DOE Hydrogen & Fuel Cell Overview
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Fuel Cell Technologies Program
Overview
- Goals & Objectives
- Technology Status & Key Challenges

Progress
- Research & Development
- Deployments
- Recovery Act Projects

Budget

Key Publications
Program Mission

The mission of the Hydrogen and Fuel Cells Program is to enable the widespread commercialization of a portfolio of hydrogen and fuel cell technologies through basic and applied research, technology development and demonstration, and diverse efforts to overcome institutional and market challenges.

Key Goals: Develop hydrogen and fuel cell technologies for:

1. Early markets such as stationary power (prime and back up), lift trucks, and portable power
2. Mid-term markets such as residential combined-heat-and-power systems, auxiliary power units, fleets and buses
3. Long-term markets including mainstream transportation applications with a focus on light duty vehicles, in the 2015 to 2020 timeframe.

Source: US DOE 10/2010- draft Program Plan
Includes basic science through the Office of Science and applied RD&D through EERE, FE, NE
Fuel Cells: Addressing Energy Challenges

Diverse Energy Sources & Fuels
- Conventional Fuels
  - Natural Gas
  - Propane
  - Diesel
  - Other Hydrocarbons
- Biomass
- Renewable Resources (wind, solar, biomass)
- Nuclear
- Natural Gas
- Coal (with carbon sequestration)

Clean, Efficient Energy Conversion
- Fuel Cells
  - Alkaline
  - Direct Methanol
  - Molten Carbonate
  - Polymer electrolyte membrane (PEM)
  - Phosphoric Acid
  - Solid Oxide

Diverse Applications
- Stationary Power
  - Primary Power & CHP (residential, commercial, industrial)
  - Backup Power
- Transportation
  - Trucks
  - Trains
  - Aircraft
  - Ships
  - Specialty Vehicles (e.g., forklifts)
- Auxiliary Power
  - Buses
  - Automobiles
- Motive Power
  - Consumer Electronics
  - Battery Chargers
  - Soldier Power

Energy Storage for Renewable Electricity
- Intermittent Renewables (solar, wind, ocean)
  \[ H_2 \]
  \[ \text{Fuel Cells or Turbines} \]
  \[ \text{Grid Power or Distributed Power} \]
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.

~24,000 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 H₂ produced annually

> 1200 miles of H₂ pipelines

Source: US DOE 09/2010
Global competition is increasing

Preliminary market analysis

International Landscape favors H₂ & Fuel Cells

- Germany (>$1.2B; 1,000 H₂ stations)
- European Commission (>$1.2B, 2008-2013)
- Japan (2M vehicles, 1,000 H₂ stations by 2025)
- Korea (plans to produce 20% of world shipments & create 560,000 jobs in Korea)
- China (thousands of small units; 70 FCVs, buses, 100 shuttles at World Expo, Olympics)
- Subsidies for jobs, manufacturing, deployments (e.g. South Africa)

Significant increase in MW shipped by non-US companies in just 1 year

>40% market growth in just one year

Example: Seoul’s

Renewable energy generation plan includes ~

48% fuel cells

Example: Denmark

Backup Power Deployments

Specific positions and numbers are not correct

50,000 potential sites
>500 deployments worldwide
A variety of technologies - including fuel cell vehicles, extended-range electric vehicles (or “plug-in hybrids”), and all-battery powered vehicles – are under development to meet our diverse transportation needs.

The most appropriate technology depends on the drive cycle and duty cycle of the application.

At extended driving ranges, benefits of fuel cell vehicles become more pronounced.
Systems Analysis — WTW Updates

Well-to-Wheels Greenhouse Gases Emissions Future Mid-Size Car (Grams of CO₂-equivalent per mile)

| Source: US DOE 10/2010 |

Analysis includes portfolio of transportation technologies and latest models and updates to well-to-wheels assumptions

Fuel cell for CHP:
75-90% less Nox
75-80% less particulates
>50% less CO₂ emissions

Analysis & Assumptions at:
http://hydrogen.energy.gov/pdfs/10001_well_to_wheels_gge_petroleum_use.pdf

Notes:
For a projected state of technologies in 2035-2045. Ultra-low carbon renewable electricity includes wind, solar, etc. Does not include the life-cycle effects of vehicle manufacturing and infrastructure construction/decommissioning. Global warming potential of primary fuels excluded.
Lifecyle Costs: Light Duty Vehicles

Preliminary Analysis

2015
• Lifetime cost of diesel ownership is roughly equivalent to an SI ICE
• HEVs and PHEV10s are competitive.
• Energy storage costs are still high for PHEV40s and EVs.

2030
• Hybrid, electrified, and fuel cell vehicles are competitive
• Diesels cost is still roughly equivalent to an SI ICE

* No state, local or utility incentives are included. Federal subsidy policies (e.g., Recovery Act 09 credits for PHEVs) are also excluded. Fuel prices follow AEO09 high oil projections (gases rises from $3.07 in 2010 to $5.47 in 2030; diesel increases from $3.02 in 2010 to $5.57 in 2030); fuel taxes are included in EIA estimates. The vehicle cost range represents a range of potential carbon prices, from $0 to $56 (the centerline is plotted at a carbon price of $20). Technology costs are estimated based on a 50% (“average”) likelihood of achieving program goals.

Advanced Light Duty Vehicle Technologies (Mid-Size)
The Program has been addressing the key challenges facing the widespread commercialization of fuel cells.

### Technology Barriers

**Fuel Cell Cost & Durability**
- Targets*: $750 per kW, 40,000-hr durability
- Vehicles*: $30 per kW, 5,000-hr durability

**Hydrogen Cost**
- Target*: $2 – 3/gge, (dispensed and untaxed)

**Hydrogen Storage Capacity**
- Target: > 300-mile range for vehicles—without compromising interior space or performance

### Market Transformation

Assisting the growth of early markets will help to overcome many barriers, including achieving significant cost reductions through economies of scale.

### Economic & Institutional Barriers

- Safety, Codes & Standards Development
- Domestic Manufacturing & Supplier Base
- Public Awareness & Acceptance
- Hydrogen Supply & Delivery Infrastructure

* Targets and Metrics are being updated in 2010.

Source: US DOE 09/2010
Progress
Projected high-volume cost of fuel cells has been reduced to $51/kW (2010)*

- More than 30% reduction since 2008
- More than 80% reduction since 2002
- 2008 cost projection was validated by independent panel**

As stack costs are reduced, balance-of-plant components are responsible for a larger % of costs.

*Based on projection to high-volume manufacturing (500,000 units/year).

**Panel found $60 – $80/kW to be a “valid estimate”: [http://hydrogendoedev.nrel.gov/peer_reviews.html](http://hydrogendoedev.nrel.gov/peer_reviews.html)
The Program has reduced PGM content, increased power density, and simplified balance of plant, resulting in a decrease in system cost.

From 2008 to 2010, key cost reductions were made by:
• Reducing platinum group metal content from 0.35 to 0.18 g/kW
• Increasing power density from 715 to 833 mW/cm²
• Simplifying balance of plant

→ These advances contributed to a $22/kW cost reduction.

Key improvements enabled by using novel organic crystalline whisker catalyst supports and Pt-alloy whiskerettes.

There are ~ 5 billion whiskers/cm².

Whiskers are ~ 25 X 50 X 1000 nm.

Whiskerettes: 6 nm x 20 nm

Source: 3M

Source: US DOE 08/2010
High volume projected costs for hydrogen production technologies continue to decrease. Low volume/early market costs are still high. Hydrogen cost range reassessed – includes gasoline cost volatility and range of vehicle assumptions.

**Projected High-Volume Cost of Hydrogen (Dispensed)—Status**

**NEAR TERM:**
- Distributed Production
  - Natural Gas Reforming
  - Ethanol Reforming
  - Electrolysis

- Low-volume (200 kg/day)
- Steam Methane Reforming
- H₂ from Combined Heat, Hydrogen, and Power Fuel Cell

**LONGER TERM:**
- Centralized Production
  - Biomass Gasification
  - Central Wind Electrolysis
  - Coal Gasification with Sequestration
  - Nuclear

Future pathways based on 2009 AEO Reference Case for 2020

**H₂ Threshold Cost:** $2-4/gge

Notes: Data points are being updated to the 2009 AEO reference case. The 2010 Technology Validation results show a cost range of $8-$10/gge for a 1,500 kg/day distributed natural gas and $10-$13/gge for a 1,500 kg/day distributed electrolysis hydrogen station.

Source: US DOE 09/2010
R&D Progress - Examples

Example: Truncated Chl Antenna Size

Improved photosynthetic solar –to-chemical energy conversion from 3 to 25% for photobiological hydrogen production by truncating the chlorophyll antenna size (Berkeley)

Demonstrated bandgap tailoring in photoactive MoS\(_2\) nanoparticles. Increased bandgap from 1.2eV to 1.8 eV for more optimal photoelectrochemical (PEC) water splitting (by quantum effects). (Stanford U.)

Source: Giner Electrochemical Systems, LLC

\(^2\) Total cost of delivery hydrogen ($/kg) in H2A Model Rev. 2.0 is $5.20
(Cost of delivery in Rev. 1.0.11 is $0.69; Rev 2.0, $1.92

Source: US DOE 12/2010
The Program is developing technologies to deliver hydrogen from centralized production facilities, efficiently and at low cost.

We’ve reduced the cost of hydrogen delivery* —
- ~30% reduction in tube trailer costs
- >20% reduction in pipeline costs
- ~15% reduction liquid hydrogen delivery costs

*Projected cost, based on analysis of state-of-the-art technology
Significant progress has been made but meeting all weight, volume, performance and cost requirements is still challenging.

Compressed gas storage offers a near-term option for initial vehicle commercialization and early markets

- Validated driving range of up to ~ 430 mi
- Cost of composite tanks is challenging
  - carbon fiber layer estimated to be >75% of cost
- Advanced materials R&D under way for the long term

**Projected Capacities for Complete 5.6-kg H₂ Storage Systems**

**Gravimetric Capacity (Wt-%)**

Year

2005 2006 2007 2008 2009 2010

Gravimetric Capacity 7 6 5 4 3 2 1

2015 Target

2010 Target

**Volumetric Capacity (kg-H₂/L)**

Year

2005 2006 2007 2008 2009 2010

Volumetric Capacity 60 50 40 30 20 10

2015 Target

2010 Target

Source: US DOE 12/2010

*Cost estimate in 2005 USD. Includes processing costs.*
**Manufacturing R&D**

- **Fuel Cell MEA Measurement R&D (NREL)**
  - Developed IR-based test stand to detect defects such as pinholes, shorts, and electrode thickness in variations
- **High Speed, low cost fabrication of gas diffusion electrodes for MEAs (BASF)**
  - Developed an innovative on-line XRF
  - Developed a predictive model for electrode variation and defect impacts on MEA performance
- **Developed process model for controlling GDL coating conditions (Ballard)**
  - Significant improvement in quality yields and GDL cost reduction estimated at 53% to-date in 2 years

**Near-term Goal for Early Markets**
Lower fuel cell stack manufacturing cost by $1000/kW (*from* $3,000/kW *to* $2,000/kW, *for* low-volume manufacturing)

**Project Emphasis**
- Electrode Deposition (BASF, PNNL)
- High Pressure Storage (Quantum Technologies)
- MEA Manufacturing (Gore, LBNL, RPI)
- Gas Diffusion Layer (GDL) Fabrication (Ballard)
- Effective Testing of Fuel Cell Stacks (PNNL, UltraCell)
- Effective Measurement of Fuel Cell Stacks (NREL, NIST)
Safety, Codes & Standards R&D

Separation Distances

Provided technical data and incorporated risk-informed approach that enabled NFPA2 to update bulk gas storage separation distances in the 2010 edition of NFPA55


Materials and Components Compatibility

• Performed testing of forklift tank materials to enable design qualification
• Added two additional Nickel alloy chapters to the Technical Reference

Fuel Quality Specification

• Draft International Standard (DIS) was submitted to ISO TC197 Nov 2010
• Technical Specification (TS) published and harmonized with SAE J2719, Committee Draft (CD) prepared
• Developing standardized sampling and analytical methodologies with ASTM

Safety Sensor Development

• Completed extensive life testing - 4,000 hrs and 10,000 thermal cycles - of a robust, ceramic, electrochemical Hydrogen safety sensor with exceptional baseline stability and resistance to H2 signal degradation

<table>
<thead>
<tr>
<th>Technical Performance Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity: 1 vol% H₂ in air</td>
</tr>
<tr>
<td>Temperature: -40°C to 60°C</td>
</tr>
<tr>
<td>Accuracy: 0.04-4% ±1% of full scale</td>
</tr>
<tr>
<td>Durability: 5 yrs without calibration</td>
</tr>
<tr>
<td>Response time: &lt;1 min at 1%</td>
</tr>
<tr>
<td>And &lt;1 sec at 4%</td>
</tr>
<tr>
<td>Recovery &lt;1 min</td>
</tr>
<tr>
<td>Low cross-sensitivity to humidity, H₂S, CH₄, CO, and VOCs</td>
</tr>
</tbody>
</table>
Demonstrations are essential for validating the performance of technologies in integrated systems, under real-world conditions.

**RECENT PROGRESS**

**Vehicles & Infrastructure**

- 152 fuel cell vehicles and 24 hydrogen fueling stations
- Over 2.8 million miles traveled
- Over 114 thousand total vehicle hours driven
- 2,500 hours (nearly 75K miles) durability
- Fuel cell efficiency 53-59%
- Vehicle Range: ~196 – 254 miles (independently also validated 430 mile range)

**Buses**

- DOE is evaluating real-world bus fleet data (DOT collaboration)
- H₂ fuel cell buses have a 41% to 132% better fuel economy when compared to diesel & CNG buses

**Forklifts**

- Over 18,000 refuelings at Defense Logistics Agency site

**Recovery Act**

- DOE (NREL) is collecting operating data from deployments for an industry-wide report

*Source: US DOE 09/2010*
Demonstrations are essential for validating the performance of technologies in integrated systems, under real-world conditions.
## Summary for Early Gen FCBs

<table>
<thead>
<tr>
<th>Site</th>
<th>AC Transit</th>
<th>SunLine</th>
<th>CTTRANSIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>UTC Power/Van Hool/ISE</td>
<td>UTC Power/Van Hool/ISE</td>
<td>UTC Power/Van Hool/ISE</td>
</tr>
<tr>
<td>Project Status</td>
<td>Complete, Buses Retired</td>
<td>In operation</td>
<td>In operation</td>
</tr>
<tr>
<td>Data Period</td>
<td>4/06 - 7/10</td>
<td>1/06 - 9/10</td>
<td>4/07 - 9/10</td>
</tr>
<tr>
<td>Number of buses</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Number months</td>
<td>52</td>
<td>57</td>
<td>43</td>
</tr>
<tr>
<td>Total Miles</td>
<td>253,166</td>
<td>110,118</td>
<td>46,468</td>
</tr>
<tr>
<td>Total Hours</td>
<td>25,244</td>
<td>8,411</td>
<td>7,235</td>
</tr>
<tr>
<td>Hydrogen used (kg)</td>
<td>41,317</td>
<td>15,365</td>
<td>9,585</td>
</tr>
<tr>
<td>Avg Speed (mph)</td>
<td>10</td>
<td>13</td>
<td>6.4</td>
</tr>
<tr>
<td>Fuel Economy Mi/kg</td>
<td>6.12</td>
<td>7.17</td>
<td>4.85</td>
</tr>
<tr>
<td>Fuel Economy Mi/DGE</td>
<td>6.92</td>
<td>8.10</td>
<td>5.48</td>
</tr>
<tr>
<td>Baseline technology</td>
<td>diesel</td>
<td>CNG</td>
<td>diesel</td>
</tr>
<tr>
<td>Fuel Economy difference</td>
<td>65%</td>
<td>132%</td>
<td>41%</td>
</tr>
</tbody>
</table>

- **Fuel economy consistently better than baseline buses.**
- ~450,000 miles travelled since 2005

Note: Blue shaded columns indicate completed projects – data are final

*Missing data from VTA buses from ‘05-’06

Source: US DOE 12/2010

eere.energy.gov
Potential deployment strategies envisioned for Fuel Cell Buses deployment scenario analysis identified in California’s Action Plan.

Assumptions

- Fuel cell bus fuel economy: 8 mpgge
  - ~2x diesel bus fuel economy
- Fuel cell fuel storage capacity is ~30 kg.
- Annual miles traveled: 35,000
- Fuel demand based on fuel cell bus rollout rates.

<table>
<thead>
<tr>
<th>Number of Fuel Cell Buses</th>
<th>Phase I</th>
<th>Phase II</th>
<th>Phase III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2010-2011</td>
<td>2012-2014</td>
<td>2015-2017</td>
</tr>
<tr>
<td>Buses</td>
<td>17</td>
<td>20-60</td>
<td>60-150</td>
</tr>
</tbody>
</table>

Source: US DOE 2010


doe.gov
The cost of hydrogen production from CHHP can be comparable to distributed SMR at low volumes.

Combined Heat, Hydrogen, and Power (CHHP)

• CHHP is an innovative approach that can:
  • Help establish an initial infrastructure for fueling vehicles, with minimal investment risk
  • Produce clean power and fuel for multiple applications
  • The Program is demonstrating a CHHP system using biogas.

Model Calculation of Energy Cost
- Calculated cost of energy (electricity, heat, and hydrogen)
- Electricity assumed to have the same value as purchased electricity
- Heat valued at 1/2 value of electricity
- Hydrogen value calculated by difference

Delivered Hydrogen Cost from Distributed SMR and MCFC System: NG @ $7/MMBtu

In cases where there is a low demand for hydrogen in early years of FCV deployment, CHHP may have cost advantages over on-site SMR production.
Biogas Resource Example: Methane from Waste Water Treatment

Biogas from waste water treatment plants is ideally located near urban centers to supply hydrogen for fuel cell vehicles.

- 500,000 MT per year of methane available from waste water treatment plants in U.S.
- Majority of resource located near urban centers.
- If ~50% of the bio-methane was available, ~340,000 kg/day of renewable hydrogen could be produced from steam methane reforming.
- Renewable hydrogen is enough to fuel ~340,000 fuel cell vehicles per day.

Source: NREL report A Geographic Perspective on Current Biomass Resource Availability in the United States, 2005
Select categories of biogas resources: Landfills, sewage treatment plants, and dairy farms.

California landfills offer greater biogas potential at ~1.6 million tons/yr of bio-methane.

~50% of the landfill biogas is utilized currently.

Sewage treatment plants in California produce ~0.1 million tons/yr of bio-methane.

Pipelines are reasonably accessible to most of biogas sources.

Exact locations of the number of potential applications for CHHP are being identified.

- Increased demand for DG: Annual distributed power installed has increased from ~9.5 MW to ~70 MW between 2004 and 2009.  
- Focuses on 2 urban areas (LA, San Fran.) with extremely high grid congestion.
- Focus on the other top urban areas with highest population density and most likely for early deployment of early market fuel cell buses.

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**GIS Map of California**

**Potential Sources of Biogas**

- Stranded vs. Utilized Biomethane

Source: NREL

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**Biomethane Gas**

- Landfills (Average CH4 MMBtu / Year)
- Sewage Treatment Plants (Average CH4 MMBtu / Year)
- Dairy Farms (Average CH4 MMBtu / Year)
- Natural Gas Pipelines (Diameter - Inches)

- > 1,500
- 1,000 - 1,500
- 500 - 1,000
- 100 - 500
- < 100
- > 200
- 100 - 200
- 50 - 100
- 10 - 50
- < 10
- > 40
- 30 - 40
- 20 - 30
- 10 - 20
- < 10

- 26 - 42
- 18 - 26
- 10 - 18
- < 10

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**Notes:**

Market Transformation activities seek to overcome barriers to commercialization

### BARRIERS

#### Market/Industry
- Lack of domestic supply base and high volume manufacturing. Estimated backlog > 100 MW
- Low-volume capital cost is >2-3x of targets
- Policies — e.g., many early adopters not eligible for $3,000/kW tax credit

#### Delivery Infrastructure
- Significant investment needed—~$55B gov’t funding required over 15 years for ~5.5M vehicles ($~10B for stations)*

#### Codes and Standards
- Complicated permitting process. 44,000 jurisdictions
- H₂-specific codes needed; only 60% of component standards specified in NFPA codes and standards are complete
- Need for domestic and international consistency

#### Education
- In spite of >7,000 teachers trained and online tools averaging 300-500 visits/month, negative public perception and safety concerns remain.

*2008 National Academies Study, Transitions to Alternative Transportation Technologies—A Focus on Hydrogen

### ADDRESSING BARRIERS—Example:

A government acquisition program could have a significant impact on fuel cell stack costs

![Graph showing impact of government acquisition program on fuel cell stack costs]

More than $40 million from the 2009 American Recovery and Reinvestment Act to fund 12 projects to deploy up to 1,000 fuel cells

FROM the LABORATORY to DEPLOYMENT:

DOE funding has supported R&D by all of the fuel cell suppliers involved in these projects.

Approximately $54 million in cost-share funding from industry participants—for a total of about $96 million.

<table>
<thead>
<tr>
<th>COMPANY</th>
<th>AWARD</th>
<th>APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delphi Automotive</td>
<td>$2.4 M</td>
<td>Auxiliary Power</td>
</tr>
<tr>
<td>FedEx Freight East</td>
<td>$1.3 M</td>
<td>Lift Truck</td>
</tr>
<tr>
<td>GENCO</td>
<td>$6.1 M</td>
<td>Lift Truck</td>
</tr>
<tr>
<td>Jadoo Power</td>
<td>$2.2 M</td>
<td>Portable</td>
</tr>
<tr>
<td>MTI MicroFuel Cells</td>
<td>$3.0 M</td>
<td>Portable</td>
</tr>
<tr>
<td>Nuvera Fuel Cells</td>
<td>$1.1 M</td>
<td>Lift Truck</td>
</tr>
<tr>
<td>Plug Power, Inc. (1)</td>
<td>$3.4 M</td>
<td>CHP</td>
</tr>
<tr>
<td>Plug Power, Inc. (2)</td>
<td>$2.7 M</td>
<td>Back-up Power</td>
</tr>
<tr>
<td>Univ. of N. Florida</td>
<td>$2.5 M</td>
<td>Portable</td>
</tr>
<tr>
<td>ReliOn, Inc.</td>
<td>$8.5 M</td>
<td>Back-up Power</td>
</tr>
<tr>
<td>Sprint Nextel</td>
<td>$7.3 M</td>
<td>Back-up Power</td>
</tr>
<tr>
<td>Sysco of Houston</td>
<td>$1.2 M</td>
<td>Lift Truck</td>
</tr>
</tbody>
</table>

Source: US DOE 10/2010
DOE ARRA-funded Early Market Fuel Cell Installations

(Actual and projected)

Exceeded 2010 target for Recovery Act fuel cell installations by more than 90% at 230 fuel cells installed:

- 206 lift trucks (35 with FedEx, 14 with Nuvera, 98 with Sysco, and 59 with GENCO)
- 24 telecommunication backup power units provided by ReliOn for AT&T.

Source: US DOE 12/2010
U.S. Fuel Cell Deployments Using DOE Market Transformation and Recovery Act Funding

Source: US DOE 10/2010
Example of RD&D to Deployments

**Project Example:**

- Stationary fuel cells (hundreds of kW to tens of MW) for commercial applications including combined heat and power (and/or cooling).
- Multimillion $ loan guarantee available.

*What more can Government do to accelerate commercialization?*

*Source: US DOE 12/2010*
### Section 1603: Payments in Lieu of Tax Credits

<table>
<thead>
<tr>
<th>Business</th>
<th>Property Location</th>
<th>Fuel Cell MWe</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gills Onions, LLC</td>
<td>California</td>
<td>0.6</td>
<td>$1,141,560</td>
</tr>
<tr>
<td>M&amp;L Commodities, Inc.</td>
<td>California</td>
<td>0.6</td>
<td>$997,913</td>
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<tr>
<td>Preservation Properties, Inc.</td>
<td>California</td>
<td>0.1</td>
<td>$300,000</td>
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<tr>
<td>Logan Energy Corporation</td>
<td>Hawaii</td>
<td>0.3</td>
<td>$900,000</td>
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<tr>
<td>Plug Power, Inc.</td>
<td>Illinois</td>
<td>0.28</td>
<td>$723,334</td>
</tr>
<tr>
<td>Logan Energy Corporation</td>
<td>South Carolina</td>
<td>0.05</td>
<td>$148,988</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td></td>
<td><strong>1.9</strong></td>
<td><strong>$4,211,795</strong></td>
</tr>
</tbody>
</table>

### Section 48C: Manufacturing Tax Credit

<table>
<thead>
<tr>
<th>Business</th>
<th>Location</th>
<th>Product</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>UTC Power Corporation</td>
<td>Connecticut</td>
<td>Fuel Cells</td>
<td>$5,300,100</td>
</tr>
<tr>
<td>W.L. Gore &amp; Associates</td>
<td>Maryland</td>
<td>Fuel Cell Membranes</td>
<td>$604,350</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>$5,904,450</strong></td>
</tr>
</tbody>
</table>

Source: US DOE & US Treasury 10/2010
Federal incentives, including §1603 grant-in-lieu of tax credit and §48, have helped facilitate commercial transition to fuel cell forklifts.

Examples¹:

- $660K: Central Grocers (Joliet, IL)
- $420K: United Natural Foods (Sarasota, FL)
- $600K: Sysco Foods (Houston, TX)
- $620K: Wegmans (Pottsville, PA)
- $320K: Kimberly Clark (Graniteville, SC)
- $400K: Coca-Cola Bottling (Charlotte, NC)
- $390K: Whole Foods (Landover, MD)

Other examples: H-E-B, Walmart, and more

¹ Source: Plug Power

Source: US DOE 12/2010
On October 5, 2009, President Obama signed Executive Order 13514 – Federal Leadership in Environmental, Energy, and Economic Performance

- Requires Agencies to:
  - Set GHG reduction Targets
  - Develop Strategic Sustainability Plans and provide in concert with budget submissions
  - Conduct bottom up Scope 1, 2 and 3 baselines
  - Track performance

Examples:
- **Achieve** 30% reduction in vehicle fleet petroleum use by 2020
- **Requires** 15% of buildings meet the Guiding Principles for High Performance and Sustainable Buildings by 2015
- **Design** all new Federal buildings which begin the planning process by 2020 to achieve zero-net energy by 2030

Potential opportunities for fuel cells and other clean energy technologies....

Source: US DOE 09/2010

http://www1.eere.energy.gov/femp/regulations/ eo13514.html
Budget
## Funding ($ in thousands)

<table>
<thead>
<tr>
<th>Key Activity</th>
<th>FY 2008</th>
<th>FY 2009</th>
<th>FY 2010</th>
<th>FY 2011 Request</th>
<th>FY 2011 House</th>
<th>2011 Senate</th>
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</thead>
<tbody>
<tr>
<td>Fuel Cell Systems R&amp;D</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>67,000</td>
<td>67,000</td>
<td>67,000</td>
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<tr>
<td>Fuel Cell Stack Component R&amp;D</td>
<td>42,344</td>
<td>61,133</td>
<td>62,700</td>
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<td>Transportation Systems R&amp;D</td>
<td>7,718</td>
<td>6,435</td>
<td>3,201</td>
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<td>Distributed Energy Systems R&amp;D</td>
<td>7,461</td>
<td>9,750</td>
<td>11,410</td>
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<tr>
<td>Fuel Processor R&amp;D</td>
<td>2,896</td>
<td>2,750</td>
<td>171</td>
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<tr>
<td>Hydrogen Fuel R&amp;D</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>40,000</td>
<td>40,000</td>
<td>47,000</td>
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<tr>
<td>Hydrogen Production &amp; Delivery R&amp;D</td>
<td>38,607</td>
<td>10,000</td>
<td>15,000</td>
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<td>Hydrogen Storage R&amp;D</td>
<td>42,371</td>
<td>57,823</td>
<td>32,000</td>
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<tr>
<td>Technology Validation</td>
<td>29,612</td>
<td>14,789</td>
<td>13,097</td>
<td>11,000</td>
<td>11,000</td>
<td>20,000</td>
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<tr>
<td>Market Transformation</td>
<td>0</td>
<td>4,747</td>
<td>15,026</td>
<td>0</td>
<td>0</td>
<td>20,000</td>
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<td>Safety, Codes &amp; Standards</td>
<td>15,442</td>
<td>12,238</td>
<td>8,839</td>
<td>9,000</td>
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<td>Education</td>
<td>3,865</td>
<td>4,200</td>
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<td>Systems Analysis</td>
<td>11,099</td>
<td>7,520</td>
<td>5,556</td>
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<td>Manufacturing R&amp;D</td>
<td>4,826</td>
<td>4,480</td>
<td>5,000</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>$206,241</strong></td>
<td><strong>$195,865</strong></td>
<td><strong>$174,000</strong></td>
<td><strong>$137,000</strong></td>
<td><strong>$137,000</strong></td>
<td><strong>$174,000</strong></td>
</tr>
</tbody>
</table>

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2. Hydrogen Fuel R&D includes Hydrogen Production & Delivery R&D and Hydrogen Storage R&D.
3. Market Transformation will fund only Safety, Codes and Standards in FY 2011.
4. FY 2009 Recovery Act funding of $42.967M not shown in table.
5. Includes SBIR/STTR funds to be transferred to the Science Appropriation; all prior years shown exclude this funding.
Total DOE Hydrogen and Fuel Cell Technologies
FY11 Budget Request (in millions of US$)

- Fuel Cell Systems R&D: 67
- Hydrogen Fuel R&D: 52
- Technology Validation: 50
- Market Transformation and Safety, Codes & Standards: 5
- Manufacturing R&D: 12
- Systems Analysis: 11
- Total FY11 Budget Request: $256 Million

Source: US DOE 09/2010

*NE: $5M represents FY10 funding
**SC Includes BES and BER
Key Publications
Program Plan

Describes the planned RD&D activities for hydrogen and fuel cell technologies

- Update to the Hydrogen Posture Plan published in 2006
- Addresses previous reviews (e.g. GAO, HTAC, NAS, etc.)
- Hard copy of Draft available for HTAC review and comment

Draft available 10/22/10 for stakeholder public comment until 11/30/10. Final will be published in early 2011.

DOEH2ProgramPlan@ee.doe.gov

Source: US DOE 10/2010
Program Plan includes Portfolio

The Role of Federal Research, Development, and Demonstration

- **Federal RD&D**
- **Commercialization and Ongoing Industry Improvements**

**Backup Power Systems**

**Primary Power Systems (Including CHP)**

**Specialty Vehicles (eg., forklifts)**

**Auxiliary Power Units for Transportation**

**Transit Buses**

**Fuel Cell Vehicles – Government & Fleets**

**Fuel Cell Vehicles – Widespread Commercialization**

**Portable Power**

**Hydrogen Fuel**

- **Hydrogen for Early Market**
- **Ongoing R&D to provide renewable, low-cost hydrogen for widespread markets**

**Stationary Power**

**Transportation**

**Portable Power**

**Near Term** → **Mid Term** → **Long Term**
The Business Case for Fuel Cells: Why Top Companies are Purchasing Fuel Cells Today
Profile of 38 companies who have ordered, installed, or deployed fuel cell forklifts, stationary fuel cells or fuel cell units.

2009 Fuel Cell Technologies Market Report
By Breakthrough Technologies Institute, http://www.btionline.org/
This report describes data compiled in 2010 on trends in the fuel cell industry for 2009 with some comparison to previous years. (July 2010).

Molten Carbonate and Phosphoric Acid Stationary Fuel Cells: Overview and Gap Analysis
By NREL and DJW Technology, LLC
This report describes the technical and cost gap analysis performed to identify pathways for reducing the costs of molten carbonate fuel cell (MCFC) and phosphoric acid fuel cell (PAFC) stationary fuel cell power plants.

Fuel Cell Today 2009 Market Analysis
The report describes sales of fuel cells in US and worldwide.
October 2010
Key Findings:

- Transition policies will be essential to overcome initial economic barriers.
- Cost-sharing & tax credits (2015 – 2025) would enable industry to be competitive in the marketplace by 2025.
- With targeted deployment policies from 2012 to 2025, FCV market share could grow to 50% by 2030, and 90% by 2050.
- Cost of these policies is not out of line with other policies that support national goals.
  - The annual cost would not exceed $6 billion—federal incentives for ethanol are expected to cost more than $5 billion/year by 2010.
  - Cumulative costs would range from $10 billion to $45 billion, from 2010 to 2025—federal incentives for ethanol have already cost more than $28 billion, and these cumulative costs are projected to exceed $40 billion by 2010.

NAS study, “Transitions to Alternative Transportation Technologies: A Focus on Hydrogen,” shows positive outlook for fuel cell technologies—results are similar to ORNL’s “Transition Scenario Analysis.”

The study was required by EPACT section 1825 and the report was released in 2008, by the Committee on Assessment of Resource Needs for Fuel Cell and Hydrogen Technologies.

www.nap.edu/catalog.php?record_id=12222

Key Findings Include:

• By 2020, there could be 2 million FCVs on the road. This number could grow rapidly to about 60 million by 2035 and 200 million by 2050.

• Government cost to support a transition to FCVs (for 2008 – 2023) estimated to be $55 billion—about $3.5 billion/year.

• The introduction of FCVs into the light-duty vehicle fleet is much closer to reality than when the NRC last examined the technology in 2004—due to concentrated efforts by private companies, together with the U.S. FreedomCAR & Fuel Partnership and other government-supported programs around the world.

• A portfolio of technologies has the potential to eliminate petroleum use in the light-duty vehicle sector and to reduce greenhouse gas emissions from light-duty vehicles to 20 percent of current levels—by 2050.

Estimated Government Cost to Support a Transition to FCVs

Source: US DOE 12/2010
The fuel cell and hydrogen industries could generate substantial revenues and job growth.

Renewable Energy Industry Study*

- Fuel cells are the third-fastest growing renewable energy industry (after biomass & solar).
- Potential U.S. employment from fuel cell and hydrogen industries of up to 925,000 jobs (by 2030).
- Potential gross revenues up to $81 Billion/year (by 2030).

DOE Employment Study

- Projects net increase of 360,000 – 675,000 jobs.
- Job gains would be distributed across up to 41 industries.
- Workforce skills would be mainly in the vehicle manufacturing and service sectors.

Total Jobs Created by Hydrogen and Fuel Cell Industries
(includes direct and indirect employment)

*Study Conducted by the American Solar Energy Society

Close to 30 hydrogen and fuel cell technologies developed by the Program entered the market.

Accelerating Commercialization

EERE-funded Fuel Cell Technologies that are Commercially Available

198 PATENTS resulting from EERE-funded R&D:
- 99 fuel cell
- 74 H₂ production and delivery
- 25 H₂ storage

60% are actively used in:
1) Commercial products
2) Emerging technologies
3) Research

Completed Fuel Cell Market Report provides an overview of market trends and profiles for select fuel cell companies

Source: Pacific Northwest National Laboratory
Key Program Documents

Annual Merit Review & Peer Evaluation Proceedings
Includes downloadable versions of all presentations at the Annual Merit Review
- Latest edition released June 2010
  www.hydrogen.energy.gov/annual_review10_proceedings.html

Annual Merit Review & Peer Evaluation Report
Summarizes the comments of the Peer Review Panel at the Annual Merit Review and Peer Evaluation Meeting
- Released January 2011
  http://www.hydrogen.energy.gov/annual_review10_report.html

Annual Progress Report
Summarizes activities and accomplishments within the Program over the preceding year, with reports on individual projects
- To be released 2011
  www.hydrogen.energy.gov/annual_progress.html

Next Annual Review: May 9 – 13, 2011
Washington, D.C.
http://annualmeritreview.energy.gov/
Collaborations

**Federal Agencies**
- DOC • EPA • NASA
- DOD • GSA • NSF
- DOE • DOI • USDA
- DOT • DHS • USPS

- Interagency coordination through staff-level Interagency Working Group (meets monthly)
- Assistant Secretary-level Interagency Task Force mandated by EPACT 2005.

**Universities**
~ 50 projects with 40 universities

**International**
- IEA implementing agreements – 25 countries
- International Partnership for Hydrogen & Fuel Cells in the Economy – 17 countries & EC, 30 projects

**DOE Fuel Cell Technologies Program***
- **Applied RD&D**
- **Efforts to Overcome Non-Technical Barriers**
- **Internal Collaboration with Fossil Energy, Nuclear Energy and Basic Energy Sciences**

**Industry Partnerships & Stakeholder Assn’s.**
- FreedomCAR and Fuel Partnership
- Fuel Cell and Hydrogen Energy Association (FCHEA)
- Hydrogen Utility Group
- ~ 65 projects with 50 companies

**State & Regional Partnerships**
- California Fuel Cell Partnership
- California Stationary Fuel Cell Collaborative
- SC H₂ & Fuel Cell Alliance
- Upper Midwest Hydrogen Initiative
- Ohio Fuel Coalition
- Connecticut Center for Advanced Technology

**National Laboratories**
- National Renewable Energy Laboratory
  - P&D, S, FC, A, SC&S, TV, MN
- Argonne
  - A, FC, P&D, SC&S
- Los Alamos
  - S, FC, SC&S
- Sandia
  - P&D, S, SC&S
- Pacific Northwest
  - P&D, S, FC, SC&S, A
- Oak Ridge
  - P&D, S, FC, A, SC&S
- Lawrence Berkeley
  - FC, A
- Lawrence Livermore
  - P&D, S, SC&S
- Savannah River
  - S, P&D
- Brookhaven
  - S, FC
- Idaho National Lab
  - P&D

**Other Federal Labs:** Jet Propulsion Lab, National Institute of Standards & Technology, National Energy Technology Lab (NETL)

*Office of Energy Efficiency and Renewable Energy*
Thank you

For more information, please contact

Sunita.Satyapal@ee.doe.gov

hydrogenandfuelcells.energy.gov
Additional Information
Fuel Cell FOA

• Up to $65 million over three years to fund continued R&D on fuel cell components. Topics include:
  1. Balance-of-Plant components
  2. Fuel Processors
  3. High Temperature Stack Component Research
  4. PEMFC MEA Integration
  5. Catalysts/Electrodes
  6. Membranes
  7. Innovative Concepts

Letter of Intent Due: January 28, 2011
Applications Due: March 3, 2011
New Solicitations

Cost Analysis FOA

- Up to $9 million to conduct independent cost analyses. Topics include:
  1. Transportation PEM Fuel Cell System Cost Assessment
  2. Stationary and Emerging Market Fuel Cell System Cost Assessment
  3. Hydrogen Storage System Assessment

Applications Due: February 18, 2011

Source: US DOE 12/2010