Hydrogen and Fuel Cell Technologies Overview

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Workshop Objectives

Purpose

• Identify and prioritize challenges and barriers to manufacture of hydrogen and fuel cell systems and components
• Identify and prioritize R&D activities that government can support to overcome the barriers

Workshop Output:

• Preliminary list of R&D needs for hydrogen and fuel cell manufacturing
• Report of workshop proceedings including plenary presentations and summary of participant input (to be made available online)

Post-Workshop Output:

• Review and update prioritized lists of challenges/barriers and opportunities for government support

Please Note:
• No sales pitches
• Not to present “mini-proposals” on particular RD&D ideas
• Not to think only “inside the box”
U.S. share of PV production has fallen significantly over the last 10 years.
Fuel Cell Market Overview

Megawatts Shipped, Key Countries: 2008-2010

- Fuel cell market continues to grow
  - ~36% increase in global MWs shipped
  - ~50% increase in US MWs shipped

North American Shipments by Application

- Various analyses project that the global fuel cell/hydrogen market could reach maturity over the next 10 to 20 years, producing revenues of:
  - $14 – $31 billion/year for stationary power
  - $11 billion/year for portable power
  - $18 – $97 billion/year for transportation

Widespread market penetration of fuel cells could lead to:
- 180,000 new jobs in the US by 2020
- 675,000 jobs by 2035

FuelCells2000, Pike Research, Fuel Cell Today, ANL

Fuel Cell Patents Reflect Emerging Growth

Clean Energy Patent Growth Index\(^{[1]}\) shows that fuel cell patents lead in the clean energy field with nearly 1,000 fuel cell patents issued worldwide in 2010.

- 3x more than the second place holder, solar, which has just ~360 patents.
- Number of fuel cell patents grew > 57% in 2010.

\(^{[1]}\) http://cepgi.typepad.com/heslin_rothenberg_farley/
Significant growth in number of patents filed by Japan, Korea, Germany, U.S.
Job creation projections show significant growth in Asia and Europe.

Annual granted fuel cell patents per country of origin (top ten)

Source: FuelCellToday
Employment Impacts of Early Markets

Developed user-friendly tool to calculate economic impacts

### Required User Input Fields
- Select State or Region: NE
- Type of Fuel Cell: PEMFC
- Application: Stationary - Backup

- Average Size of Manufactured Fuel Cell: 5 kW
- Fuel Cells Manufactured by Year: 2000
- Annual Fuel Cell Production (kW/year): 10,000
- Time Frame (years): 5

### Optional User Input Fields
- Existing Fuel Cell Production Capacity (kW/year): 10,000
- Additional Manufacturing Capacity to be Constructed (kW/year): 10,000
- Sales Price ($/kW): $2,000
- Production Cost ($/kW, initial): $1,301
- Progress Ratio: 0.97
- Production Volume for Initial Cost: 10,000
- Scale Elasticity: 0.2
- Full Production Level (kW/year): 25,000
- Annual Rate of Technological Progress: 2%
- Average Production Cost Over Time Frame ($/kW): $1,098
- Installation Cost ($/kW): TBD
- Operations & Maintenance Cost ($/kW, annual): TBD

### Preliminary Analysis

Gross National Impact of PEMFCs in Forklifts

**Includes short-term jobs** (construction/expansion of mfg capacity, installation & infrastructure) & on-going jobs (manufacturing, O&M and fuel production & delivery)

- Tax credit expires in 2016.
- $1,300/kW initial mfg cost (Battelle), $4,200/kW retail price.
- Shipments reach 3,300 annually by 2020 (Greene et. al.) out of ~100,000.
- 15,000 FC forklifts in operation by 2020 (<2 percent of Class 1-3 forklifts).
- Average of 60 fuel cells/site, 250 site installations by 2020.

**Technology/Market Assumptions:**

- 42 Mfg. Facility Construction or Expansion
- 929 Installation & Infrastructure
- 630 Manufacturing
- 316 Fuel
- 290 O&M

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*Argonne National Lab/RCF*
Deployments of fuel cells in early markets have reduced costs substantially.

- 50% or greater reduction in costs
- 2008 model generally underestimated cost reductions

Comparison of 2008 ORNL Study and 2010 Fuel Cell Cost Estimates

2005 and 2010 averages based on estimates supplied by OEMs. 2010 predicted assumed government procurements of 2,175 units per year, total for all market segments. Predictions assumed a progress ratio of 0.9 and scale elasticity of -0.2.
Federal budget in fuel cells complements industry

DOE’s funding is critical to the emerging fuel cell industry

Fuel cell industry is less established than other clean energy industries—DOE funds have significant impact on smaller, emerging industries such as fuel cells.

Additional Information
## Funding ($ in thousands)

<table>
<thead>
<tr>
<th>Key Activity</th>
<th>FY 2011 Appropriation ($ thousands)</th>
<th>FY 2012 Request ($ thousands)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Cell Systems R&amp;D</td>
<td>43,000</td>
<td>45,450</td>
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<tr>
<td>Hydrogen Fuel R&amp;D</td>
<td>33,000</td>
<td>35,000</td>
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<tr>
<td>Technology Validation</td>
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<td>8,000</td>
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<tr>
<td>Safety, Codes &amp; Standards</td>
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<tr>
<td>Systems Analysis</td>
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<td>3,000</td>
</tr>
<tr>
<td>Manufacturing R&amp;D</td>
<td>3,000</td>
<td>2,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>98,000</strong></td>
<td><strong>100,450</strong></td>
</tr>
</tbody>
</table>

Budget is approximately $100 million per year
High-tech U.S. trade balances are struggling.
The mission of the Defense Production Act (DPA) Title III Program (Title III) is to "create assured, affordable, and commercially viable production capabilities and capacities for items essential for national defense."

Can we do this for hydrogen and fuel cells?
Fuel Cells - Where are we today?

**Fuel Cells for Stationary Power, Auxiliary Power, and Specialty Vehicles**

The largest markets for fuel cells today are in stationary power, portable power, auxiliary power units, and forklifts.

- **~75,000** fuel cells have been shipped worldwide.
- **>15,000** fuel cells shipped in 2009 (> 40% increase over 2008).

*Fuel cells can be a cost-competitive option for critical-load facilities, backup power, and forklifts.*

**Fuel Cells for Transportation**

In the U.S., there are currently:

- **> 200 fuel cell vehicles**
- **~ 20 active fuel cell buses**
- **~ 60 fueling stations**

*Sept. 2009: Auto manufacturers from around the world signed a letter of understanding supporting fuel cell vehicles in anticipation of widespread commercialization, beginning in 2015.*

**Production & Delivery of Hydrogen**

In the U.S., there are currently:

- **~9 million metric tons** of $H_2$ produced annually
- **> 1200 miles** of $H_2$ pipelines

*Source: US DOE 09/2010*