FUEL CELL TECHNOLOGIES PROGRAM

Stakeholders Webinar – Budget Briefing

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy


# Overview of Hydrogen & Fuel Cell Budget

February 24, 2011

**Sunita Satyapal**

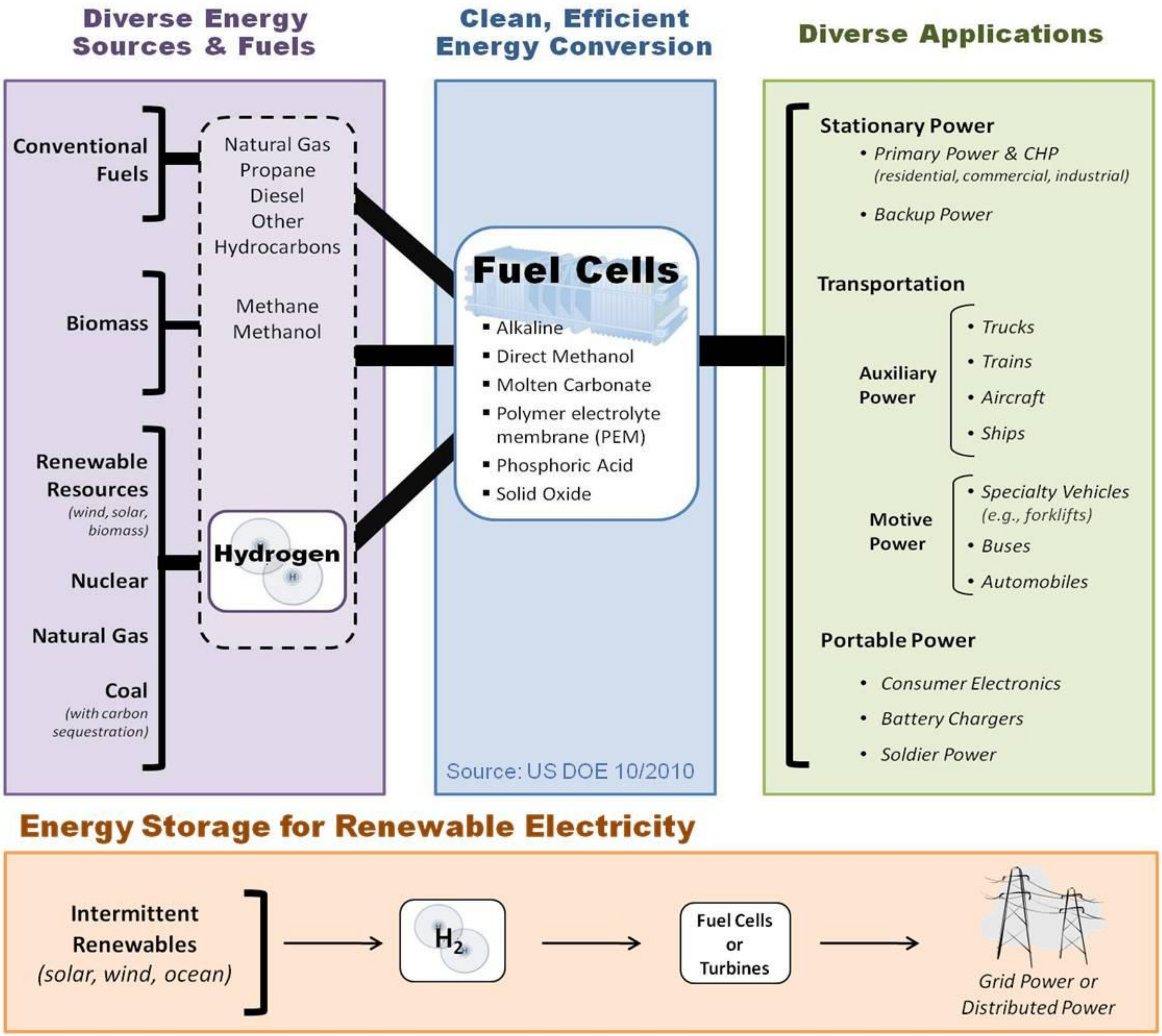
U.S. Department of Energy

Fuel Cell Technologies Program

Program Manager

# Fuel Cells: For Diverse Applications





## The FY 2012 Budget Request:

- Develop cost competitive hydrogen and fuel cell technologies for diverse applications to meet long-term goals of $30/kW for transportation, $750/kW for stationary power, and $2-4/gge for hydrogen production and delivery.

### Continues New Sub-programs for:

- ***Fuel Cell Systems R&D***
  - Consolidates four sub-programs: *Fuel Cell Stack Components R&D, Transportation Fuel Cell Systems, Distributed Energy Fuel Cell Systems*, and *Fuel Processor R&D*
  - Technology-neutral fuel cell systems R&D for diverse applications
- ***Hydrogen Fuel R&D***
  - Consolidates *Hydrogen Production & Delivery* and *Hydrogen Storage* activities
- **Recognizes critical need for Safety Codes and Standards**

### Defers funding for:

- **Education**
- **Market Transformation** (Due to deployments and ongoing data collection and analyses underway through the Recovery Act)

# FY 12 Budget Background



- The FY 2012 Hydrogen and Fuel Cells request allows the Department to sustain a balanced research and development (R&D) portfolio, with emphasis on batteries and advanced vehicles, as well as on renewable power and energy efficiency.
  - DOE funding has already reduced the cost of fuel cells by more than 80% since 2002 and by 30% since 2008[1]. Hydrogen and fuel cell technologies are still part of the portfolio but will have an impact in the longer term.
- To enable domestic competitiveness, EERE will continue to support R&D of hydrogen and multiple types of fuel cells for diverse applications (in stationary power, portable power, and transportation, including fuel cell vehicles).
- DOE's Recovery Act funding ($43 million) will deploy up to 1,000 fuel cells for early market applications and will provide data and lessons-learned from early market deployments
  - Funding has been reduced for aspects of the program with less impact on R&D progress, such as Market Transformation.
  - Further Market Transformation and Education activities are deferred until results from Recovery Act funding are available.

[1] http://www.hydrogen.energy.gov/pdfs/10004_fuel_cell_cost.pdf

# DOE $H_2$ & Fuel Cells Budgets: *FY07 – FY12*

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

| | Funding *($ in thousands)* | | | | |
|---|---|---|---|---|---|
| | FY 2007 Approp. | FY 2008 Approp. | FY 2009 Approp. | FY 2010 Approp. | FY 2012 Request |
| EERE Hydrogen & Fuel Cells | 189,511 | 206,241 | 195,865 | 174,000[2] | 100,450 |
| Fossil Energy (FE)[1] | 21,513 | 21,773 | 26,400 | 26,400 | 0 |
| Nuclear Energy (NE) | 18,855 | 9,668 | 7,500 | 5,000 | TBD |
| Science (SC) | 36,388 | 36,484 | 38,284 | 38,284 | TBD |
| **DOE TOTAL** | **266,267** | **276,481** | **268,049** | **243,684** | **TBD** |

**Note: No funding requested for SECA Program FY12 (FE)**

# EERE $H_2$ & Fuel Cells Budgets

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

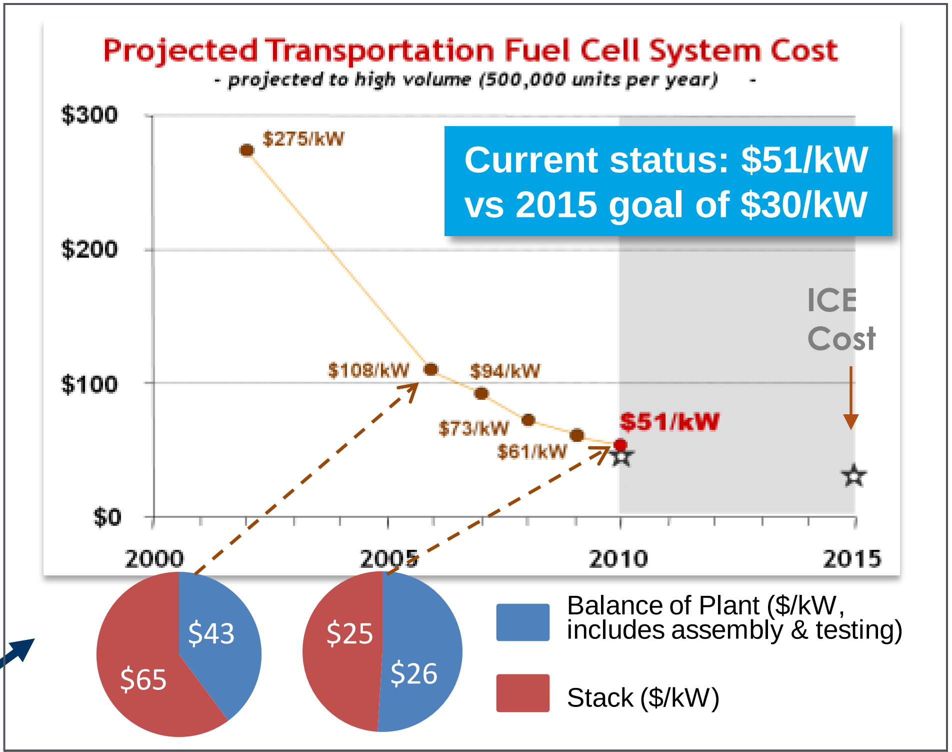
| Funding *($ in thousands)* | | | |
|---|---|---|---|
| ***Key Activity*** | **FY 2009[4]** | **FY 2010 Current Appropriation** | **FY 2012 Request** |
| **Fuel Cell Systems R&D[1]** | **-** | **75,609** | **45,450** |
| Fuel Cell Stack Component R&D | 61,133 | | |
| Transportation Systems R&D | 6,435 | | - |
| Distributed Energy Systems R&D | 9,750 | | - |
| Fuel Processor R&D | 2,750 | | - |
| **Hydrogen Fuel R&D[2]** | **-** | **45,750** | **35,000** |
| Hydrogen Production & Delivery R&D | 10,000 | | - |
| Hydrogen Storage R&D | 57,823 | | - |
| **Technology Validation** | **14,789[5]** | **13,005** | **8,000** |
| **Market Transformation[3]** | **4,747** | **15,005** | **-** |
| Early Markets | 4,747 | 15,005 | - |
| Safety, Codes & Standards | 12,238[5] | 8,653 | 7,000 |
| Education | 4,200[5] | 2,000 | - |
| **Systems Analysis** | **7,520** | **5,408** | **3,000** |
| **Manufacturing R&D** | **4,480** | **4,867** | **2,000** |
| **Total** | **$195,865** | **$170,297** | **$100,450[6]** |

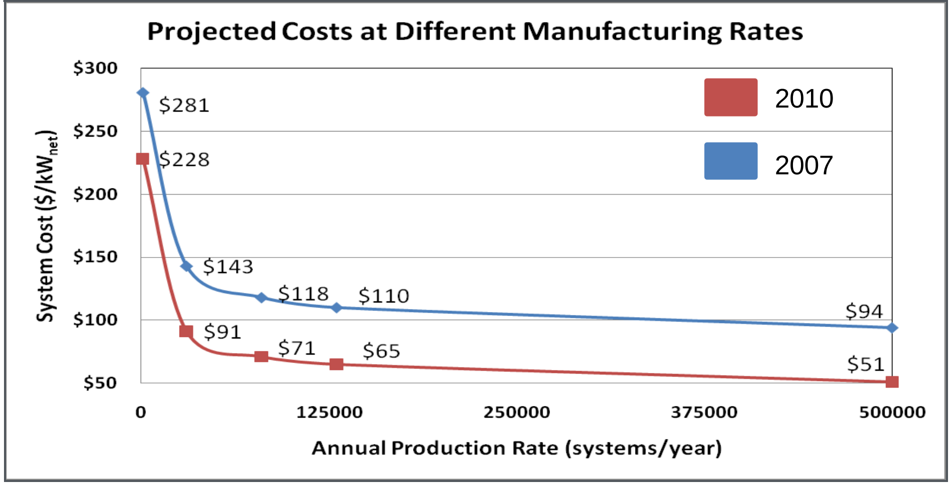
[1] Fuel Cell Systems R &D includes Fuel Cell Stack Component R&D, Transportation Systems R&D, Distributed Energy Systems R&D, and Fuel Processor R&D [2] Hydrogen Fuel R&D includes Hydrogen Production & Delivery R&D and Hydrogen Storage R&D [3] No Market Transformation in FY 2012. [4] FY 2009 Recovery Act funding of $42.967M not shown in table [5] Under Vehicle Technologies Budget in FY 2009 [6] Includes SBIR/STTR funds to be transferred to the Science Appropriation; all prior years shown exclude this funding

**DOE-funded efforts have reduced the projected high-volume cost of fuel cells 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*

# Fuel Cell R&D — *Progress*

***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:**

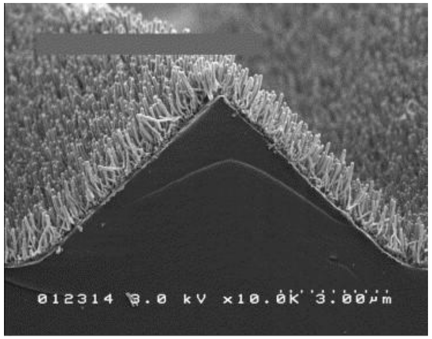
- **Reducing platinum group metal content from 0.35 to 0.18 g/kW**
- **Increasing power density from 715 to 833 mW/cm$^2$**
- **Simplifying balance of plant**

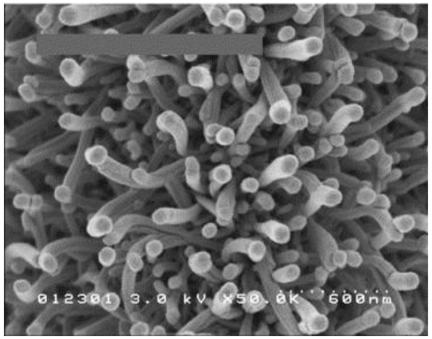
**→ These advances contributed to a $22/kW cost reduction.**

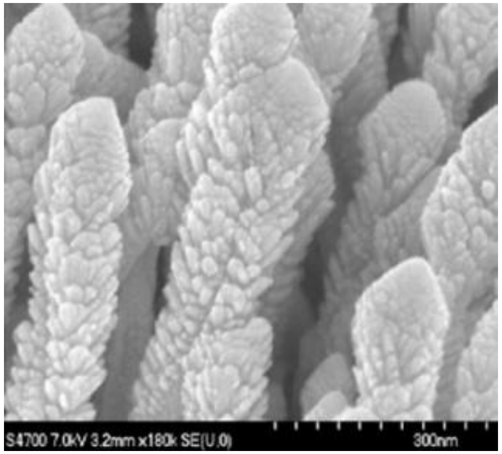
Key improvements enabled by using novel organic crystalline whisker catalyst supports and Pt-alloy whiskerettes.

There are ~ 5 billion whiskers/cm$^2$.

Whiskers are ~ 25 X 50 X 1000 nm.




Whiskerettes:
6 nm x 20 nm

**Source: 3M**

# Fuel Cell Systems R&D: *Key FY 2012 Activities*

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

***Continue R&D of fuel cell systems for stationary, portable, and transportation applications, using multiple technologies (including PEM, solid oxide, and alkaline fuel cells) and a variety of fuels (including hydrogen, diesel, natural gas, and bio-derived renewable fuels).***

## The Program will continue its emphasis on:

- Science & engineering at the cell level
- Integration and component interactions at the systems level
- Balance-of-plant components (such as water transport, sensors, and air compression)

## Key R&D areas (*core technologies*):

- **Catalysts** Focus on approaches that will increase activity and utilization of current PGM and PGM-alloy catalysts, as well as non-PGM catalyst approaches for long-term applications.
- Develop **high-temperature membranes** that will reduce the negative effects of impurities and decrease the size of the cooling system.
- Improve **PEM-MEAs** (for stationary and transportation applications) through integration of MEA components.
- Develop **transport models** and in-situ and ex-situ experiments to provide data for model validation.
- Identify **degradation mechanisms** and develop approaches to mitigate their effects.
- Investigate and quantify **effects of impurities** on fuel cell performance.
- **Durability & accelerated stress-testing**—determine their correlation with real-world degradation.
- **BOP component** development such as sensors, air compression, and humidifiers

## Applications—examples of systems R&D in FY 2012

- **Portable Power. Focus on materials improvements for direct-methanol fuel cells.**
  - Reduce anode & cathode catalyst loading, while improving catalytic activity and durability.
  - Improve membranes, to reduce crossover and increase proton conductivity.

- **Stationary distributed power generation**

  Includes integrated FC systems for distributed power generation and CHP applications

  - Develop FC systems for µ-CHP (1-10 kW) for residential and light commercial applications
  - Improve stack components for high-temperature fuel cells including PEM-PBI-type and SOFC
  - Develop **BOP components**, such as sensors and blowers
  - For **fuel processors**, concentrate on component integration, fuel flexibility, and clean-up of deleterious fuel components

# Funding Opportunity Announcements (FOAs) Pending FY11 Appropriations

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

## 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**

## Cost Analysis FOA

Up to $9 million to conduct independent cost analyses. Topics include:

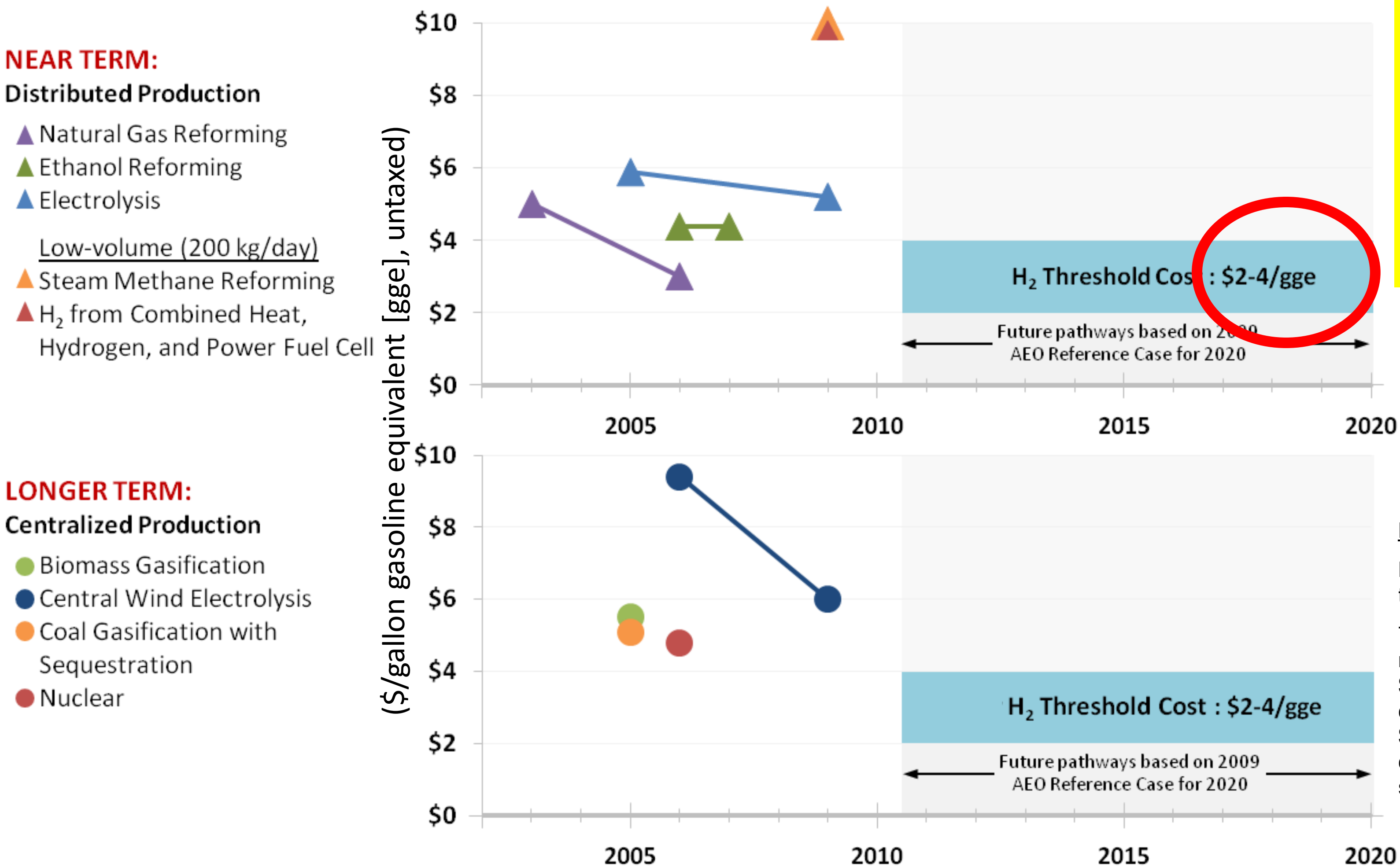
1. Transportation PEM Fuel Cell System Cost Assessment
2. Stationary and Emerging Market Fuel Cell System Cost Assessment
3. Hydrogen Storage System Assessment

**Applications Due: February 18, 2011**

***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

Being updated to address gasoline cost volatility and range of vehicle assumptions



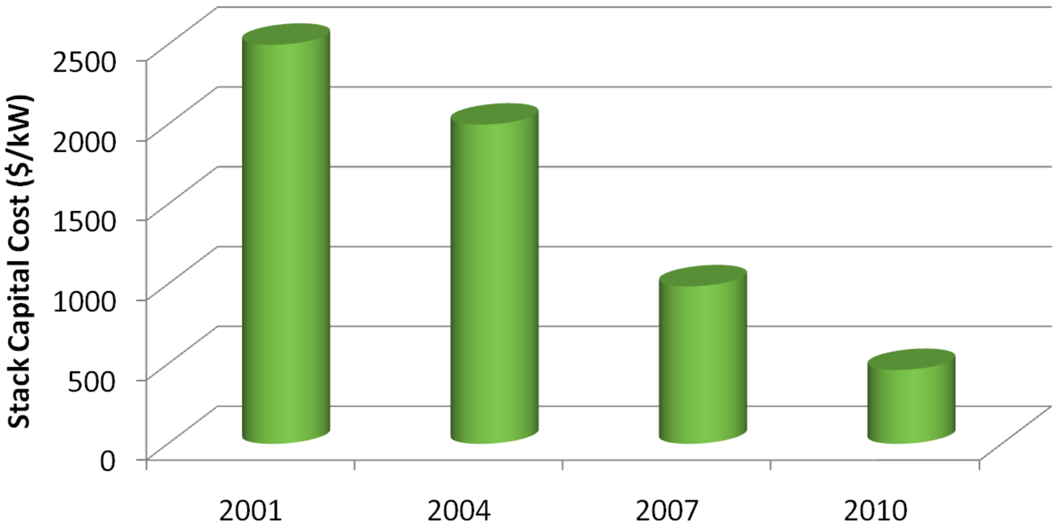

Notes:

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.

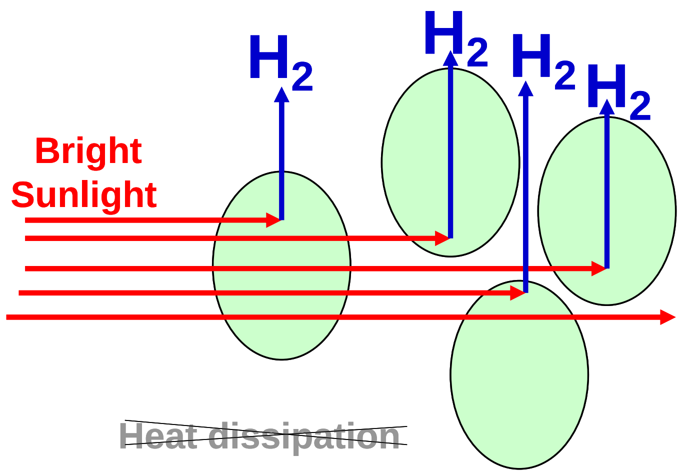
# R&D Progress - Examples

**Production: Reduced Electrolyzer Stack Cost by over 80% since 2001[2]**




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

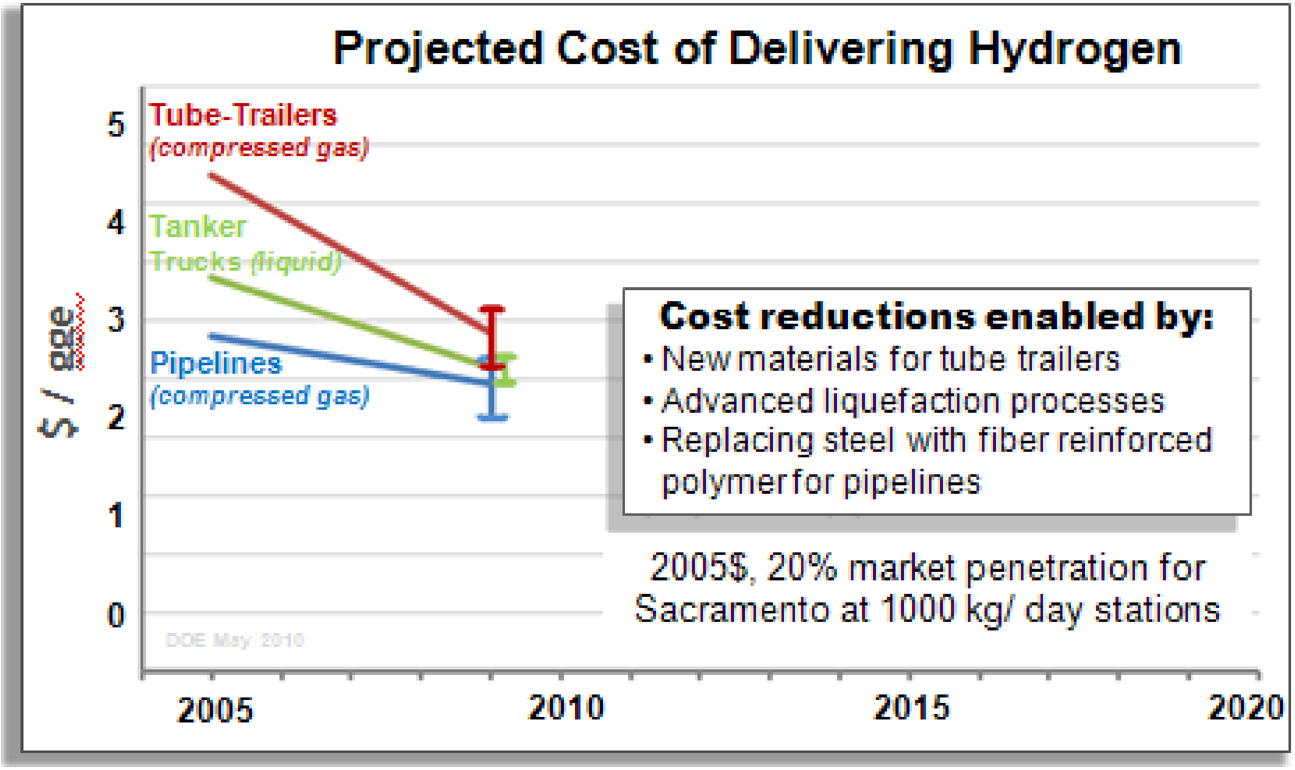
**Example: Truncated Chl Antenna Size**




UC Berkeley

- 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.)

***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**

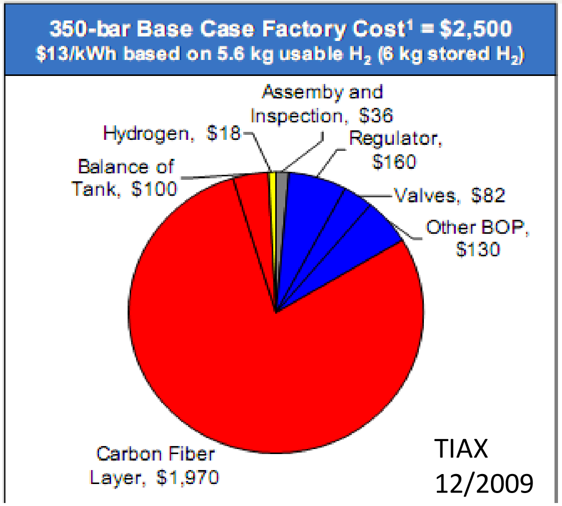
***Projected cost, based on analysis of state-of-the-art technology**

# $H_2$ Storage R&D

***Significant progress has been made but meeting all weight, volume, performance and cost requirements is still challenging.***

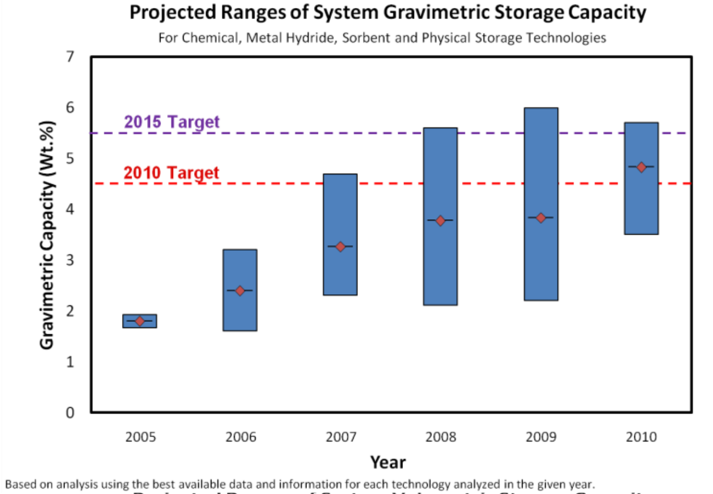
Compressed gas storage offers a near-term option for initial vehicle commercialization and early markets

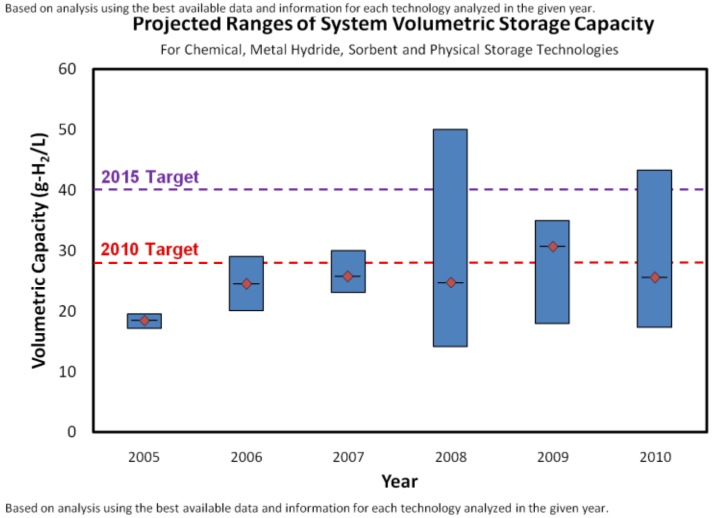
- Validated driving range of up to ~ 430 mi
- Cost of composite tanks is challenging
    - carbon fiber layer estimated to be >75% of cost
- Advanced materials R&D under way for the long term




[1] Cost estimate in 2005 USD. Includes processing costs.

## Projected Capacities for Complete 5.6-kg $H_2$ Storage Systems



# **Hydrogen Fuel R&D:** *Key FY 2012 Activities*



***Focuses on materials research and technology to address key challenges to hydrogen production, delivery, and storage, and to enable low-cost, carbon-free hydrogen fuels from diverse renewable pathways.***

***→ Request focuses on continuing funding to existing projects.***

## Production R&D key focus areas for FY 2012:

Achieve a 25% reduction in electrolyzer capital cost reducing the projected hydrogen cost from $6/gge in 2009 to less than $5/gge.

Develop materials with photoelectrochemical conversion efficiency of 10% compared to a 4% baseline, reducing the projected hydrogen cost from $6/gge in 2009 to less than $5/gge .

. Improve the durability of high-efficiency PEC materials to 1000 hours.

→***Production R&D, ongoing work:*** *Existing projects in longer-term centralized production will continue (including **solar thermochemical** and **biological**).*

## Delivery R&D key focus areas for FY 2012:

Work towards increasing the pressure capability of electrochemical hydrogen compression from 6,000 to 12,000 psi for potential use in hydrogen stations in the long term.

Develop fiberglass-based storage vessels that exhibit high pressure capacities to enable 7000 psi and a~ 50% reduction in cost relative to carbon-fiber wrapped tanks in the long term.

***Focuses on materials research and technology to address key challenges to hydrogen production, delivery, and storage, and to enable low-cost, carbon-free hydrogen fuels from diverse renewable pathways.***

***→ Request focuses on continuing funding to existing projects.***

## Storage R&D key focus areas for FY 2012:

**Engineering Center of Excellence** will continue advancing complete system engineering design of materials-based technologies.

**Material and system development** will continue for early market applications as well as for automotive applications.

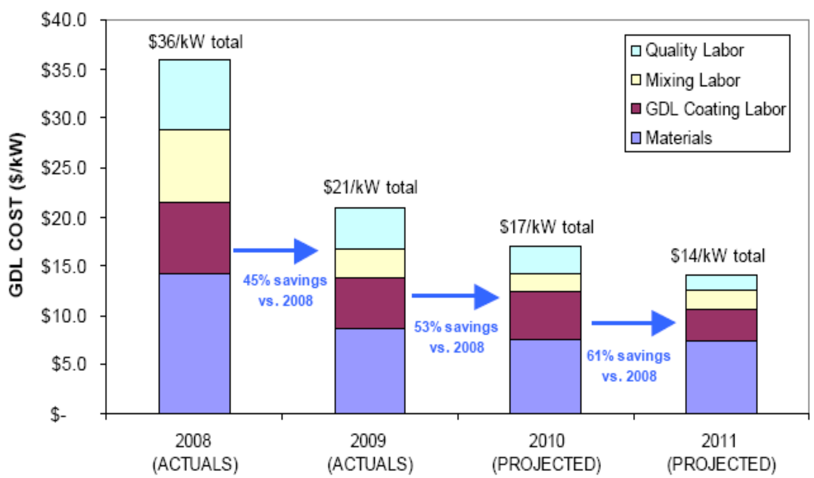
Include efforts to lower cost for high strength carbon fiber for compressed gas storage vessels.

**$H_2$ for Energy Storage will be included, pending FY11 appropriations**

# 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

## GDL Actual Costs




Source: Ballard

## 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)

# **Manufacturing R&D:** *Key FY 2012 Activities*

***Manufacturing R&D will continue to develop processes and technologies to enable low-cost, high-volume manufacturing of hydrogen and fuel cell technologies. Near-term activities will encompass R&D of technologies critical to an early start-up of high-volume commercialized products.***

## Key Focus Area:

**Develop low-cost, high-volume continuous in-line MEA quality control measurement technologies in 2012, on track to develop continuous fabrication and assembly processes for polymer electrolyte membranes by 2016.**

## EMPHASIS

- Workshop will help prioritize key areas for manufacturing R&D under budget constraints
  - Novel fabrication methods for MEAs
  - MEA and stack assembly processes
  - Reduce costs for stack conditioning and leak testing
  - Lower costs for high pressure carbon composite tanks

***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)
- $H_2$ 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

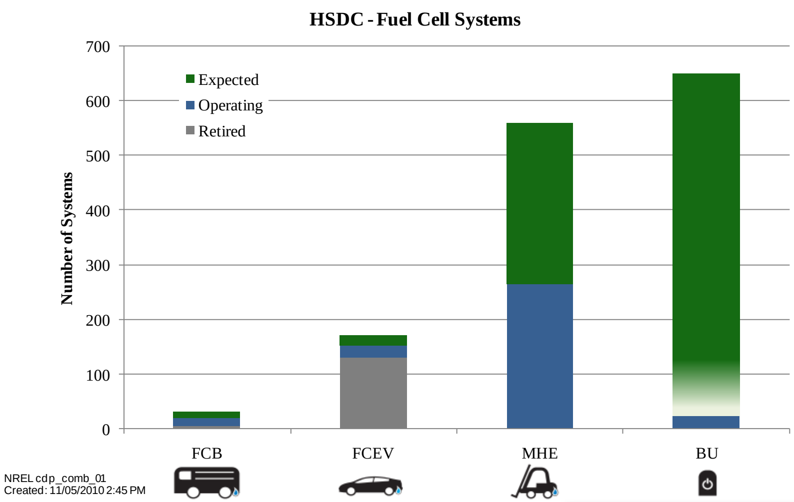


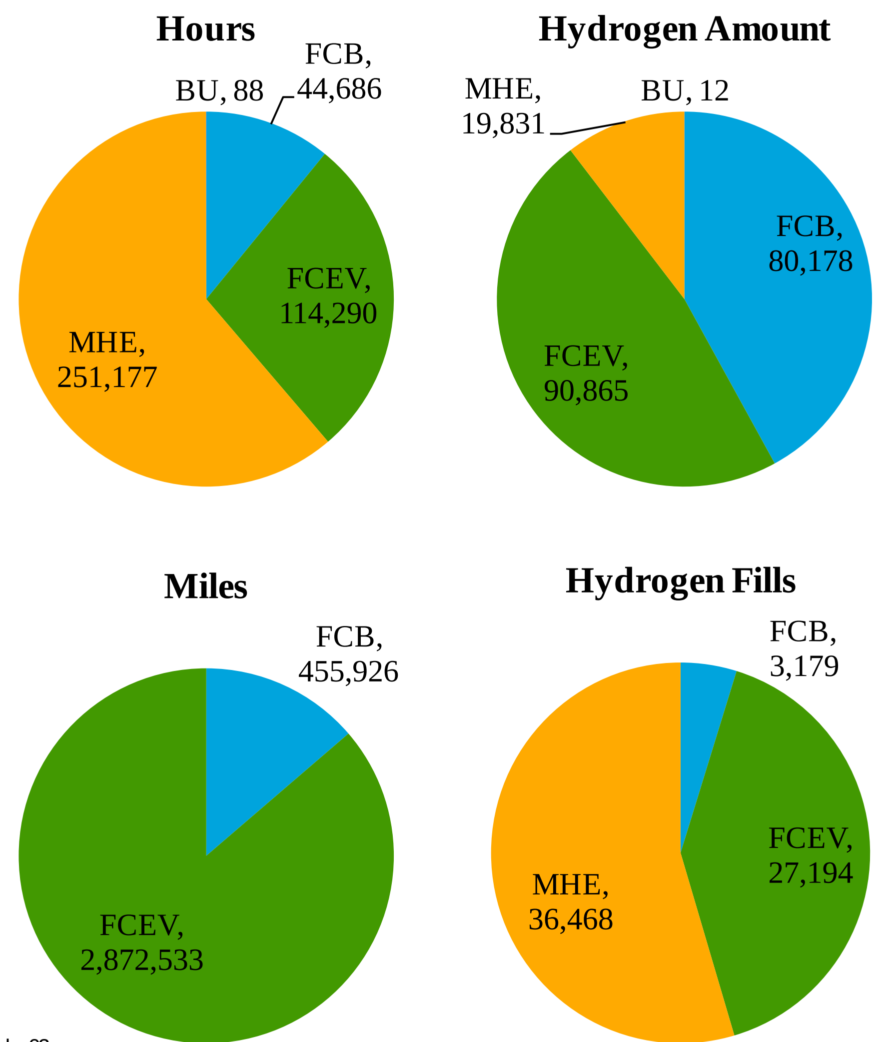
Source: US DOE 09/2010

# Technology Validation

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

***Demonstrations are essential for validating the performance of technologies in integrated systems, under real-world conditions.***




NREL cdp_comb_02
Created: 11/15/2010 9:45 AM

***Continue early-market-application data collection and conduct limited validation activities to address fuel cell systems used in stationary power applications, mass-transit, and light-duty vehicles***

## FY 2012 Activities

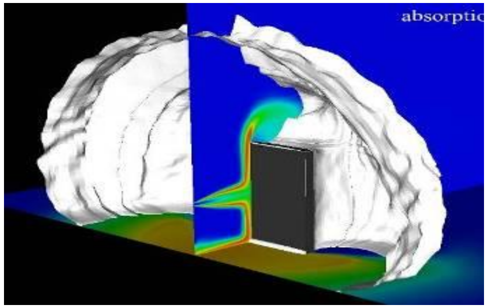
- **Data Collection Activities** Demonstration projects will continue with data collection and operation of backup power systems and specialty vehicles; collaboration with DOT on the Fuel Cell Bus Program will continue; and support for CHHP (*combined heat, hydrogen, and power*) demonstration will continue (in collaboration with the California Air Resources Board and the South Coast Air Quality Management District).

- **Other Activities** Issue a Funding Opportunity Announcement for projects related to residential stationary fuel cells, Combined hydrogen heat hydrogen and power fuel cell systems and Auxiliary Power Units for aircraft and heavy duty trucks (Request for Information planned for stakeholder input).

## Separation Distances

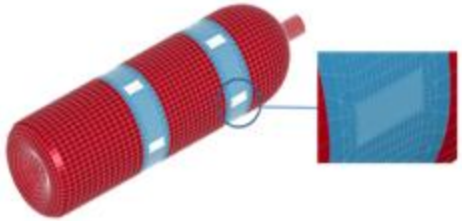
Provided technical data and incorporated risk-informed approach that enabled NFPA2 to update bulk gas storage separation distances in the 2010 edition of NFPA55

Barrier walls reduce separation distances – simulated position of allowable heat flux iso-surface for 3-minute employee exposure (2009 IFC).



## 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

| Technical Performance Requirements | |
|---|---|
| Sensitivity: 1 vol% $H_2$ in air | Temperature: -40°C to 60°C |
| Accuracy: 0.04-4%<br>±1% of full scale | Durability: 5 yrs without calibration |
| Response time: <1 min at 1%<br>And <1 sec at 4%<br>Recovery <1 min | Low cross-sensitivity to humidity, $H_2S$, $CH_4$, CO, and VOCs |

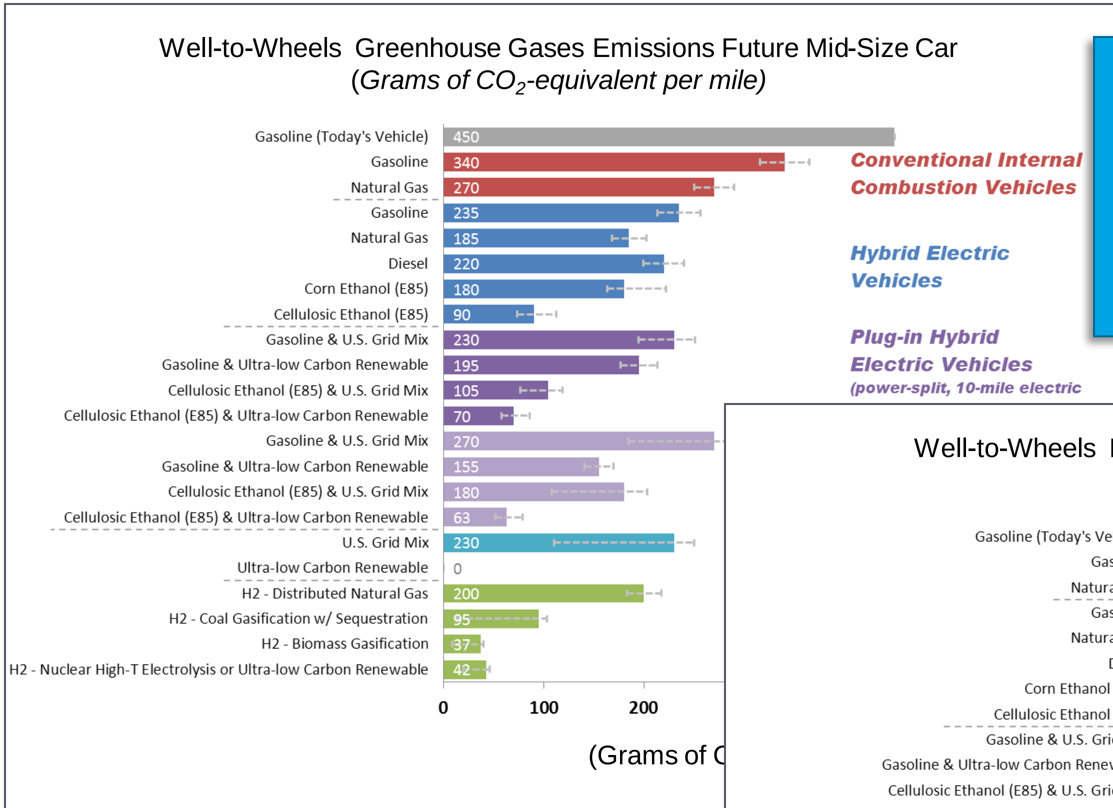
***Continue critical R&D needed for the development of codes and standards and develop and disseminate safety best practices and lessons learned.***

## The Program will continue emphasis on:

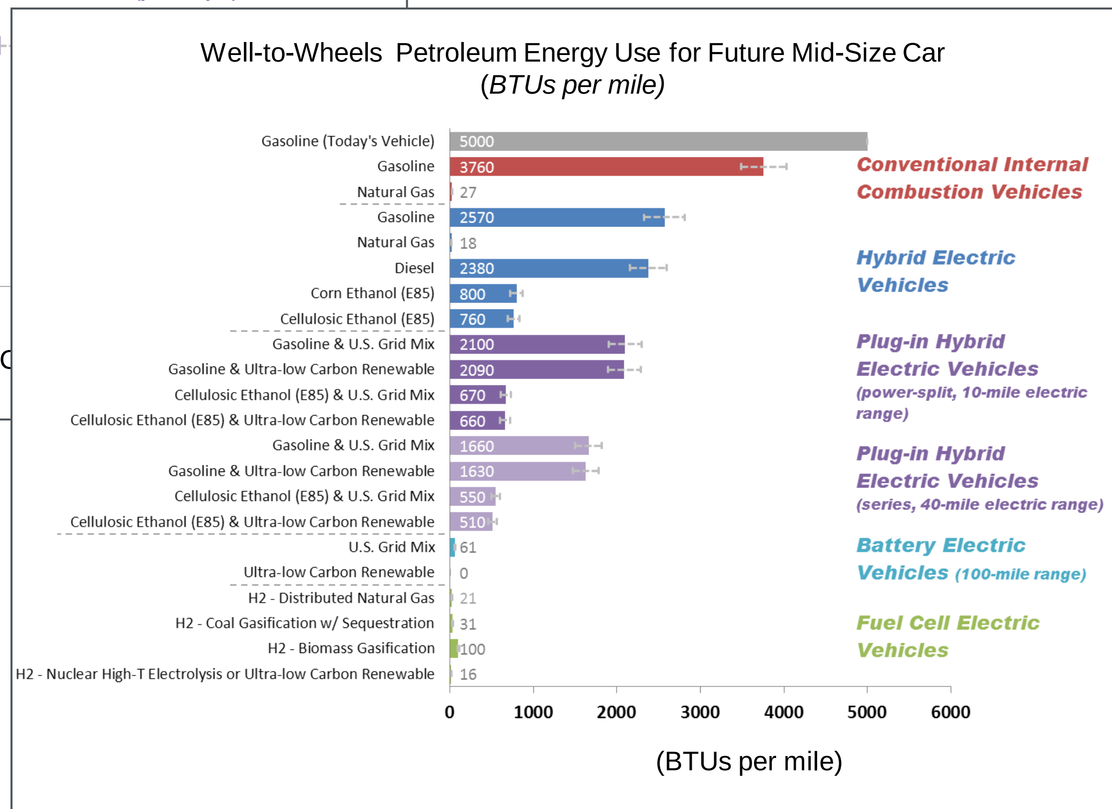
- R&D to ensure the scientific basis for Safety, Codes and Standards.
- Coordination and harmonization of regulations, codes and standards (RCS) through international and domestic technical working groups.
- Coordination and dissemination of relevant hydrogen safety information.

## Key R&D areas (*core technologies*):

- Technically validated hydrogen release and materials characterization data needed for development and revisions of codes and standards.
- Risk assessment and establishment of protocols to identify and mitigate risk.
- Testing protocols for components and systems including high pressure vessels.
- Hydrogen quality, measurement, and metering.
- Adoption and harmonization of test methodologies for hydrogen fuel specification.
- Coordination and dissemination of relevant hydrogen safety information.




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




*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.

## Preliminary Analysis

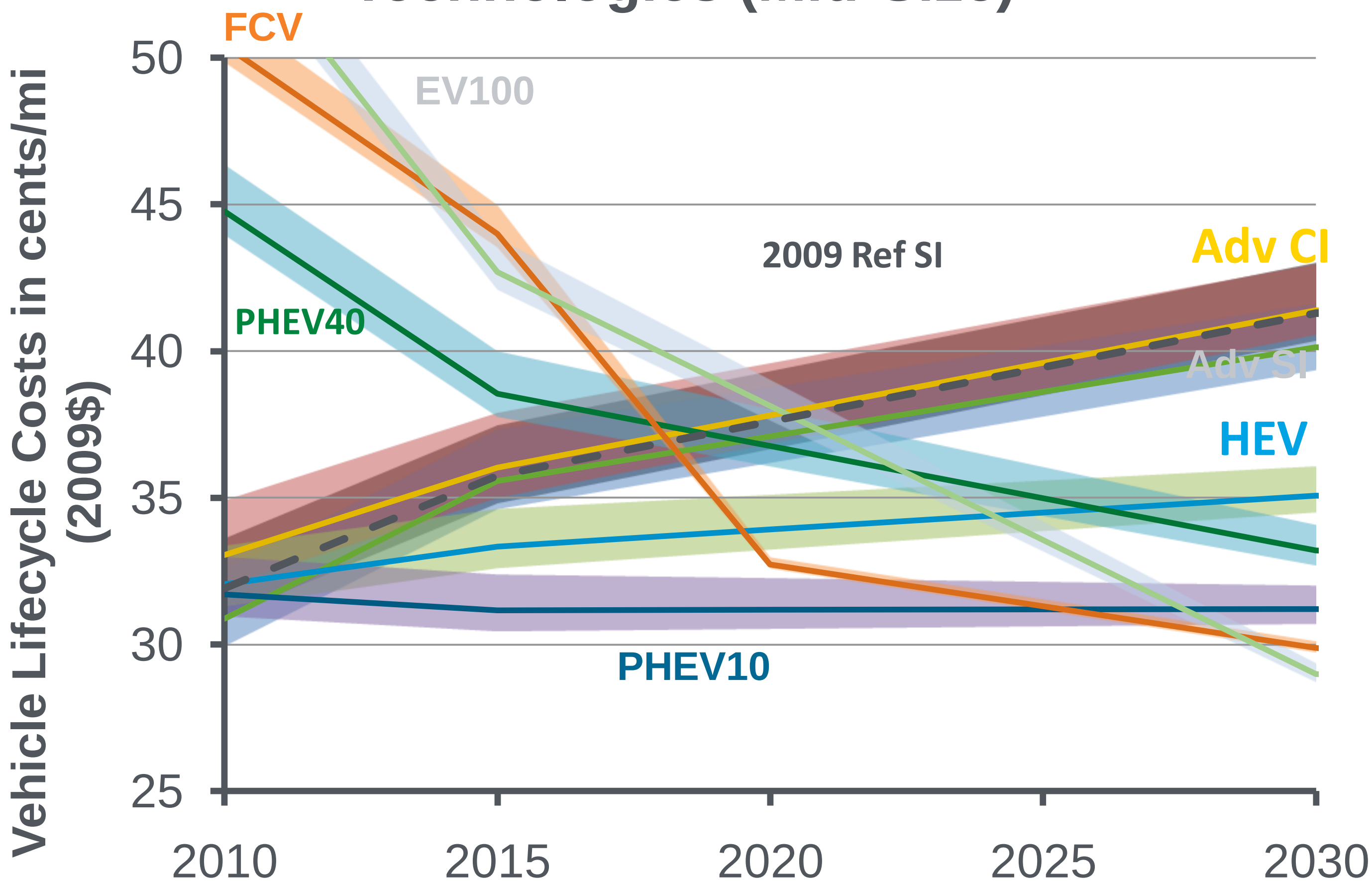
2015

- 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

## Advanced Light Duty Vehicle Technologies (Mid-Size)




* 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.

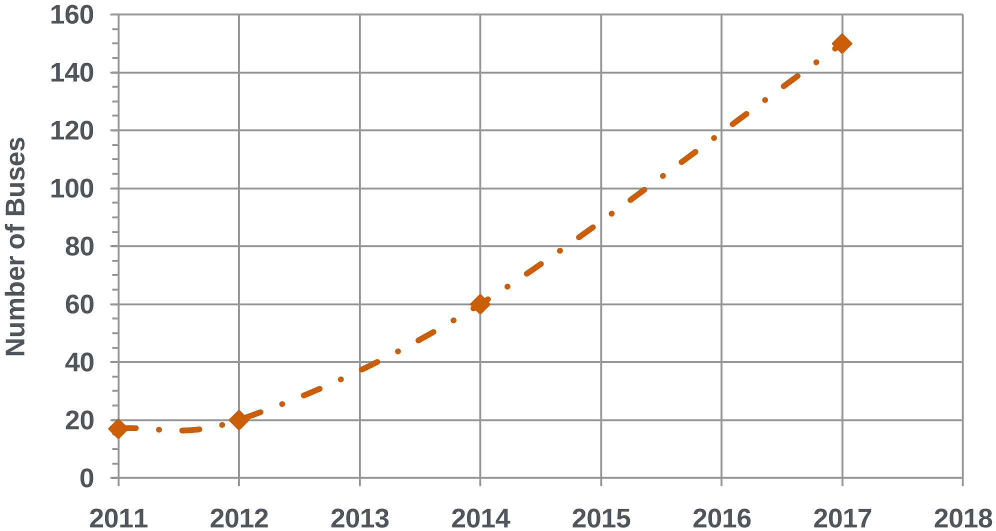
Source: Presentation to ERAC, November 30, 2010

# Fuel Cell Bus Buildout Analysis

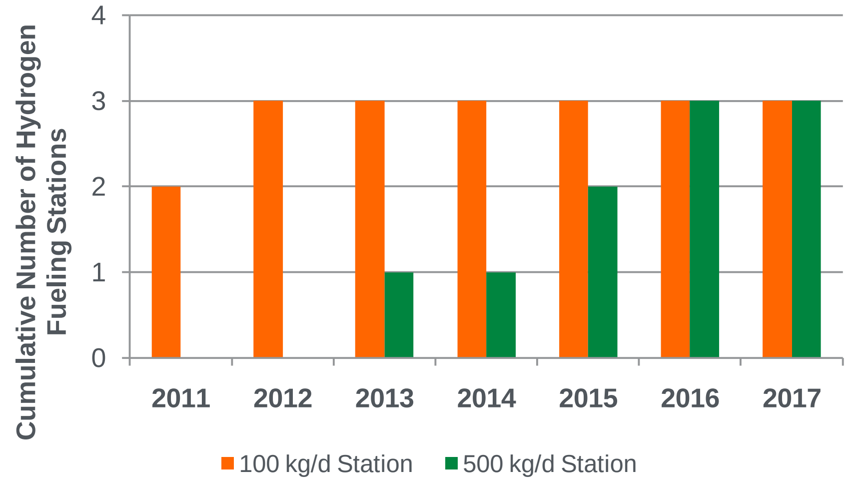
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

***Potential deployment strategies envisioned for Fuel Cell Buses deployment scenario analysis identified in California's Action Plan.***

## Bus Rollout Scenario




## Potential $H_2$ Fueling Station Buildout for Buses




| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|
| | Phase I | Phase II | | | Phase III | | |
| Number of Fuel Cell Buses* | 17 | 20 – 60 | | | 60 – 150 | | |
| Minimum Number of 100 kg/d Stations | 2 | 1 | 0 | 0 | 0 | 0 | 0 |
| Minimum Number of 500 kg/d Stations | 0 | 0 | 1 | 0 | 1 | 1 | 0 |

Notes: The station requirements for the fuel cell bus build out was based on ANL analysis with the HDSAM delivery model.

**Source:* California Fuel Cell Partnership, *Action Plan*, April 2010 based on industry input.

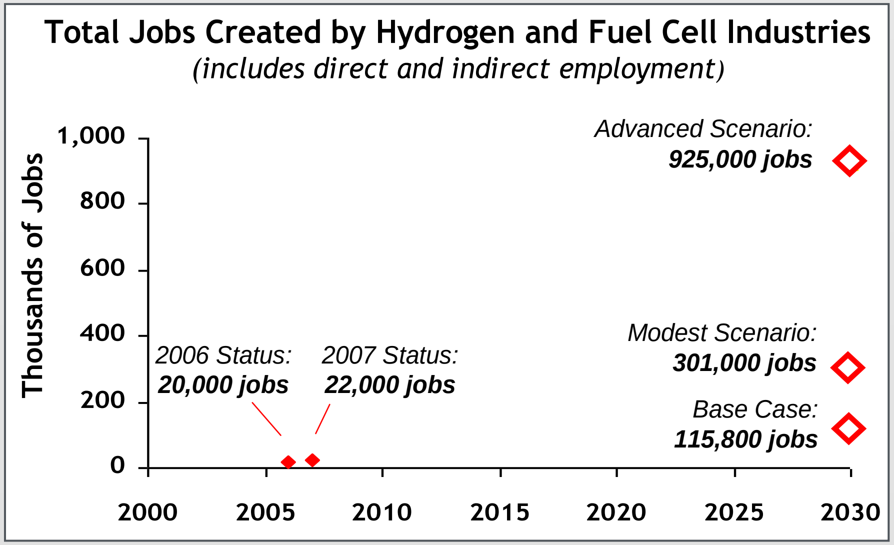
# Fuel Cells - *The Economic Potential*

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

***The fuel cell and hydrogen industries could generate substantial revenues and job growth.***

## Renewable Energy Industry Study*

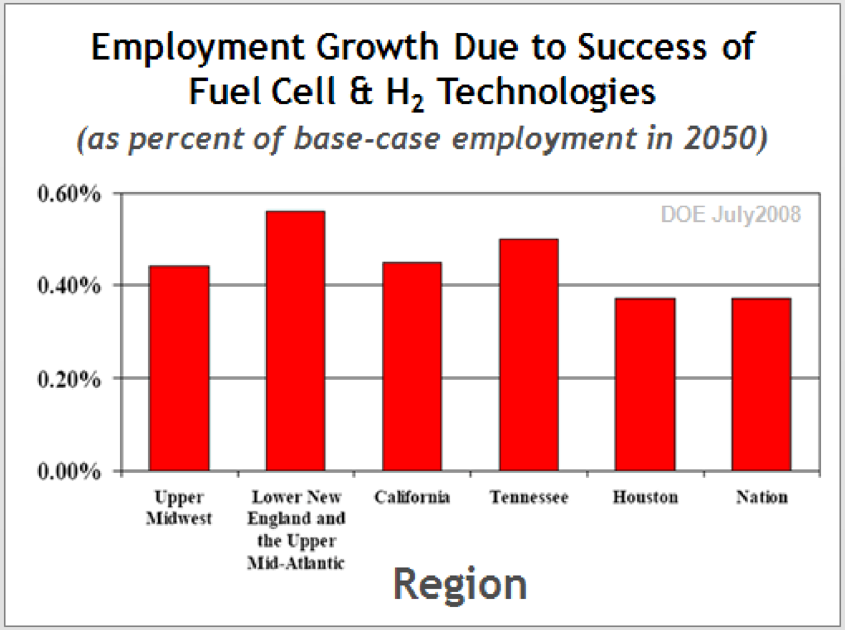
- **Fuel cells are the third-fastest growing renewable energy industry** (after biomass & solar).
- Potential U.S. employment from fuel cell and hydrogen industries of **up to 925,000 jobs** (by 2030).
- Potential gross revenues up to **$81 Billion/year** (by 2030).




*Study Conducted by the American Solar Energy Society
*www.ases.org/images/stories/ASES/pdfs/CO_Jobs_Final_Report_December2008.pdf*

## 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.




*www.hydrogen.energy.gov/pdfs/epact1820_employment_study.pdf*

# Systems Analysis: *Key FY 2012 Activities*

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

***Maintenance/development of analytical models and tools to help quantify program effects such as GHG, criteria pollutants and petroleum use. Identify research, analyze environmental trade-offs, and evaluate business cases for various applications, such as material handling, CHP, and stationary and portable power.***

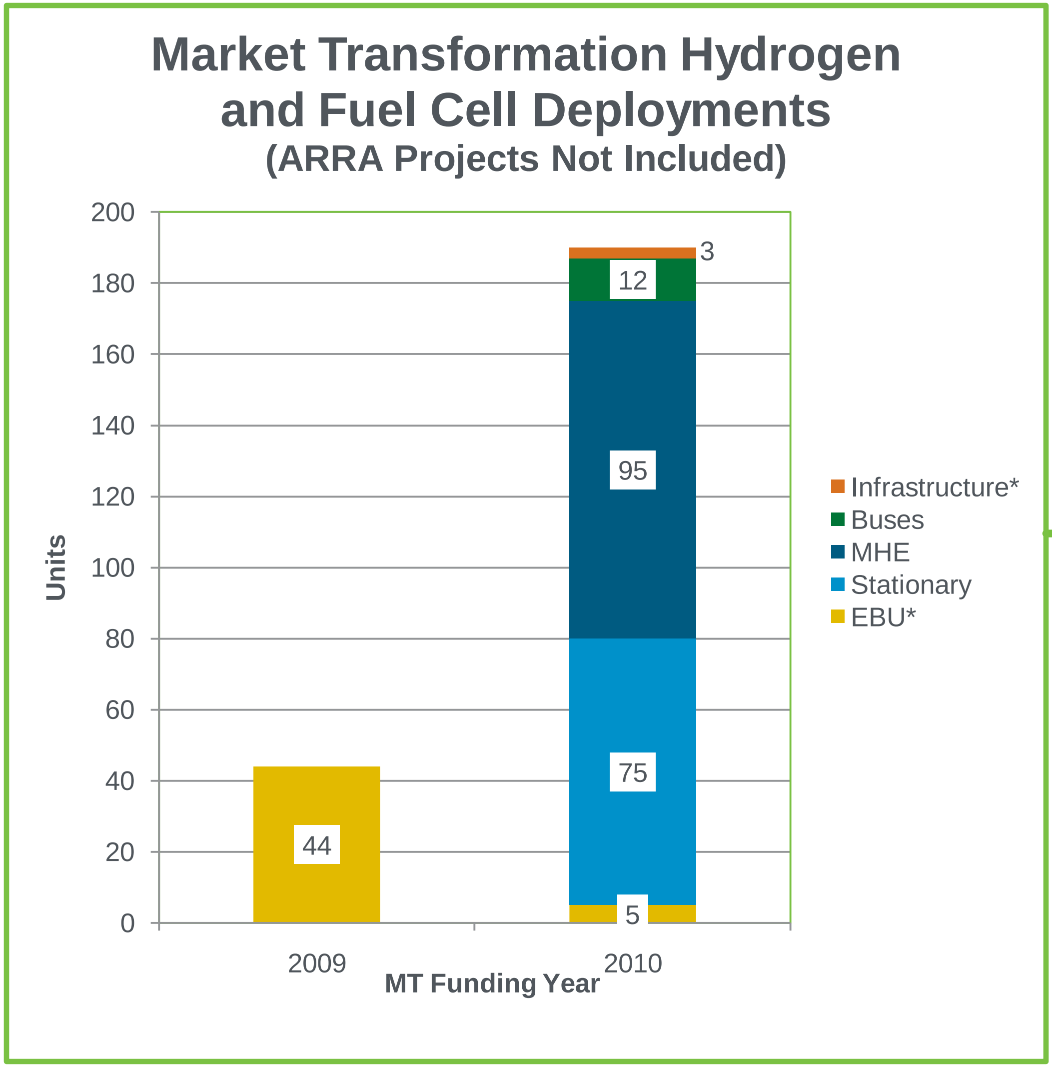
## The *Systems Analysis* Subprogram will focus on:

- Updating models for program analysis, using cost, performance and environmental information from independent reviews and research projects.
- Providing support and input to program elements, such as go/no-go decisions and risk analysis.
- Assessing market penetration, job creation, and opportunities for fuel cell applications in the near term—material handling, back-up power, and residential/commercial CHP markets.
- Ensuring analysis consistency and transparency by updating and maintaining analysis portfolio and information databases.

## Key analysis areas:

- **Environmental benefits of utilizing renewable fuels**—benefits of using landfill gas and other types of biogases, and miscellaneous sources of gases (such as unused streams from industrial processes) for stationary fuel cells will continue to be updated on a well-to-wheels basis.
- **Cross-cutting analysis of tradeoffs and synergies** — e.g.infrastructure and resource availability.
  - Assess business cases of biogas cleanup for stationary fuel applications; infrastructure applications and integration in a domestic fueling network; and fuel cell Combined Heat and Power (CHP) applications for Federal facilities.
- **Market studies**—assessment of opportunities for early market applications & job growth.
- **Effects of a policies (e.g. federal fuel cell acquisition program)**—on cost reduction and job creation.
- **Infrastructure analysis**— assessment of gaps and drivers for early market infrastructure cost for transportation and power generation applications.

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy




## Total Deployments by Type*

**2009 Deployments ($5 Million)**
- 44 EBU Units

**2010 Deployment ($15 Million)**
- 5 Mobile Light Stands
- 75 Micro CHP Units
- 95 MHE Units
- 12 HICE Buses
- 1 Electrolyzer
- 1 Mobile Refueler
- 1 Hydrogen Reformer (Landfill Gas)

* Figures include Market Transformation funding only, ARRA and Other are excluded

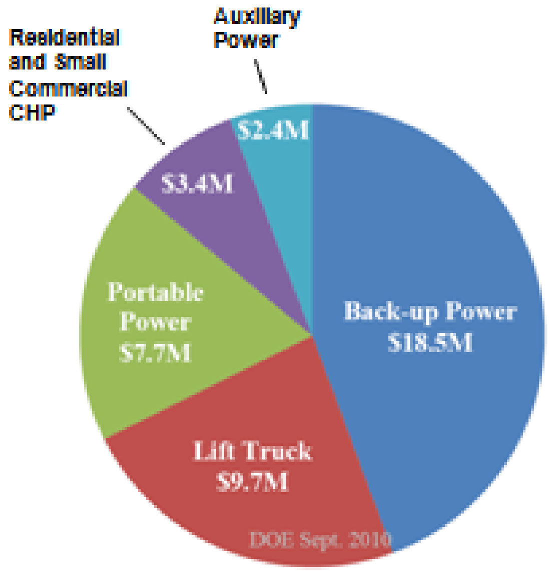
# Speed & Scale

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

## *$42 million from the 2009 American Recovery and Reinvestment Act to fund 12 projects to deploy up to 1,000 fuel cells*

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

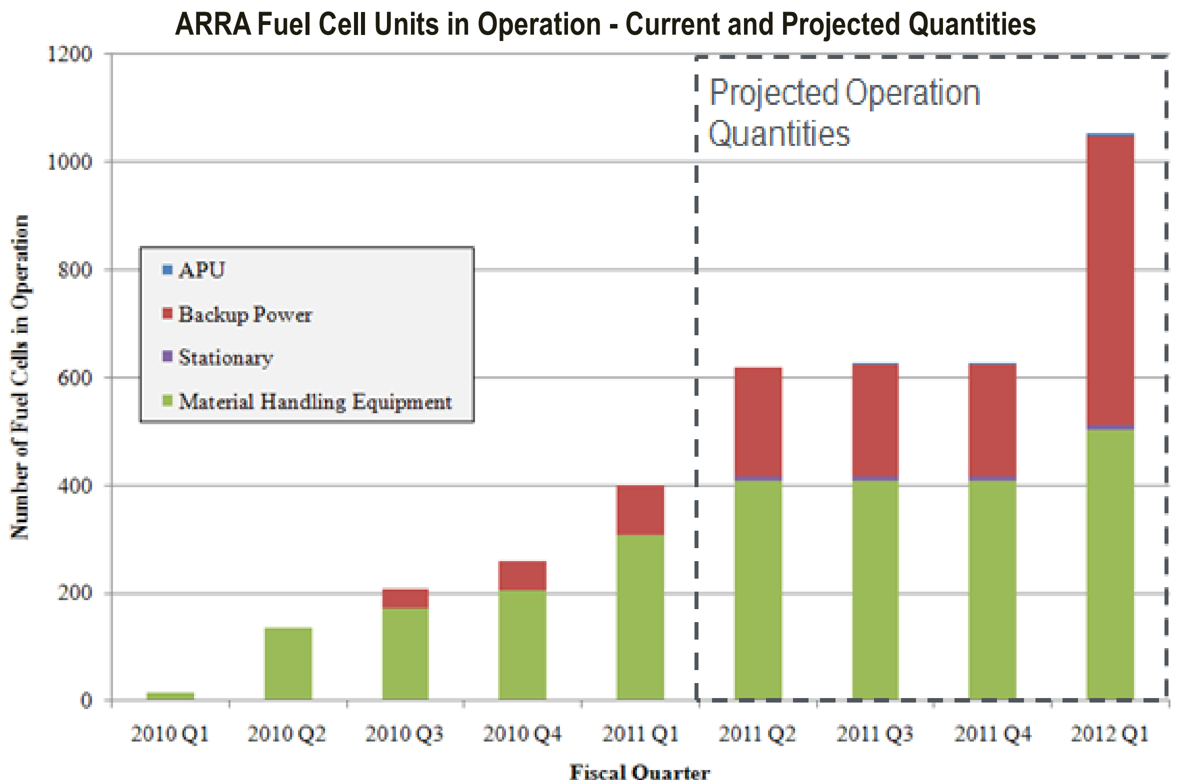
- 206 lift trucks (35 with FedEx, 14 with Nuvera, 98 with Sysco, and 59 with GENCO)
- 24 telecommunication backup power units provided by ReliOn for AT&T.




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

**Major companies such as FedEx, Coca Cola, Whole Foods, Sprint, AT&T, Sysco and Wegmans are installing fuel cells**

**Federal Agencies: DOD-DLA: ~120 fuel cell life trucks to four distribution centers, FAA :~26 back-up power fuel cells ; CERL: >200 kW in fuel cell backup power across nine federal installations.**




*Compiled using data from National Renewable Energy Laboratory (NREL).

# EERE Budget: *FY09 – FY12*

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

| **Funding** *($ in thousands)* | | | |
|---|---|---|---|
| **Activity** | **FY 2009** | **FY 2010 Current Approp.** | **FY 2012 *Request*** |
| Biomass and Biorefinery Systems | 214,245 | 216,225 | 340,500 |
| Building Technologies | 138,113 | 219,046 | 470,700 |
| Federal Energy Management Program | 22,000 | 32,000 | 33,072 |
| Geothermal Technology | 43,322 | 43,120 | 101,535 |
| Hydrogen Technology | 164,638 | 0 | 0 |
| Hydrogen and Fuel Cell Technologies | 0 | 170,297 | 100,450 |
| Water Power | 39,082 | 48,669 | 38,500 |
| Industrial Technologies | 88,196 | 94,270 | 319,784 |
| Solar Energy | 172,414 | 243,396 | 457,000 |
| Vehicle Technologies | 267,143 | 304,223 | 588,003 |
| Weatherization & Intergovernmental Activities | 516,000** | 270,000 | 393,798 |
| Wind Energy | 54,370 | 79,011 | 126,859 |
| Facilities & Infrastructure | 76,000 | 19,000 | 26,407 |
| Strategic Programs | 18,157 | 45,000 | 53,204 |
| Program Direction | 127,620 | 140,000 | 176,605 |
| Congressionally Directed Activities | 228,803 | 292,135 | 0 |
| RE-ENERGYSE | 0 | 0 | 0 |
| Adjustments | -13,238 | 0 | -26,364 |
| **Total** | **$2,156,865** | **2,216,392** | **3,200,053** |

* SBIR/STTR funding transferred in FY 2009 was $19,327,840 for the SBIR program and $2,347,160 for the STTR program.

** Includes $250.0 million in emergency funding for the Weatherization Assistance Grants program provided by P.L. 111-6, "The Continuing Appropriations Resolution, 2009."

# DOE Collaboration Opportunities

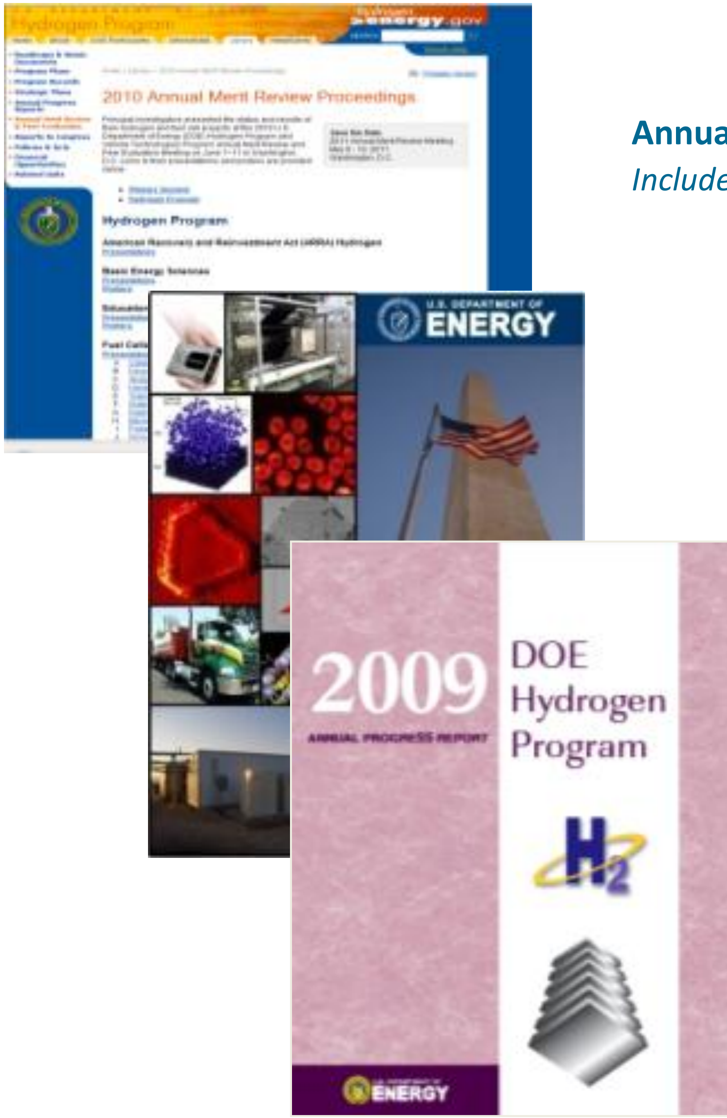
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

**Fuel Cell Technologies Program**

| Program | Program Key Focus |
| --- | --- |
| Buildings ($471M) | Develop and scale up deployment of technologies, tools, and standards for making residential and commercial buildings more energy-efficient, affordable, and better performing. |
| Industrial Technologies ($320M) | Research and develop advanced manufacturing and materials technologies and accelerate industrial adoption of energy efficient and clean energy technologies. Help U.S. producers to become global leader in production of clean energy technologies. |
| Solar ($457M) (e.g. EFRC) | "Sun Shot" – Enable grid parity before the end of the decade by achieving $1/W installed price for PV (without subsidies). Develop new innovative materials and thermal storage to enable CSP to compete with intermediate and baseload power markets. |
| Biomass ($331M) | Develop and transform domestic biomass resources into biofuels, bioproducts, & biopower: 1) Complete steps to achieve a modeled cost of less than $2/gal (by volume) of cellulosic ethanol in 2012 and progress towards $3/gal for renewable hydrocarbon fuels by 2017 (both in 2007$), 2) Collaborate with Office of Sc. to develop synthetic-biology tools to enhance national capability in biomanufacturing, 3) validate 15 M gallons of annual advanced biofuel production capacity,4) Provide incentive for advanced biofuel production via a reserve auction. |
| Vehicle Technologies ($588M) | Strategic research, development and deployment activities supporting the goal of 1 M electric drive vehicles on U.S. roads by 2015. |
| FEMP ($33M) - Federal facilities - EO 13514 | Facilitates the Federal Government's implementation of sound, cost effective energy management and investment practices resulting in lifecycle saving of over 52 trillion Btus. Increased funding for technical assistance will support Federal cost and GHG reduction efforts by developing guidance, technical assistance and GHG reporting protocols. |
| ARPA-E ($550M) **Innovative concepts** | Focuses on high risk, high payoff concepts - technologies promising genuine transformation in the ways we generate, store and utilize energy. |

# Key Program Documents

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy




**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*

- **Released February 2011**

www.hydrogen.energy.gov/annual_progress.html

**Next Annual Review: May 9 – 13, 2011**

**Washington, D.C.**

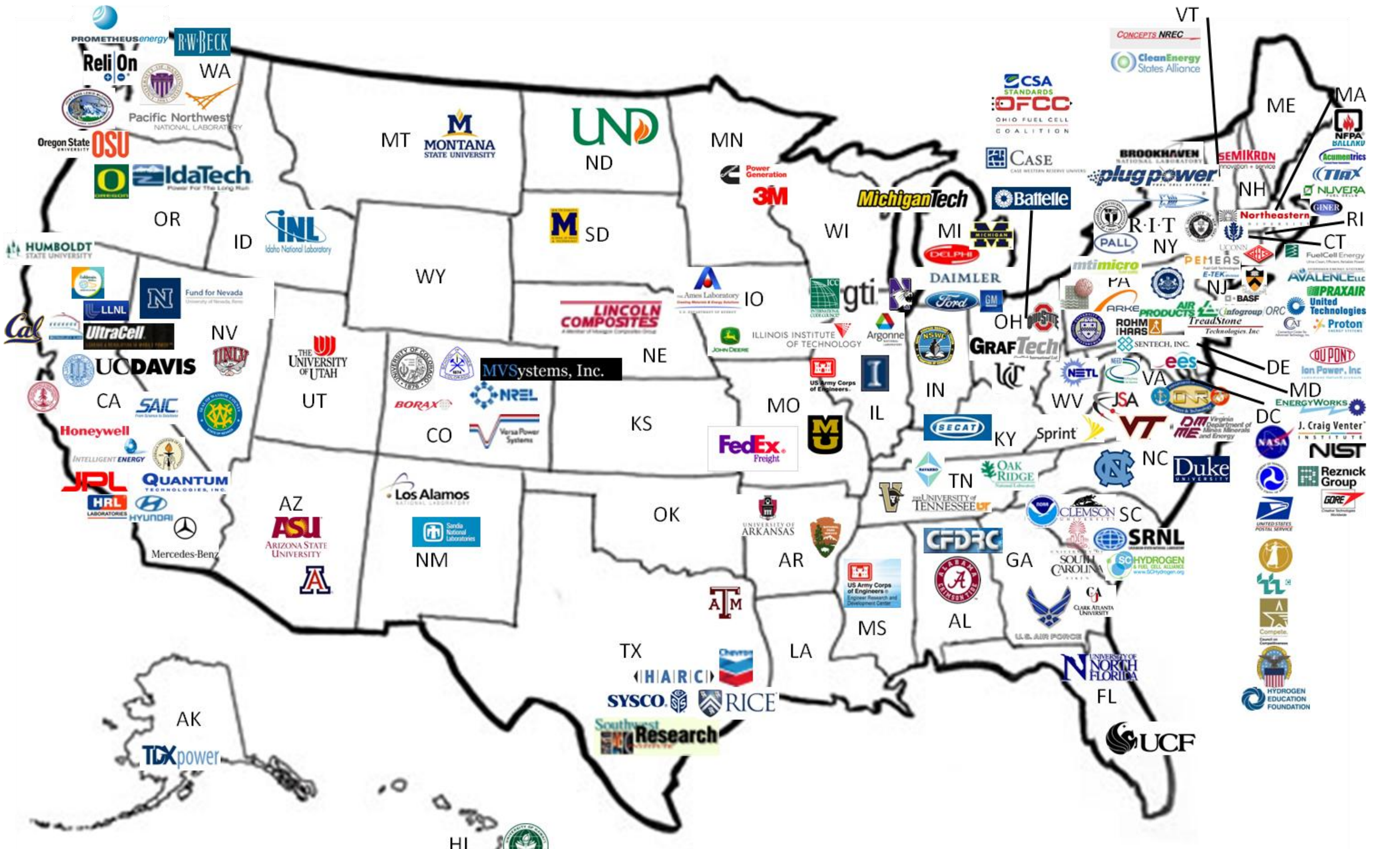
***http://annualmeritreview.energy.gov/***

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy


- Fact sheets on:
  - FCT's Subprograms
    - Fuel Cells
    - Production & Delivery
    - Storage
    - Safety, Codes & Standards
    - Technology Validation
  - Case studies
    - Backup Power
    - MHE
    - CHHP
  - Financing
  - Accomplishments

# Examples of DOE-funded Partners and Locations – Fuel Cell Technologies Program

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy




Source: US DOE 2010

# Thank you

Sunita.Satyapal@ee.doe.gov

**www.hydrogenandfuelcells.energy.gov**