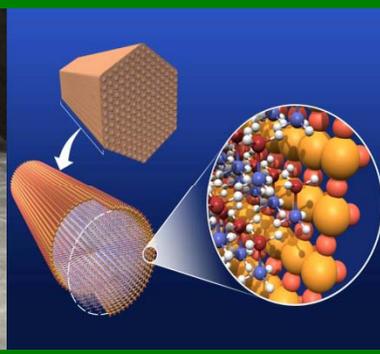




U.S. DEPARTMENT OF
ENERGY



Hydrogen & Fuel Cells Program Overview

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Hydrogen and Fuel Cells Program
U.S. Department of Energy

Hydrogen + Fuel Cells 2011 International Conference and Exhibition
Vancouver, Canada
May 17, 2011

Hydrogen and Fuel Cells Key Goals

Enable widespread commercialization of hydrogen and fuel cell technologies:

- Early markets such as stationary power, lift trucks, and portable power
- Mid-term markets such as residential CHP systems, auxiliary power units, fleets and buses
- Long-term markets including mainstream transportation applications/light duty vehicles

Diverse Energy Sources & Fuels

Biomass
Natural Gas
Propane
Diesel
Other Hydrocarbons
Methane
Methanol

Hydrogen
from renewables
or low carbon
resources

Clean, Efficient Energy Conversion



Fuel Cells

- Alkaline
- Direct Methanol
- Molten Carbonate
- Polymer Electrolyte Membrane (PEM)
- Phosphoric Acid
- Solid Oxide

Benefits

- **Efficiencies can be 60% (electrical) and 85% (with CHP)**
- **> 90% reduction in criteria pollutants**

Diverse Applications

Stationary Power



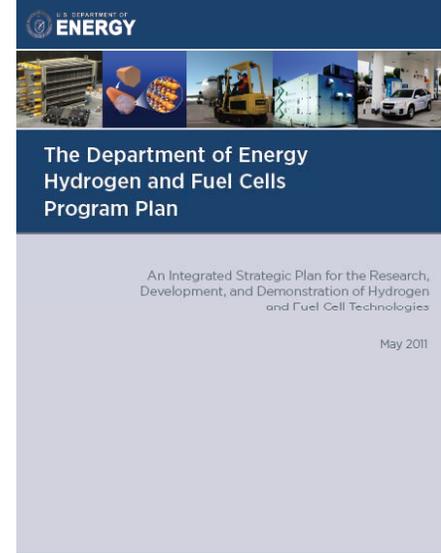
Transportation



Portable Power

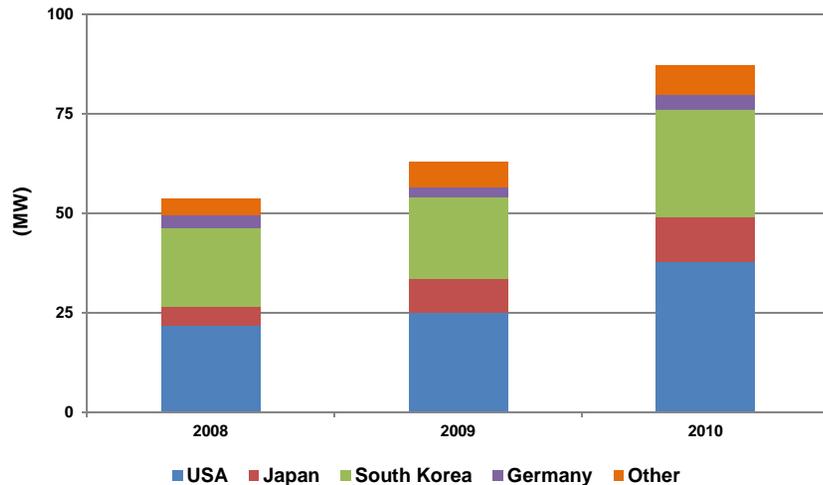


Updated Program Plan 2011

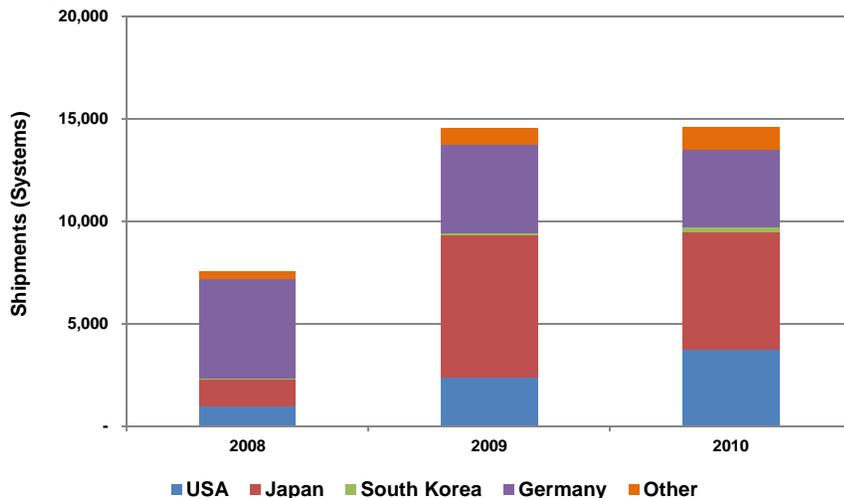


Fuel Cell Market Overview

Megawatts Shipped, Key Countries: 2008-2010



System Shipments, Key Countries: 2008-2010



Fuel cell market continues to grow

- ~36% increase in global MWs shipped
- ~50% increase in US MWs shipped
- Published several reports
 - The Business Case for Fuel Cells
 - State of the States: Fuel Cells in America
 - 2010 Fuel Cell Market Report



Source: U.S. DOE, May 2011

FuelCells2000, Pike Research, Fuel Cell Today, ANL

<http://www.fuelcells.org/BusinessCaseforFuelCells.pdf>
<http://www.fuelcells.org/StateoftheStates.pdf>

DOE EERE Funding (\$ in thousands)	
<i>Key Activity</i>	FY 2012 Request
Fuel Cell Systems R&D	\$45,450
Hydrogen Fuel R&D	\$35,000
Technology Validation	\$8,000
Safety, Codes & Standards	\$7,000
Systems Analysis	\$3,000
Manufacturing R&D	\$2,000
Total	\$100,450

~\$38 M/year
for Basic
Energy
Sciences

\$42 M under
Recovery Act

The Program continues its robust activities to support RD&D of hydrogen and fuel cell technologies for diverse applications.

Coordination with States- e.g. > CA: \$45M spent/committed over 4-5 yrs plus \$18M planned for FY11-12 (focus on infrastructure)

Progress – Fuel Cell R&D

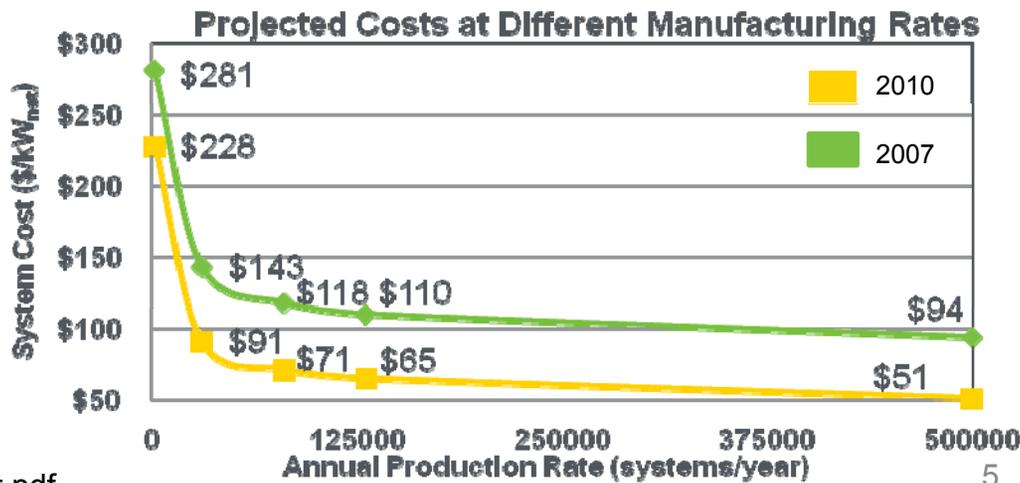
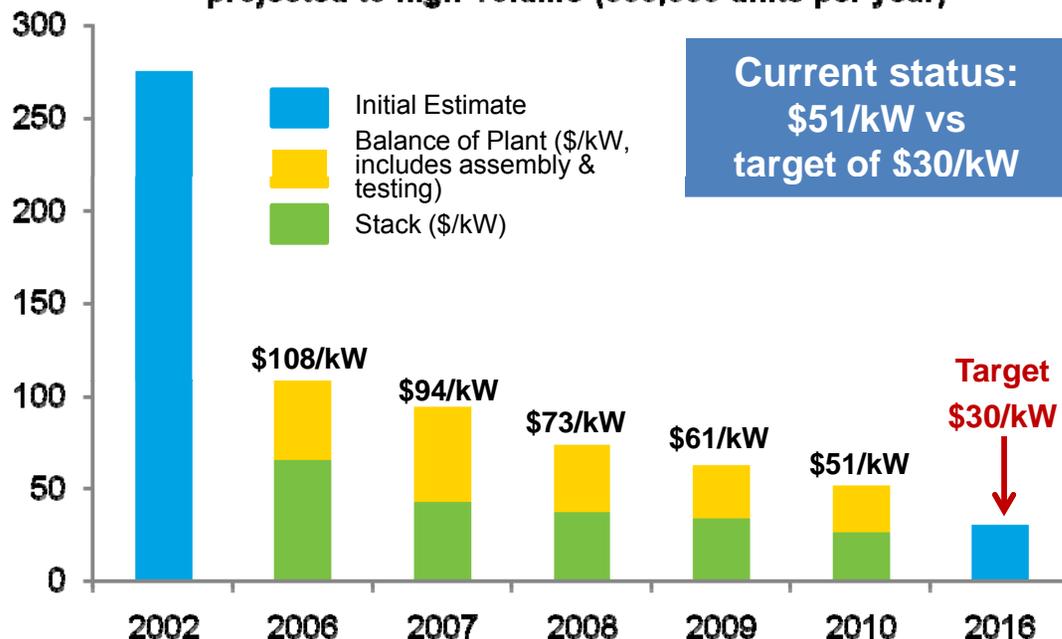
DOE-funded R&D efforts have reduced the projected high-volume cost of fuel cells to \$51/kW (2010)*

- **More than 30% cost reduction since 2008**
- **More than 80% cost reduction since 2002**

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

**Panel found \$60 – \$80/kW to be a “valid estimate” for 2008 http://hydrogen.doe.gov/peer_reviews.html

Projected Transportation Fuel Cell System Cost -projected to high-volume (500,000 units per year)-



Source: U.S. DOE, May 2011

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

Progress – Hydrogen R&D

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:

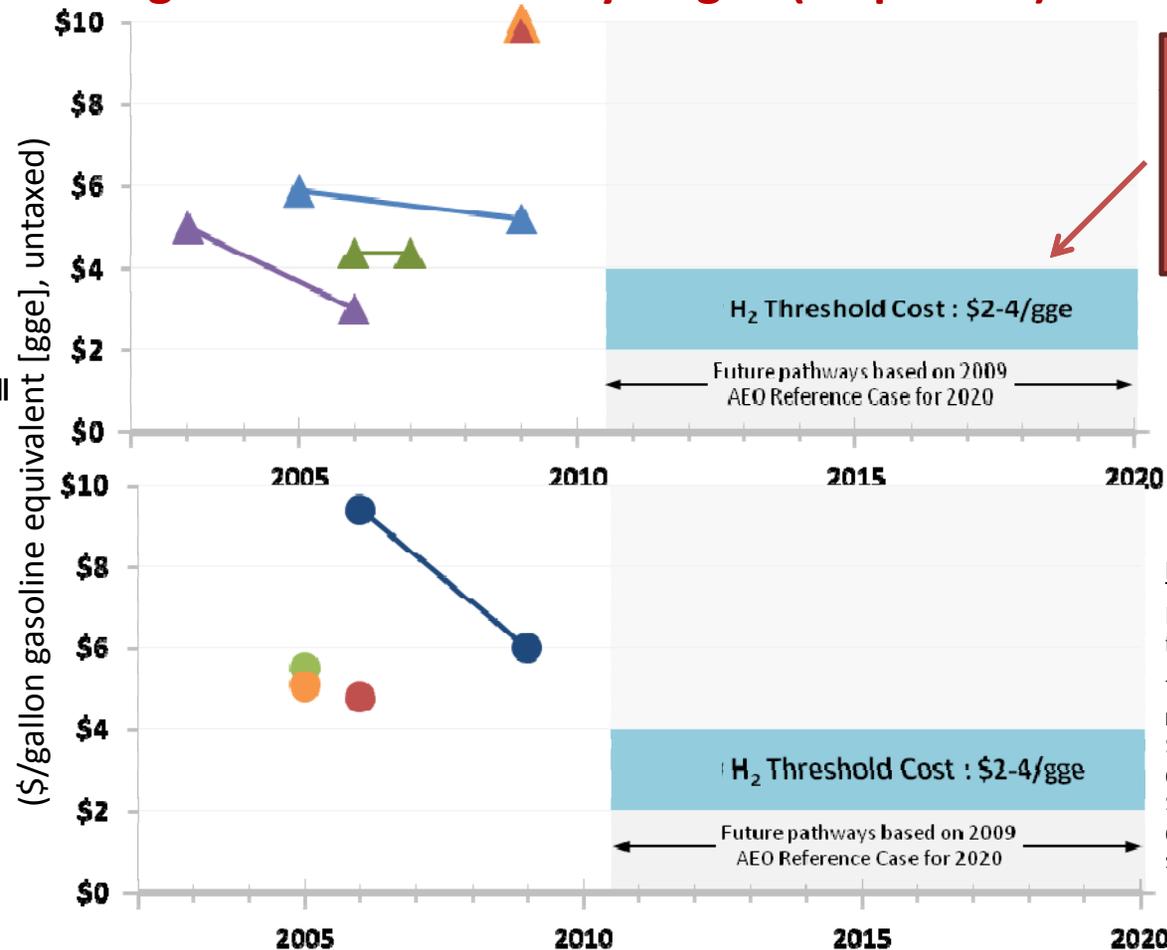
Distributed Production

- ▲ 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



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: U.S. DOE, May 2011

Delivery: Projected an additional 33% improvement in tube trailer capacity in the last yr
Storage: Validated 430 mi range on single fill. Focus is tank cost and materials R&D

Demonstrations are essential for validating technologies in integrated systems

Real-world Validation

Vehicles & Infrastructure

- 155 fuel cell vehicles and 24 hydrogen fueling stations
- Over 3 million miles traveled
- Over 131 thousand total vehicle hours driven
- 2,500 hours (nearly 75K miles) durability
- Fuel cell efficiency 53-59%
- Vehicle Range: ~196 – 254 miles (430 miles on separate FCEV)

Buses (with DOT)

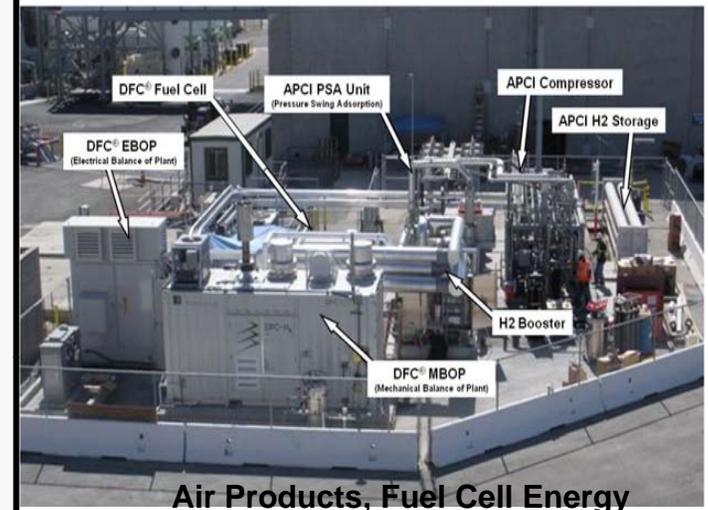
- H₂ fuel cell buses have a 42% to 139% better fuel economy when compared to diesel & CNG buses

Forklifts

- Over 44,000 refuelings at Defense Logistics Agency site

CHHP (Combined Heat, Hydrogen and Power)

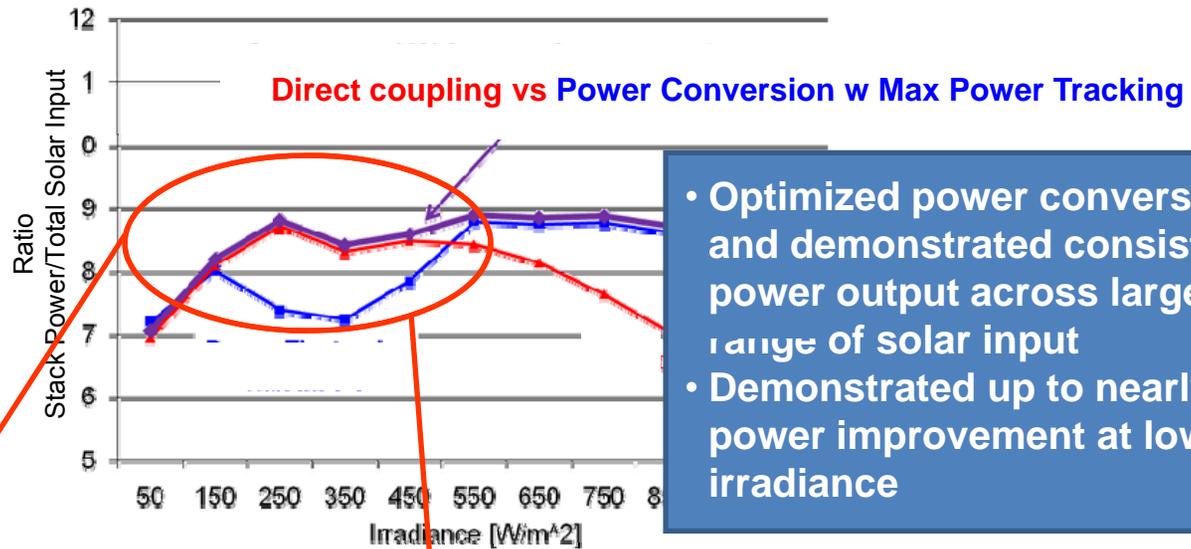
- Achieved 54% (hydrogen + power) efficiency of fuel cell when operating in hydrogen co-production mode
- 100 kg/day capacity, renewable hydrogen supply



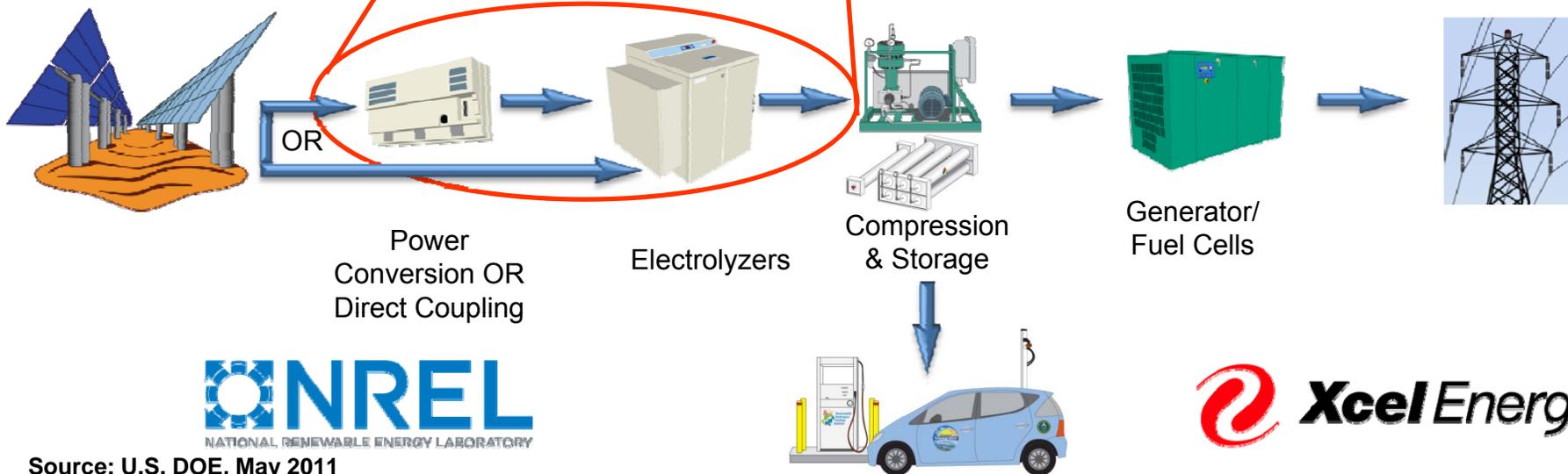
Hydrogen & Fuel Cells for Energy Storage

Improved efficiency of renewable H₂ production by matching the polarization curves of PV & electrolyzers to enable direct coupling.

Expanded Facility to test multiple technologies (wind, solar, electrolyzers, fuel cells/ generators, plus H₂ refueling)



- Optimized power conversion and demonstrated consistent power output across larger range of solar input
- Demonstrated up to nearly 20% power improvement at low irradiance



Source: U.S. DOE, May 2011



DOD-DOE Memorandum of Understanding

Strengthen coordination and partnerships between DOE and DOD.

Workshops Held

Waste-to-Energy

Aviation APUs

Shipboard APUs

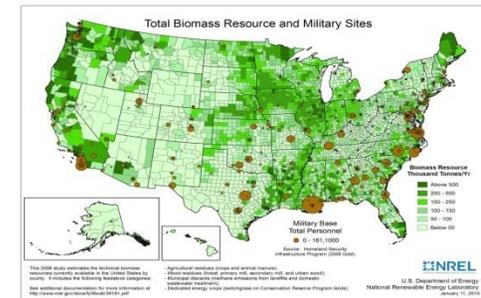
Outcomes & Next Steps

DOD-DOE working group formed to identify opportunities.

Industry working group established

Bio/logistics fuels reforming

Impact



634,000 million BTUs potential energy savings using waste-to-energy CHP²

Potentially reduce NOx emissions by ~900-2,200 tons/yr for aircraft & 1,200-2,000 tons/yr for GSE²

Shipboard fuel cells capable of saving ~11,000-16,000 bbls/ship/yr²

¹FCHEA, <http://www.fcchea.org/index.php?id=14>, ² DOD Estimates

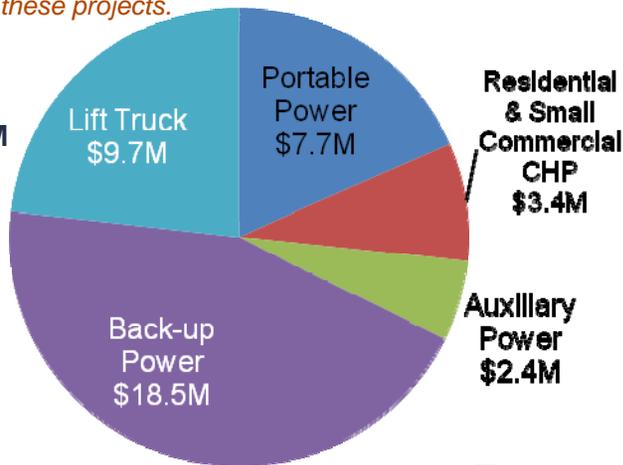
Progress – Market Transformation & Recovery Act

Deployed more than 630 fuel cells to date for use in forklifts and backup power at several companies including Sprint, AT&T, FedEx, Kimberly Clark, and Whole Foods

FROM the LABORATORY to DEPLOYMENT:

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

DOE: \$42 M
Cost-share: \$54 M
Total: \$96 M.



• Forklifts

- FedEX Freight East, GENCO, Nuvera Fuel Cells, Sysco Houston

• Back-up Power

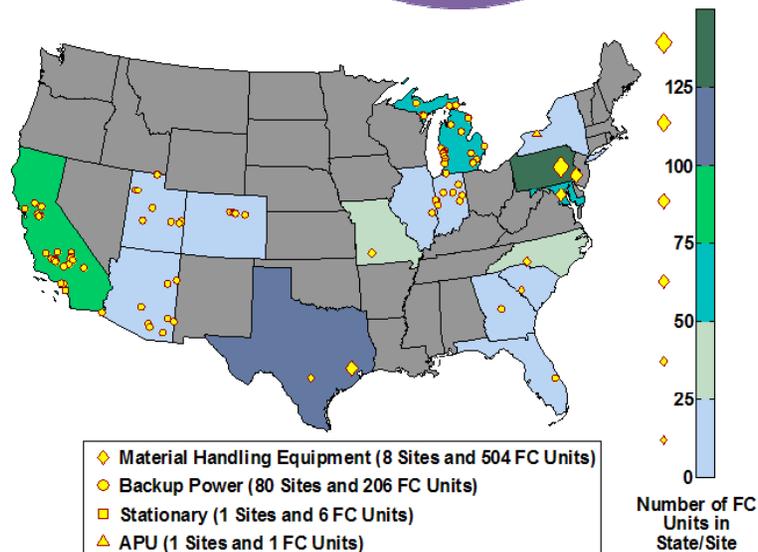
- Plug Power, Inc., ReliOn, Inc., Sprint Nextel

• Portable Power

- Jadoo Power, MTI MicroFuel Cells, Univ. of N. Florida

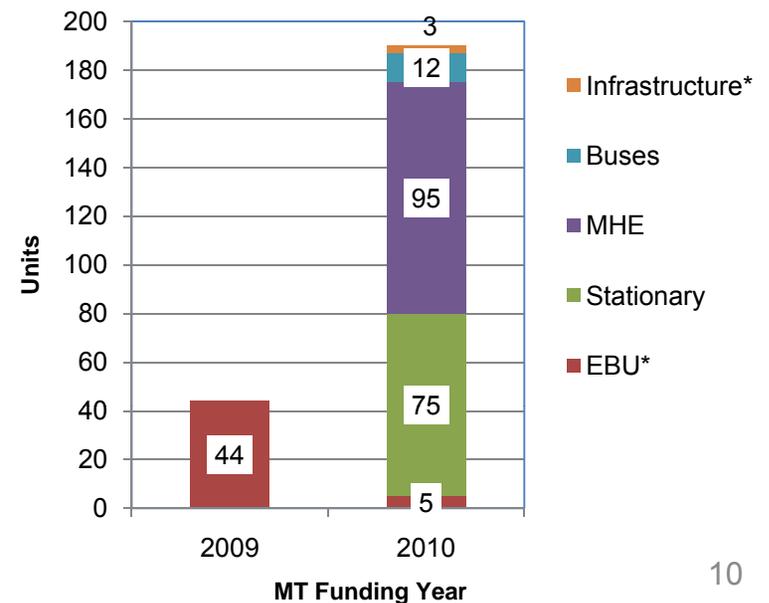
• Auxiliary Power

- Delphi Automotive



ARRA JOBS STATUS (Jan 2011)
~50 jobs reported on Recovery.gov

Market Transformation Hydrogen and Fuel Cell Deployments*

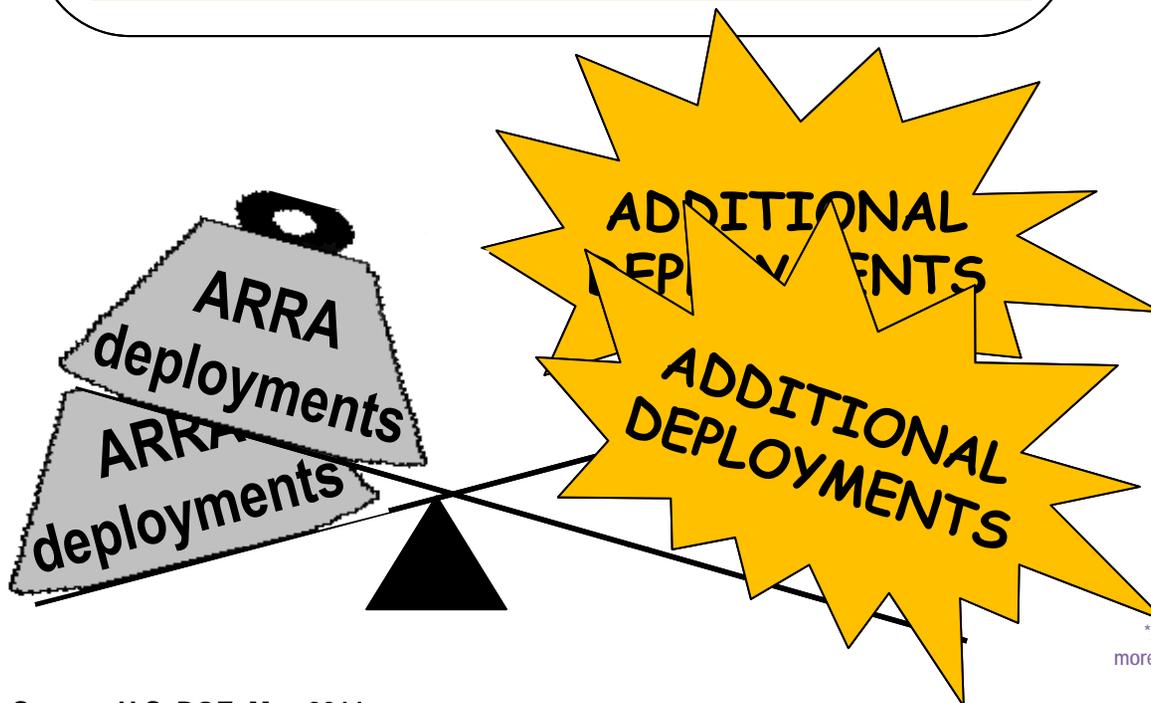


Accomplishments

Data Collection Snapshot (NREL)

ARRA Material Handling Equipment Data	As of 12/31/2010
Hydrogen Dispensed	> 18,500 kg
Hydrogen Fills	> 38,800
Hours Accumulated	> 307,400 hrs
Durability	~3,000 hrs*
Reliability	75% w/MTBF > 100 hrs

Additional fuel cell lift truck deployments taking place based on ARRA experience and lessons learned!

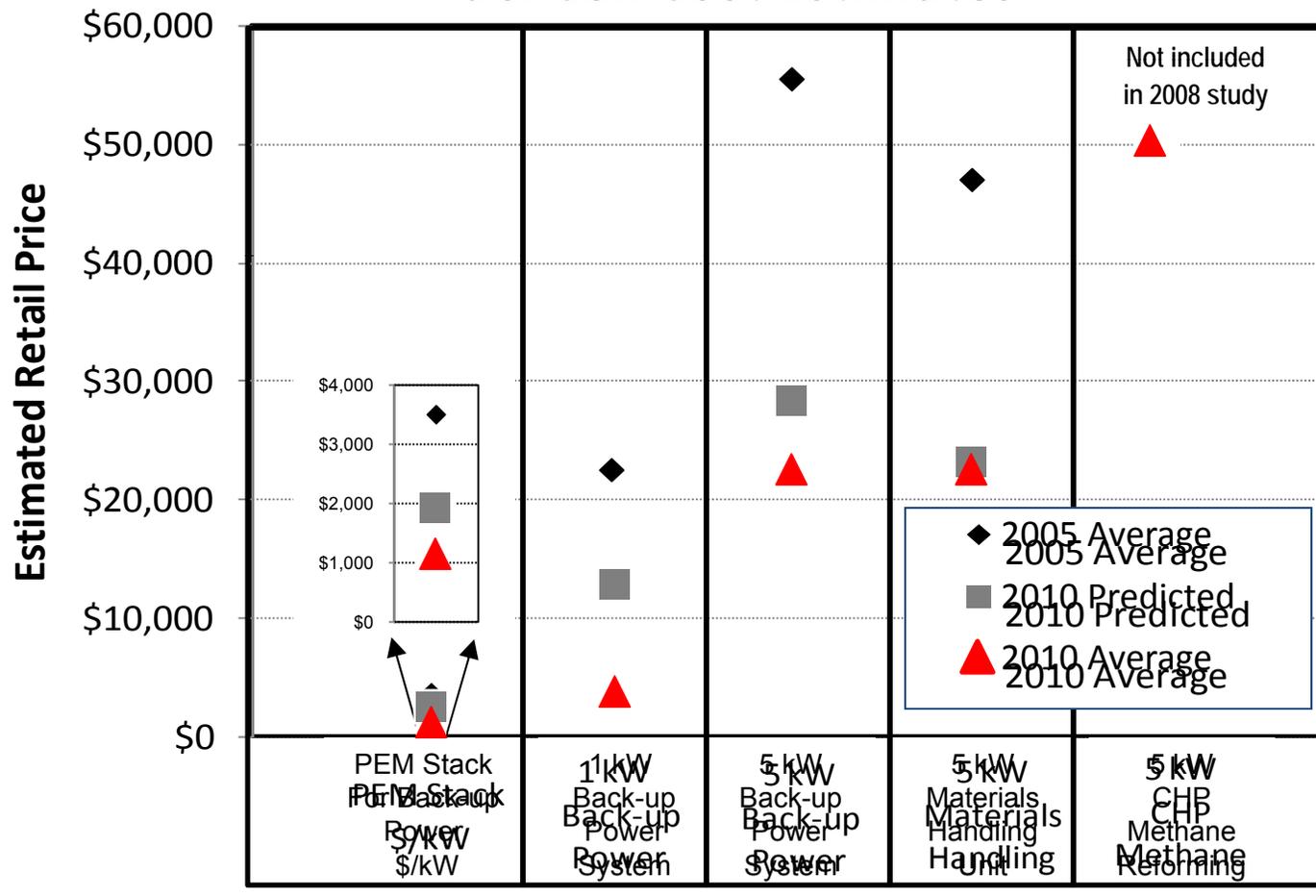


**MORE THAN 500
ADDITIONAL FUEL CELL
FORKLIFTS PLANNED**
**E.g., Sysco, H-E-B
Grocery, BMW**

*Average projected hours to 10% voltage drop of all the fleets with a max fleet project of more than 9,500 hours. 25% of systems have more than 2,300 operation hours and one fleet averages more than 2,6000 operation hours.

Early Market Cost Reduction Analysis

Comparison of 2008 ORNL Study and 2010 Fuel Cell Cost Estimates



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

Oak Ridge National Laboratory
MANAGED BY UT-BATTELLE
FOR THE DEPARTMENT OF ENERGY
ORNL/TM-2010/101

Status and Outlook for the U.S. Non-Automotive Fuel Cell Industry: Impacts of Government Policies and Assessment of Future Opportunities

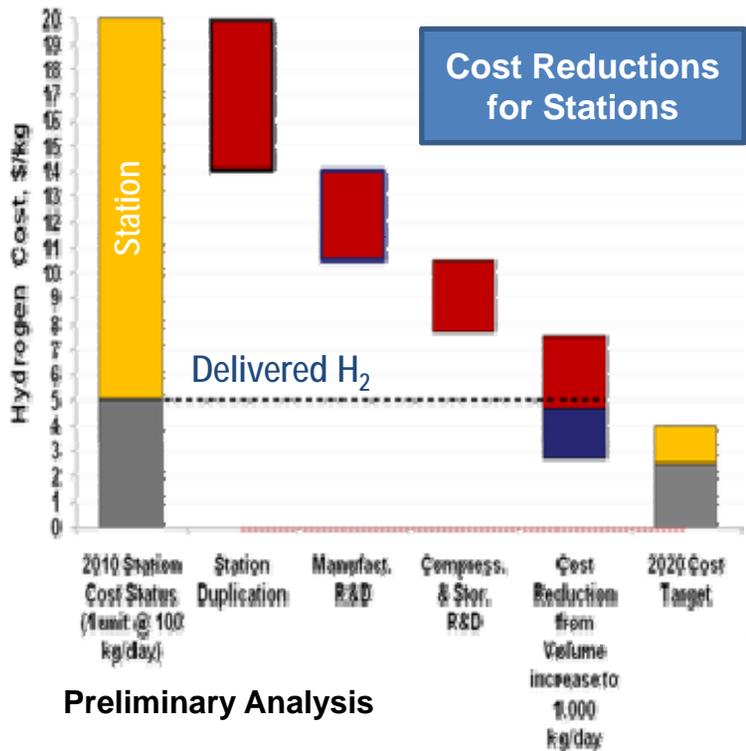
May 2011

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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.

Additional Analysis - Hydrogen Infrastructure



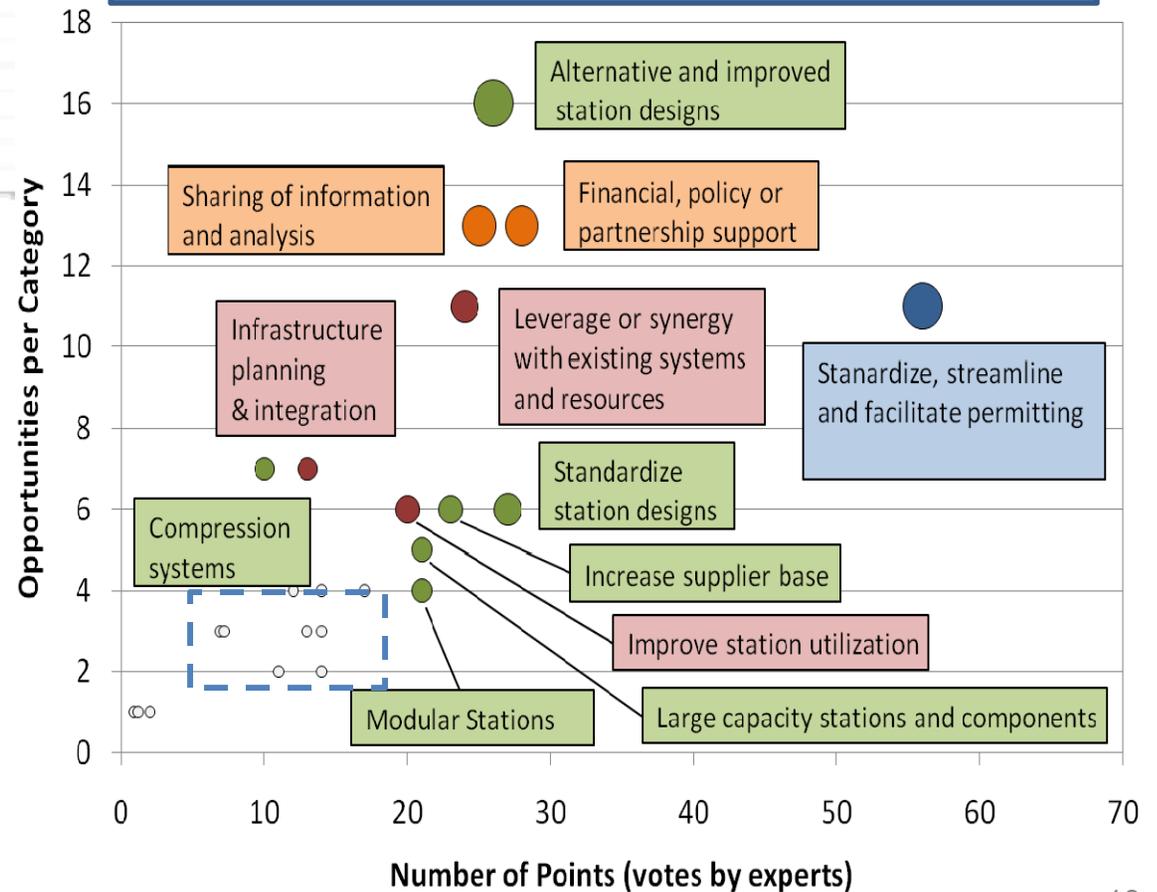
Preliminary Analysis

1. Cost reduction from station duplication will require ~120 stations and was based on 3% reduction for a doubling of capacity.
2. Cost of H₂ delivered to station is ~\$5/kg.
3. Station cost reductions based on ANL Hydrogen Delivery Systems Analysis Model (HDSAM).
4. Current station cost based on current California state funded stations. Capital cost ~ \$2.5 million.

Source: U.S. DOE, May 2011

Identified opportunities for reducing infrastructure cost. High-priority opportunities include station designs, streamlining/standardizing permitting process, and financial, policy and partnership support.

Cost Reductions Opportunities Identified by Experts



RFI: Tech. Validation

Closes June 1, 2011

Areas of Interest

- Innovative concepts for:
 - Stationary fuel cell systems for residential and commercial applications
 - Combined-heat-hydrogen-and-power (CHHP) co-production fuel cell systems
- Technology Validation projects for other markets

For more information:

http://www1.eere.energy.gov/hydrogenandfuelcells/news_detail.html?news_id=16873

<http://www07.grants.gov/search/search.do?&mode=VIEW&oppld=84333>

RFI: Bus Targets

Closes July 1, 2011

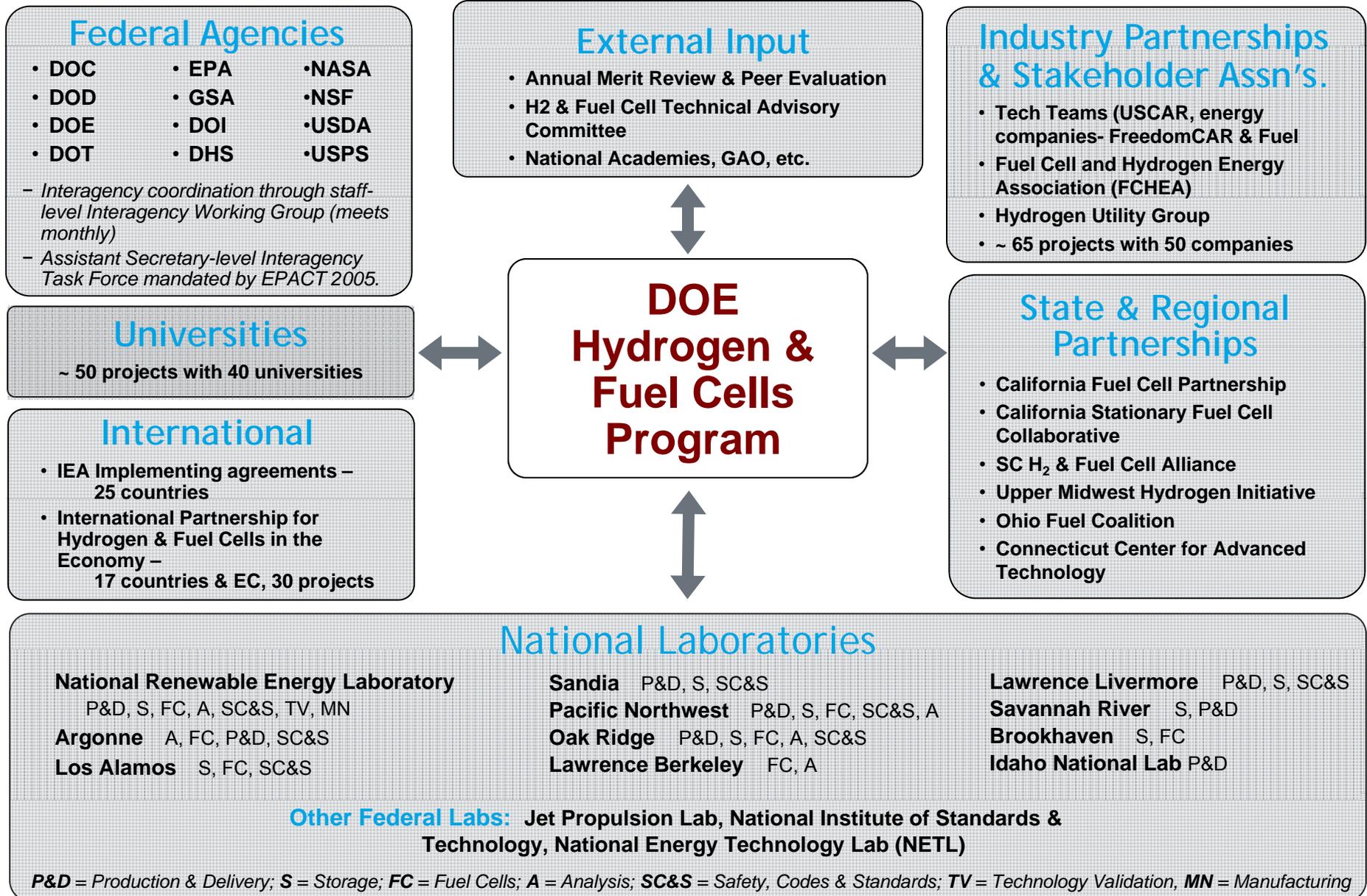
Areas of Interest

- Solicit feedback on performance, durability and cost targets for fuel cell transit buses
- Sponsored by



Questions may be addressed to:
DOEFCBUSRFI@go.doe.gov

Acknowledgements



Thank you

For more information, please contact

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Hydrogenandfuelcells.energy.gov

Hydrogen.energy.gov