>
<td>18a</td>
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<tr>
<td>3.3 Guidebook for Stakeholders</td>
<td>18b</td>
<td></td>
<td>E</td>
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<td>Task 4. Information Dissemination</td>
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## Milestones and Deliverables

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<thead>
<tr>
<th>Milestones</th>
<th>Deliverables</th>
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<tr>
<td><strong>Task 1. Tech / Market / Econ Analyses</strong></td>
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<tr>
<td>1(a,b). Expert focus groups for technology ratings</td>
<td>A. Interim report on econ/tech/market analyses</td>
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<tr>
<td>2(a,b). Annual update of technology ratings</td>
<td>B. Updated interim report</td>
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<tr>
<td>3. Identify and segment markets</td>
<td></td>
</tr>
<tr>
<td>4. Identify highest potential opportunities</td>
<td></td>
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<tr>
<td>5. Impact of financial incentives and special programs</td>
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<tr>
<td>7(a,b). Impacts of restructuring &amp; oil dependency</td>
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<tr>
<td>8. Government policy impacts</td>
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<tr>
<td>9. Critical success factors and barriers</td>
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<tr>
<td>10. Environmental Assessment</td>
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<tr>
<td>11. Value policy incentives and disincentives</td>
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<tr>
<td>12. Contingent analyses</td>
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</tbody>
</table>
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<table>
<thead>
<tr>
<th>Milestones</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Task 2. Scenario Analyses</strong></td>
<td></td>
</tr>
<tr>
<td>13(a,b). Expert focus groups to define descriptors</td>
<td>C. Report on PEMFC scenarios</td>
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<tr>
<td><strong>Task 3. Stakeholder Involvement</strong></td>
<td></td>
</tr>
<tr>
<td>15. Stakeholder involvement plan and list</td>
<td>E. Letter report of interview or meeting results</td>
</tr>
<tr>
<td>16. Develop interview protocol</td>
<td>F. Stakeholder feedback report</td>
</tr>
<tr>
<td>17(a,b,c). Focus groups</td>
<td>G. Guidebook</td>
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<tr>
<td>18(a,b). Stakeholder Partnership Team (SPT) meeting</td>
<td></td>
</tr>
<tr>
<td><strong>Task 4. Information Dissemination</strong></td>
<td>H. Seminar presentations</td>
</tr>
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</table>

Technical Accomplishments/Progress

- Developed integrated evaluative approach.

- Completed two expert focus groups to provide input on descriptors for the Interactive Future Simulations model.

- Currently surveying fuel cell developers, users, and competitors in the back-up power marketplace.

- Evaluating non-technical factors, like industry factors and policy issues, that will affect the commercialization of back-up power marketplace.

\[ S_{PEM(t)} = P_t \times Q_{PME(t)} \]
Given competitive P & quality, subject to:

\[ Q_{PEM} = (Q_{tot(t)} \times \sum_0^t (R_{PEM(n)}) \times f(Q_{tot(t)}, C_{R&D}, I_t) \]

\[ R_{PEM} = f(K, C_s, b, d, m, r) \]
Technical Approach - Scenario Analysis
Methodology Battelle

- Topic Question
- Expert Focus Groups (3)
- Identify Issues
- Descriptors (18-24)
  - Trend Analysis
  - White Papers
- Cross-Impact Matrix
- refinements, iterations & simulations
- Policy Decisions
- Robust Strategies
- Most Likely Scenarios
**Technical Accomplishment: Scenario Analysis**

**Topic Question:** What will be the most likely markets and economic impacts of stationary PEM fuel cells in the range of 1kW to 250 kW in the U.S. by the year 2015?

- Focus group 1 (December 12, 2003 in Columbus, Ohio): 16 participants representing the Ohio Fuel Cell Coalition, NASA Glenn Research Center, FirstEnergy, GrafTech, Johnson Matthey Fuel Cells, The Ohio State University, EWI, Cinergy, Ohio Department of Development, American Electric Power, Case Western Reserve University, and Battelle.

- Identified and rank-ordered 65 potential drivers impacting the market for stationary PEM fuel cells in the U.S. to the year 2015.
Technical Accomplishments: Scenario Analysis

Scenario Analysis 2 (May 12, 2004 in Washington D.C.)

- Value of PEM Fuel Cell to Customers
- Cost of PEM Fuel Cells
- PEM Fuel Cell Investments
- PEM Fuel Cell Manufacturing
- PEM Fuel Cell Stack Technical Advances
- Hydrogen Availability
- Fossil Fuel Technological Improvements
- Energy Storage Technologies
- Environmental Regulations and Standards
- Public Policy Support for PEM Fuel Cells
- National Energy Policy and Security
- Electrical Grid Sufficiency and Reliability
- Cogeneration, Backup Power, and DG Options
- Grid Electricity Prices
- Prices of Fuels for PEM Fuel Cells
- Fuel Cell Commercialization Leadership
- PEM Fuel Cell Stationary Power Units in Japan and Europe
- PEM Fuel Cells in Automotive Applications
- PEM Fuel Cell Applications and Markets
- Economic Impact of PEM Fuel Cells
Backup Power Market Analysis Model

Secondary Research
- Surveys/Interviews
- Expert Focus Groups
- Stakeholder Groups

Primary Research

Economic and Market Analysis Model

Scenario Analysis

Most Likely Market Applications

Most Likely Scenarios for Success
Technical Accomplishments: Market Analysis for Back-up Power Markets

- Secured and reviewed economics reports on distributed energy/PEM fuel cell markets.
- Determined types of primary data required.
- Completed development of survey instruments.
- Completed initial identification and characterization of major market segments.
- Competing technology information obtained including UPS systems, battery technologies, microturbines, generators, photovoltaics and wind power.
- Industry factors determined through secondary research, interviews with industry experts, and scenario analysis focus groups.
- Benchmarking of PEM FC technology for back-up power markets initiated.
Interactions and Collaboration

Key Stakeholders

Guidance on key factors to be considered in Assessment

Stakeholder Focus Groups

Provide guidance on specific market assessment Peer review assessments

Stakeholder Partnership Team

Identify Key Success Factors and Barriers PEM Fuel Cell Vision 2020 Assessment Input

Stakeholder feedback from public and private users initiated

Industry
Consumers
R&D Community
Electric Utilities
Fuel Suppliers
Investment
Community
Policy Setters
Substitutes

Battelle

DOE

DOE Review Mtg-PEM Fuel Cell Systems
Stakeholder Feedback from Public and Private Consumers on Critical Commercialization Factors

16 surveys or in-depth interviews completed (April 23). Some key themes are:

• Cost is the most significant barrier in most cases;
• Reliability a must;
• Durability critical and not adequate; and
• Hydrogen storage / reformation an issue.

Selected Comments:

• Clean green and reduced emissions important to their customers. (Starwood Hotels)
• “Having higher reliability than my competitors has given me new customers!” (Nat. Bank Omaha)
• “What better place to demonstrate the latest in clean technology, given we have 3 million visitors/year” (Yellowstone National Park)
Future Work

• Complete scenario analysis Fall 2004.
• Select / evaluate additional market segment.
• Begin work on additional technology assessment.
• Begin enhanced economic analysis (e.g., contingent valuation).
• Initiate stakeholder focus-group and hold meetings.
• Update technology and market data.