Employment Impacts of Early Markets for Hydrogen and Fuel Cell Technologies

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Overview

Timeline
Start date: October 2010
End date: December 2012
Percent complete: 80%

Budget
Total funding: $980k (FY09-11)
DOE share: 100%
  • Funding for FY11: $640k
  • Funding for FY12: $100k

Barriers
• Lack of Readily Available, Objective, and Technically Accurate Information (A)
• Regional Differences (E)
• Difficulty of Measuring Success (F)

Partners
• Argonne National Laboratory
• RCF Economic & Financial Consulting
• Stakeholders:
  Public agencies
  Industry organizations
  Manufacturers
  Researchers
Relevance

• Provide a means for calculating employment and other economic implications of fuel cell investments. The Jobs and Output Benefits of Stationary Fuel Cells (JOBS FC) model translates investment and operations expenditures into direct, indirect and induced jobs and economic activity.

• Meet DOE and stakeholder needs to measure economic impacts of fuel cell technology deployment by region and application. This is essential information for local, state and national policy decisions, public and private investment decisions and program planning and analysis.

• Collaborate with stakeholders to create a user-friendly tool with appropriate functionality, to acquire/review input data and to validate results.
JOBS FC uses input-output approach to model FC deployment

- JOBS FC is a user-friendly spreadsheet-based tool that calculates direct, indirect and induced job creation, wages and sales resulting from FC production, installation, operation and fueling.
- JOBS FC uses Regional Input-Output Modeling System (RIMS II) multipliers to capture effect of expenditures on earnings, output and employment.
- JOBS FC models gross and net jobs created by 3 technologies, 3 applications, multiple FC capacities (defaults shown).

### Unit Capacity (kW)

<table>
<thead>
<tr>
<th></th>
<th>LT PEM</th>
<th>PAFC</th>
<th>MCFC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I/II Forklift</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class III Forklift</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cell Tower Backup Power</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prime Power (with CHP)</td>
<td>400</td>
<td>1400</td>
<td></td>
</tr>
</tbody>
</table>

Jobs are created at each stage in FC production, fuel infrastructure, O&M, and fuel supply chains (direct + indirect jobs), as well as from re-spending dollars in economy (induced jobs).
JOBS FC models expenditure flows through the supply chain


Approach

Fuel Cell Application Cost Breakdown

Courtesy of Ballard Power Systems.

Building and Structures
- materials
- labor
equipment

Facility Cost
- Machinery and Tooling
- Land
electrodes
- electrolyte membrane

Stack
- MEA
- GDL
catalyst
- labor

Bipolar Plates
- End Plates
- Tie rods
- Current Collectors
- Gaskets
- Manifolds
- Labor

BOP
- System Assembly Labor
- Utilities
- General Expenses

Production Costs

Testing
- Packaging
- Rail
- Truck

Modal Costs
- Handling

FC Manufacturing

Fuel Cell

Fueling

Modular Equipment
Fuel Storage

Reforming

Curtis of BMW Manufacturing Co., LLC

FC O&M

Installation

On-Site Power
- Grid Connection

Electrical

Infrastructure
- Transportation Access
- Utilities
- Buildings

Site Preparation

Packing

Handling

FC Shipping

Courtesy of BMW Manufacturing Co., LLC
JOBS FC models expenditures for different geographies

Jobs occur where expenditures occur. Domestic manufacturing, installation, and use create the most jobs, but imports and exports also create jobs.

- JOBS FC use RIMS II multipliers for 61 different geographies to account for geographic variation.
- Jobs are created from imported FCs installed and operated inside the region (no manufacturing facility construction & FC production impacts occur).
- Jobs are created from exported FCs installed & operated outside the region (no installation, O&M of FCs and fuel infrastructure & fuel purchase impacts occur).
- Net effects exclude jobs displaced by FCs (unless FCs displace imports).
# FY 2012 Accomplishments

<table>
<thead>
<tr>
<th>Due date</th>
<th>Milestone</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec. 2011</td>
<td>Beta 1.0 test</td>
<td>Complete</td>
</tr>
<tr>
<td>Feb. 2012</td>
<td>Beta 2.0 test</td>
<td>Complete</td>
</tr>
<tr>
<td>May 2012</td>
<td>JOBS FC 1.0 launch</td>
<td>Complete</td>
</tr>
<tr>
<td>May 2012</td>
<td>Initial employment estimates for forklift &amp; backup power FCs deployed under ARRA</td>
<td>“High Level” Complete</td>
</tr>
<tr>
<td>Sept. 2012</td>
<td>Final employment estimates for forklift and backup power (BuP) FCs deployed under ARRA</td>
<td>Data collection/ validation</td>
</tr>
<tr>
<td>Dec. 2012</td>
<td>JOBS FC 1.1</td>
<td>Data collection/ validation</td>
</tr>
</tbody>
</table>

*Beta 1.0 and Beta 2.0*  
3/30/12  

*JOBS FC 1.0*  
5/15/12  

*Updates & Analyses JOBS FC 1.1*  
12/31/12
Completed beta tests and JOBS FC 1.0 launch

Products:
- JOBS FC Beta 1.0 (12/15/11)
- JOBS FC Beta 2.0 (2/28/12)
- JOBS FC 1.0 (5/15/12)
- Draft & Final Users’ Guides
- JOBSFC.es.anl.gov portal and EERE link
- Web-based user training scheduled for 5/22/12

Comments on:
- User interface
- Default values/assumptions
- Functionality/usefulness
- Technologies/applications
- Operating system
‘Reference’ scenarios show potential for thousands of net job-years*

<table>
<thead>
<tr>
<th>Reference Scenario Parameter</th>
<th>Forklifts</th>
<th>Backup Power</th>
<th>Prime Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity (kW)</td>
<td>Class I/II</td>
<td>PAFC</td>
<td>MCFC</td>
</tr>
<tr>
<td>Installations:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>1,500</td>
<td>1,849</td>
<td>1,826</td>
</tr>
<tr>
<td>2016</td>
<td>3,000</td>
<td>3,457</td>
<td>3,339</td>
</tr>
<tr>
<td>2017</td>
<td>4,500</td>
<td>4,906</td>
<td>4,730</td>
</tr>
<tr>
<td>2018</td>
<td>6,000</td>
<td>6,229</td>
<td>6,030</td>
</tr>
<tr>
<td>2019</td>
<td>7,500</td>
<td>7,435</td>
<td>7,316</td>
</tr>
<tr>
<td>2020</td>
<td>9,000</td>
<td>8,593</td>
<td>8,616</td>
</tr>
</tbody>
</table>

*One job-year = one year of work for one person. Results exclude manufacturing facility construction which could generate ≈ 800 additional job-years for PEM applications.

Note, positive and negative values on stacked bar charts must be summed to yield total net effects (sum shown by line overlaid on chart).
Accomplishments: Reference scenario cont’d.

Forklift FCs can add $millions to gross earnings & $billions to output

- Gross job-years
- Net job-years
- Displaced job-years

US gross job-years*

<table>
<thead>
<tr>
<th>Year</th>
<th>Forklift Fuel Cell Supply Chain</th>
<th>Forklift Fuel Cell Induced</th>
<th>H2 Fueling Infr. Supply Chain</th>
<th>H2 Fueling Infr. Induced</th>
<th>Hydrogen Fuel Supply Chain</th>
<th>Hydrogen Fuel Induced</th>
<th>FC and Infr. Maintenance Supply Chain</th>
<th>FC and Infr. Maintenance Induced</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>200</td>
<td>300</td>
<td>100</td>
<td>100</td>
<td>200</td>
<td>300</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>2016</td>
<td>250</td>
<td>350</td>
<td>150</td>
<td>150</td>
<td>250</td>
<td>350</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>2017</td>
<td>300</td>
<td>400</td>
<td>200</td>
<td>200</td>
<td>300</td>
<td>400</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>2018</td>
<td>350</td>
<td>450</td>
<td>250</td>
<td>250</td>
<td>350</td>
<td>450</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>2019</td>
<td>400</td>
<td>500</td>
<td>300</td>
<td>300</td>
<td>400</td>
<td>500</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>2020</td>
<td>450</td>
<td>550</td>
<td>350</td>
<td>350</td>
<td>450</td>
<td>550</td>
<td>350</td>
<td>350</td>
</tr>
</tbody>
</table>

*Excludes manufacturing facility construction which could generate ≈ 400 additional jobs.

US gross earnings

| Year | US gross earnings
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>$000 (2010)</td>
</tr>
<tr>
<td>2016</td>
<td>$000 (2010)</td>
</tr>
<tr>
<td>2017</td>
<td>$000 (2010)</td>
</tr>
<tr>
<td>2018</td>
<td>$000 (2010)</td>
</tr>
<tr>
<td>2019</td>
<td>$000 (2010)</td>
</tr>
<tr>
<td>2020</td>
<td>$000 (2010)</td>
</tr>
</tbody>
</table>

US gross output

| Year | US gross output
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>$000 (2010)</td>
</tr>
<tr>
<td>2016</td>
<td>$000 (2010)</td>
</tr>
<tr>
<td>2017</td>
<td>$000 (2010)</td>
</tr>
<tr>
<td>2018</td>
<td>$000 (2010)</td>
</tr>
<tr>
<td>2019</td>
<td>$000 (2010)</td>
</tr>
<tr>
<td>2020</td>
<td>$000 (2010)</td>
</tr>
</tbody>
</table>

Net Job-years = Gross job-years - Displaced job-years

Gross job-years

Displaced job-years
**Accomplishments**

Parametric analysis of forklift reference scenario shows high sensitivity to unit growth, less to capacity & operating hours.

- Unit growth (2015-2020) produces biggest change in job estimates.
- Gross results equally sensitive to FC capacity & annual operating hrs.
- Net results least sensitive to operating hrs.

**Values Modeled in Parametric Analysis**

<table>
<thead>
<tr>
<th>Parameter (% change)</th>
<th>-100%</th>
<th>-50%</th>
<th>-25%</th>
<th>Base</th>
<th>+25%</th>
<th>+50%</th>
<th>+100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity (kW):</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class I/II</td>
<td>NA</td>
<td>5</td>
<td>7.5</td>
<td>10</td>
<td>12.5</td>
<td>15</td>
<td>NA</td>
</tr>
<tr>
<td>Class III</td>
<td>NA</td>
<td>1</td>
<td>1.5</td>
<td>2</td>
<td>2.5</td>
<td>3</td>
<td>NA</td>
</tr>
<tr>
<td>H2 molecule cost ($/kg)</td>
<td>NA</td>
<td>2.75</td>
<td>4.12</td>
<td>5.50</td>
<td>6.87</td>
<td>8.25</td>
<td>NA</td>
</tr>
<tr>
<td>Growth (units/yr)</td>
<td>NA</td>
<td>1500</td>
<td>2250</td>
<td>3000</td>
<td>3750</td>
<td>4500</td>
<td>NA</td>
</tr>
<tr>
<td>Operating hrs/yr</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>2500</td>
<td>3125</td>
<td>3750</td>
<td>5000</td>
</tr>
</tbody>
</table>
Results for backup power and prime power applications are less sensitive to unit growth than are forklifts.

Prime power estimates are most sensitive to capacity.

Gross & net (not shown) results for BuP equally sensitive to FC capacity & operating hrs, slightly more sensitive to unit growth, least sensitive to manufacturing cost.

H2 cost for BuP (not shown) not examined due to extremely low use.

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### Values Modeled in Parametric Analysis

<table>
<thead>
<tr>
<th>Parameter (% change)</th>
<th>-50%</th>
<th>-25%</th>
<th>Base</th>
<th>+25%</th>
<th>+50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity (kW): BuP (PEM)</td>
<td>2.5</td>
<td>3.75</td>
<td>5</td>
<td>7.5</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>700</td>
<td>1050</td>
<td>1400</td>
<td>1750</td>
<td>2100</td>
</tr>
<tr>
<td>Prime (MCFC)</td>
<td>5</td>
<td>2250</td>
<td>3000</td>
<td>3750</td>
<td>4500</td>
</tr>
<tr>
<td>Natural gas cost ($/mcf)</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Unit growth: Backup pwr.</td>
<td>1500</td>
<td>2250</td>
<td>3000</td>
<td>3750</td>
<td>4500</td>
</tr>
<tr>
<td>Prime pwr.</td>
<td>5</td>
<td>8</td>
<td>10</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>Operating hrs/yr (BuP):</td>
<td>24</td>
<td>36</td>
<td>48</td>
<td>60</td>
<td>72</td>
</tr>
<tr>
<td>Required run time</td>
<td>12</td>
<td>18</td>
<td>24</td>
<td>30</td>
<td>36</td>
</tr>
<tr>
<td>Annual run time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015 BuP mfg. cost ($/kW)</td>
<td>550</td>
<td>825</td>
<td>1110</td>
<td>1375</td>
<td>1650</td>
</tr>
</tbody>
</table>
ARRA deployments resulted in 800–950 job-years to date (500–550 excluding FC manufacturing)

- Initial results: ≈800–950 job-years to date
- Excluding jobs from
  - Financing, taxes
  - Remaining forklift and cell tower deployments
  - BuP in non-cell tower applications
  - Post-2011 fueling, FC & fuel infrastructure O&M, stack replacement

*Results on stacked bar charts appear deceptive. Negative values must be added to positive values to yield total net effects.*
Stakeholders have been key collaborators for peer review, data collection/validation & beta testing.

Public Agencies:
- South Carolina Hydrogen and Fuel Cell Alliance
- California Stationary Fuel Cell Consortium
- Connecticut Center for Advanced Technology
- Ohio Fuel Cell Coalition
- NYSERDA
- Clean Energy States Alliance
- California Fuel Cell Partnership
- Virginia Clean Cities

Trade Associations:
- FCHEA
- Fuel Cells 2000

Manufacturers:
- PlugPower
- ReliOn
- Idatech
- UTC Power
- Fuel Cell Energy
- Ballard

Customers:
- Sprint-Nextel
- Metro PCS
- Whole Foods
- Sierra Nevada

Researchers:
- ORNL
- NREL
- PNNL
- Battelle

Beta tester/Peer reviewer
Tool expansion & analysis is focus of FY 2012 and beyond

May-2012

June-2012

July-2012

Aug-2012

Dec-2012

Develop site-specific tool & evaluate ARRA projects

Add prime power manufacturing and H2 production

Complete model update and documentation

User training, data validation and documentation

Future work

Potential model expansion:

- Debt or other financing
- High temperature PEMFC
- Transportation applications
- SOFC
- CHHP

Employment

Earnings

Economic output

Deployment

Supporting Infrastructure

H2 Production, FC Manufacturing
Summary

• **Relevance:** Provide a means for DOE and stakeholders to estimate employment and other economic impacts of deploying fuel cells in stationary, backup power and materials handling applications.

• **Approach:** Using input-output economic modeling within the context of a user-friendly tool to calculate direct, indirect and induced employment, earnings and economic output.

• **Collaborations:** Active partnership between ANL & RCF. Extensive stakeholder interaction.

• **Technical accomplishments and progress:**
  – Designed tool, conducted beta tests, developed users’ guide and posted model at [http://JOBSFC.es.anl.gov](http://JOBSFC.es.anl.gov) to calculate economic impact of FC production, installation and operation for early markets at state, regional and national levels (61 potential geographies).
  – Began analysis of employment impacts of ARRA forklift and cell tower backup power projects.
  – Conducted sensitivity analyses of selected parameters.

• **Future research:**
  – Conduct web-based user training for JOBS FC.
  – Add capability to model site-specific FC installations, H2 production and prime power FC manufacturing.
  – Validate and refine fuel cell operational and economic defaults.
  – Develop capability to model CHHP, debt or other financing, transportation applications, and high temperature PEMFC and SOFC technologies.