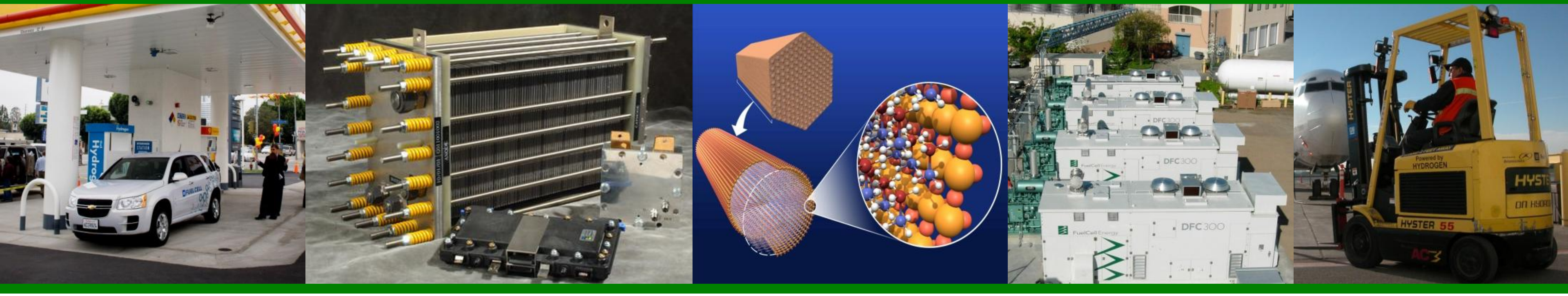
U.S. DEPARTMENT OF ENERGY



Hydrogen & Fuel Cells Program Overview

Dr. Sunita Satyapal

Program Manager

2011 Annual Merit Review and Peer Evaluation Meeting

May 9, 2011

Hydrogen and Fuel Cells Key Goals

U.S. DEPARTMENT OF ENERGY

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

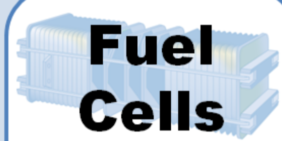
Methane

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**

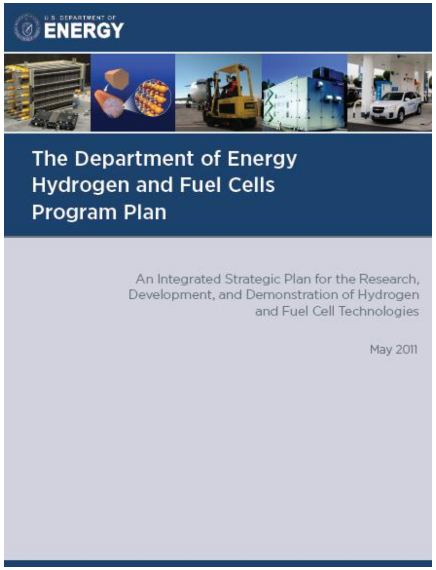
Diverse Applications

Stationary Power

Transportation

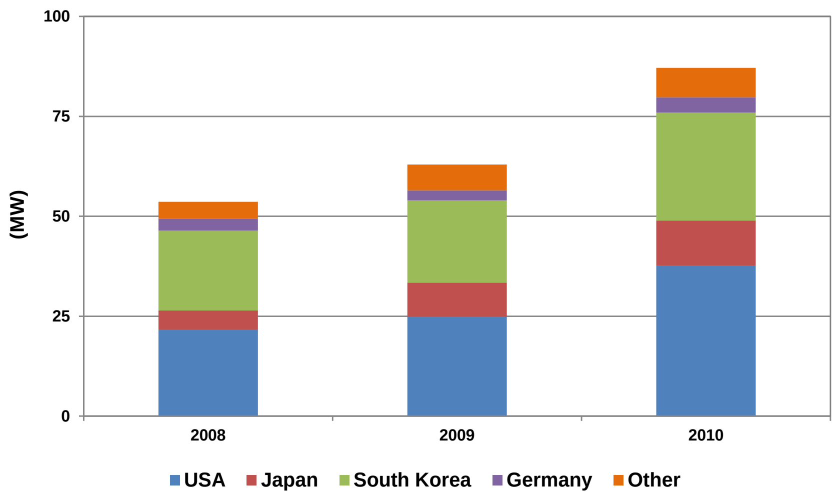
Portable Power

Updated Program Plan May 2011

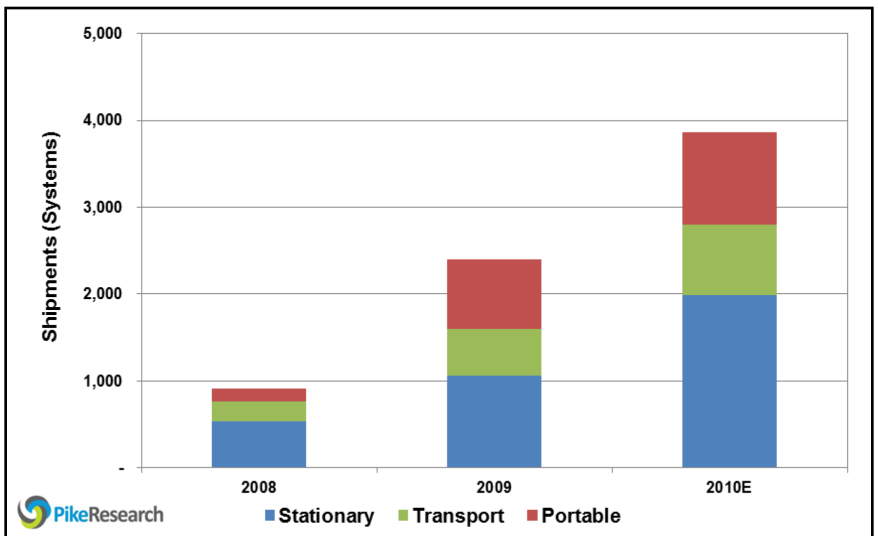


Fuel Cell Market Overview

Megawatts Shipped, Key Countries: 2008-2010



North American Shipments by Application



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

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

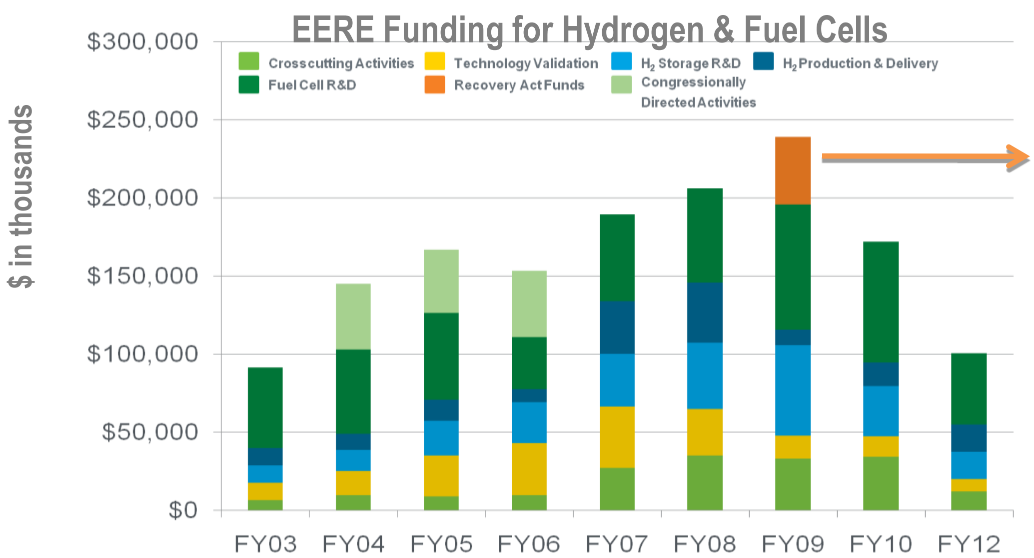
FuelCells2000, Pike Research, Fuel Cell Today, ANL

Hydrogen & Fuel Cells - Budgets

U.S. DEPARTMENT OF ENERGY

EERE Funding (*$ in thousands*)		
Key Activity	**FY 2010**	**FY 2012 Request**
Fuel Cell Systems R&D	**75,609**	**45,450**
Hydrogen Fuel R&D	**45,750**	**35,000**
Technology Validation	**13,005**	**8,000**
Market Transformation	**15,005**	**0**
Safety, Codes & Standards	**8.653**	**7,000**
Education	**2,000**	**0**
Systems Analysis	**5,408**	**3,000**
Manufacturing R&D	**4,867**	**2,000**
Total	**$170,297**	**$100,450**

~$38 M/year for Basic Energy Sciences



Additional $42 M under Recovery Act

[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; Hydrogen Fuel R&D includes Hydrogen Production & Delivery and Hydrogen Storage R&D; No Market Transformation in FY 2012; FY 2009 Recovery Act funding of $42M not shown in Table. FY 12 Includes SBIR/STTR funds.

Key Challenges

U.S. DEPARTMENT OF ENERGY

The Program has been addressing the key challenges facing the widespread commercialization of fuel cells.

Technology Barriers*

Fuel Cell Cost & Durability

Targets*:

***Stationary Systems:* $750 per kW, 40,000-hr durability**

***Vehicles:* $30 per kW, 5,000-hr durability**

Hydrogen Cost

Target: $2 – 4 /gge, (dispensed and untaxed)

Hydrogen Storage Capacity

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

Technology Validation:

Technologies must be demonstrated under real-world conditions.

Economic & Institutional Barriers

Safety, Codes & Standards Development

Domestic Manufacturing & Supplier Base

Public Awareness & Acceptance

Hydrogen Supply & Delivery Infrastructure

Market Transformation

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

Progress – Fuel Cell R&D

U.S. DEPARTMENT OF ENERGY

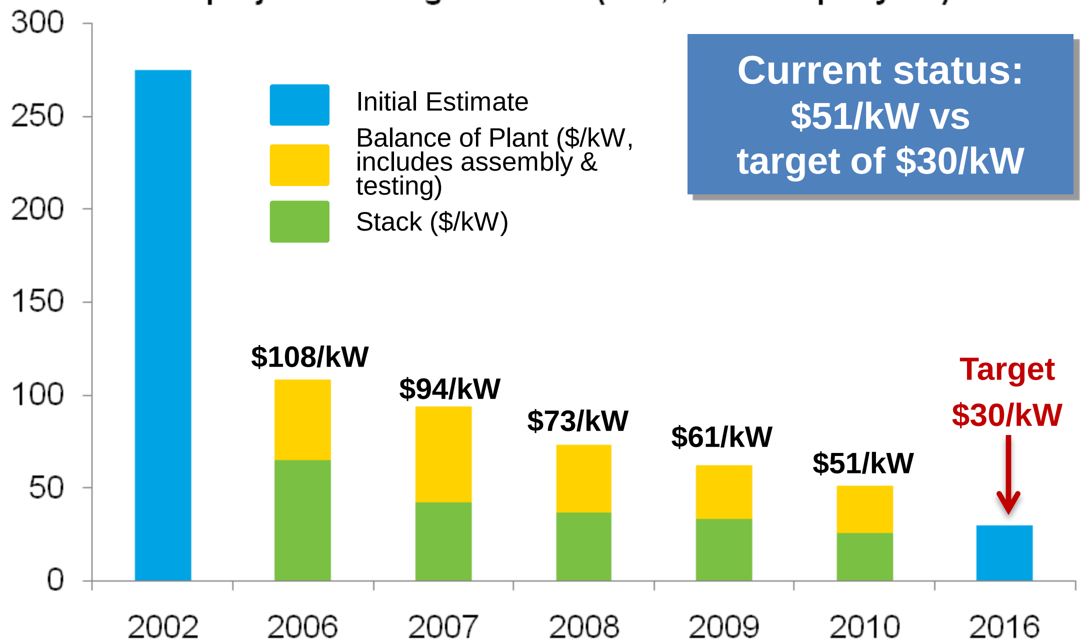
Reduced the projected high-volume cost of fuel cells to $51/kW (2010)*

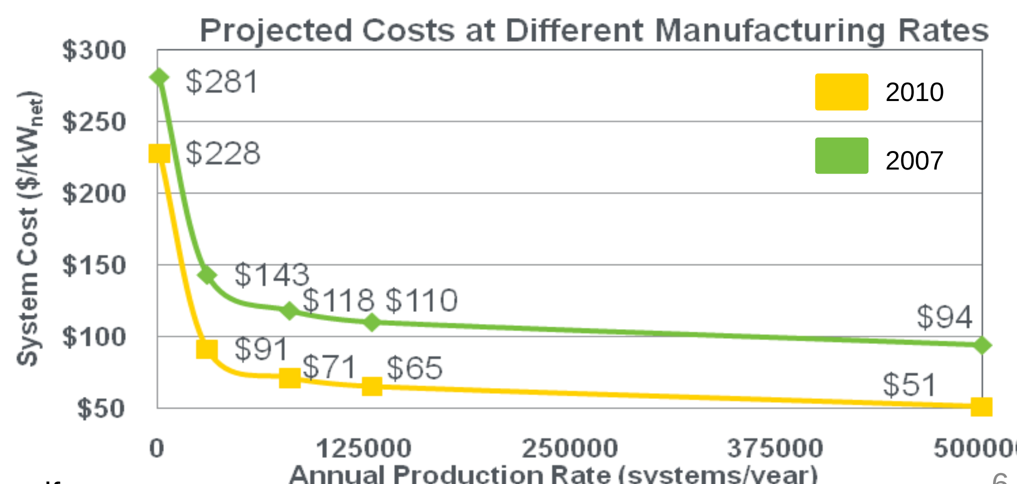
- ***More than 30% reduction since 2008***
- ***More than 80% reduction since 2002***

Demonstrated advanced gas diffusion layer manufacturing processes that have reduced cost by >50% and increased manufacturing capacity by 4X since 2008 (Ballard)

Projected Transportation Fuel Cell System Cost

-projected to high-volume (500,000 units per year)-





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

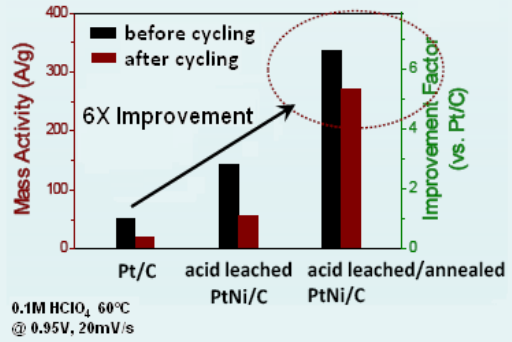
*****Panel found $60 – $80/kW to be a "valid estimate" for 2008 http://hydrogendoedev.nrel.gov/peer_reviews.html***

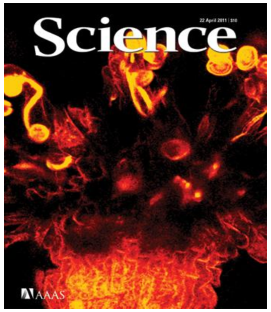
http://www.hydrogen.energy.gov/pdfs/10004_fuel_cell_cost.pdf

Progress – Fuel Cell R&D

U.S. DEPARTMENT OF ENERGY

Progress continues in low and zero Pt catalysts





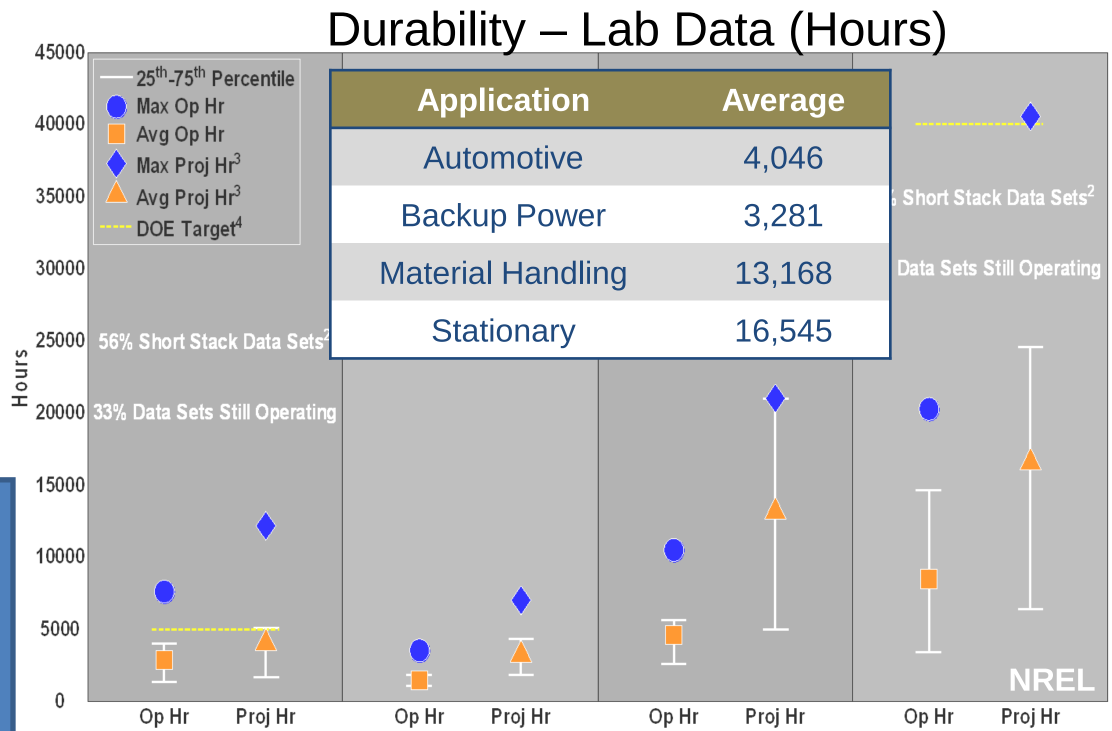
G. Wu, K. L. More, C. M. Johnston, P. Zelenay, *Science*, **332**, 443-7 (2011)

- **Developed and demonstrated non PGM catalysts (polyaniline/ cyanamide-based catalysts)**
- **Demonstrated more than 6X the performance of Pt using nanosegregated binary and ternary Pt alloy catalysts**

R. Adzic honored as Brookhaven Natl Lab Inventor of the Year for his work on fuel cell catalysis!

LANL, ORNL, ANL, BNL

Tracking durability for diverse applications. Maximum projected durability exceeds some DOE targets.



Application	Average
Automotive	4,046
Backup Power	3,281
Material Handling	13,168
Stationary	16,545

Tracking durability data from multiple companies (NREL)

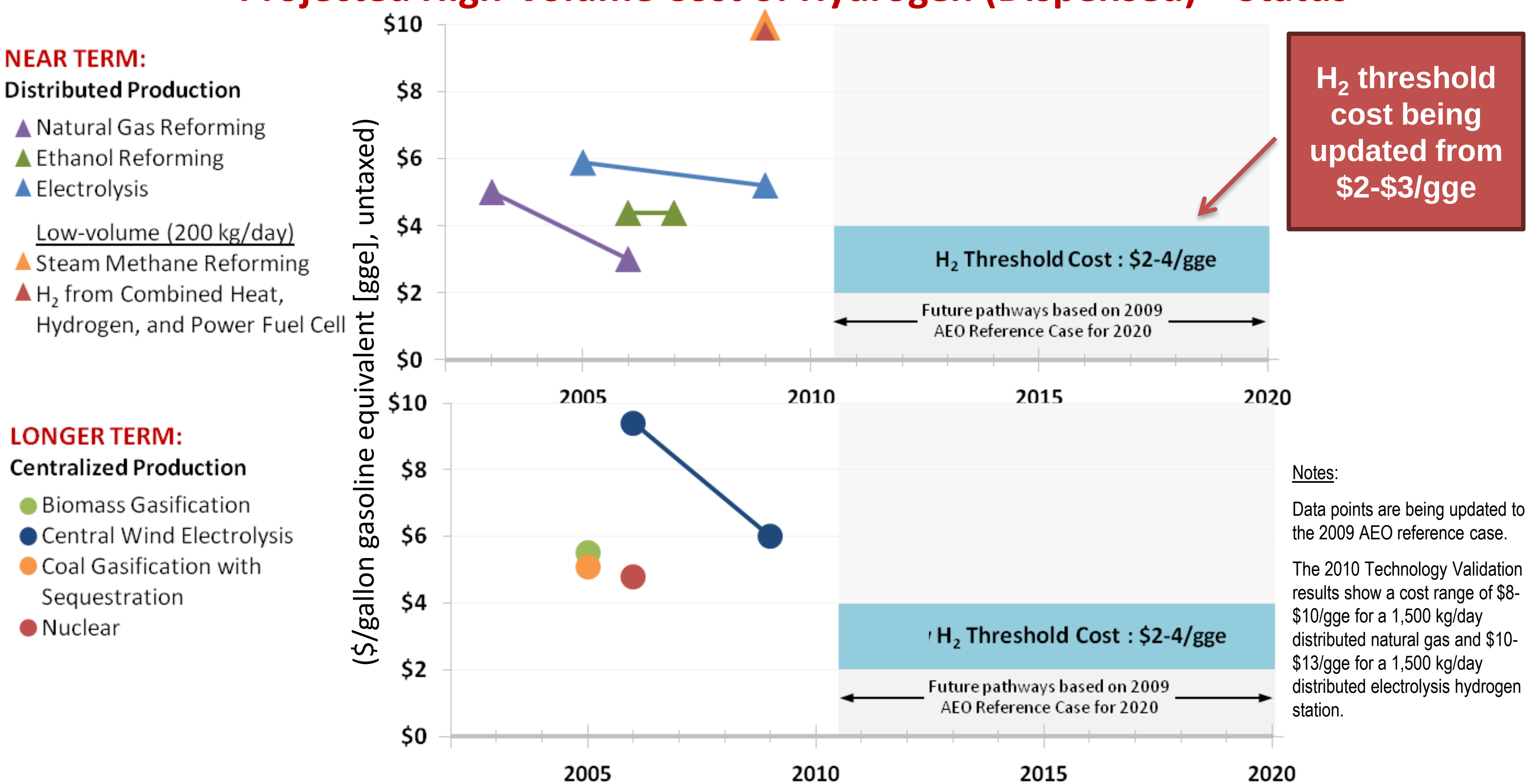
- **Demonstrated >10,000 hours for SOFCs (Acumentrics)**
- **Achieved 10,000 simulated start/stop cycles with new catalyst, greatly exceeding target (3M)**

Progress – Hydrogen Production & Delivery

U.S. DEPARTMENT OF ENERGY

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



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.

Hydrogen Delivery: Projected an additional 33% improvement in tube trailer capacity in the last year due to optimized carbon composites vessel design (Lincoln Composites)

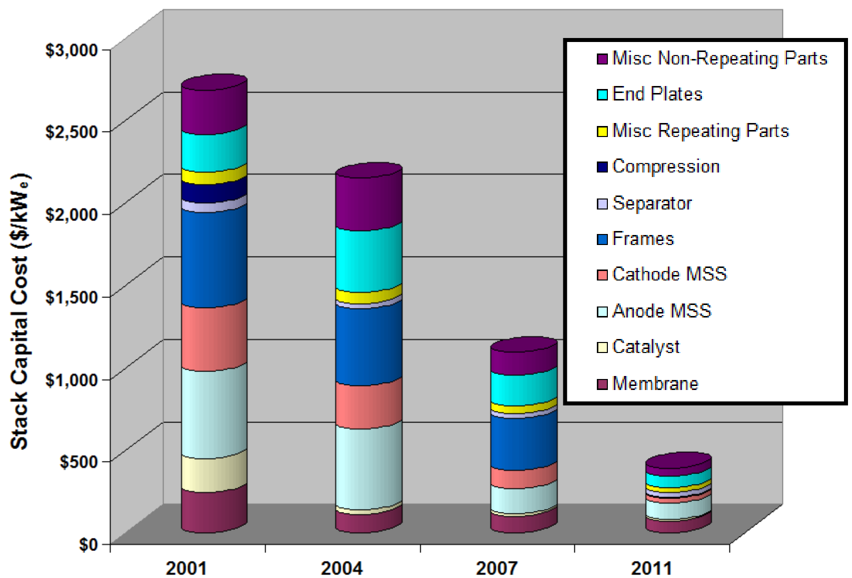
Progress – Hydrogen Production

U.S. DEPARTMENT OF ENERGY

Demonstrated continued progress in hydrogen cost reduction

Reduced electrolyzer cost by 80% since 2001

- **15% cost reduction in just the last year**
- **Projected high volume capital cost of $350/kW (vs. 2012 target $400/kW) (Proton, Giner)**

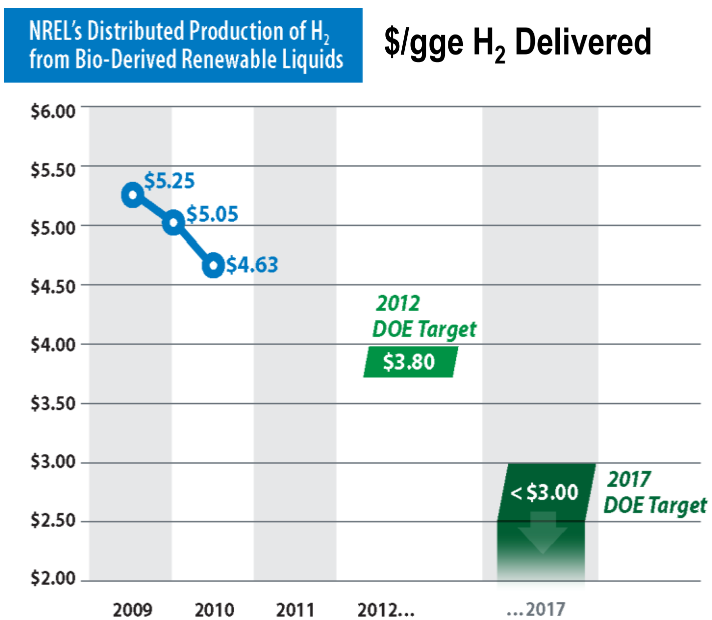


Photoelectrochemical Conversion (PEC):

- **Demonstrated potential to exceed 10% solar-to-hydrogen efficiency target**

>16% observed at lab scale (NREL)

Autothermal Reforming of Pyrolysis Oil



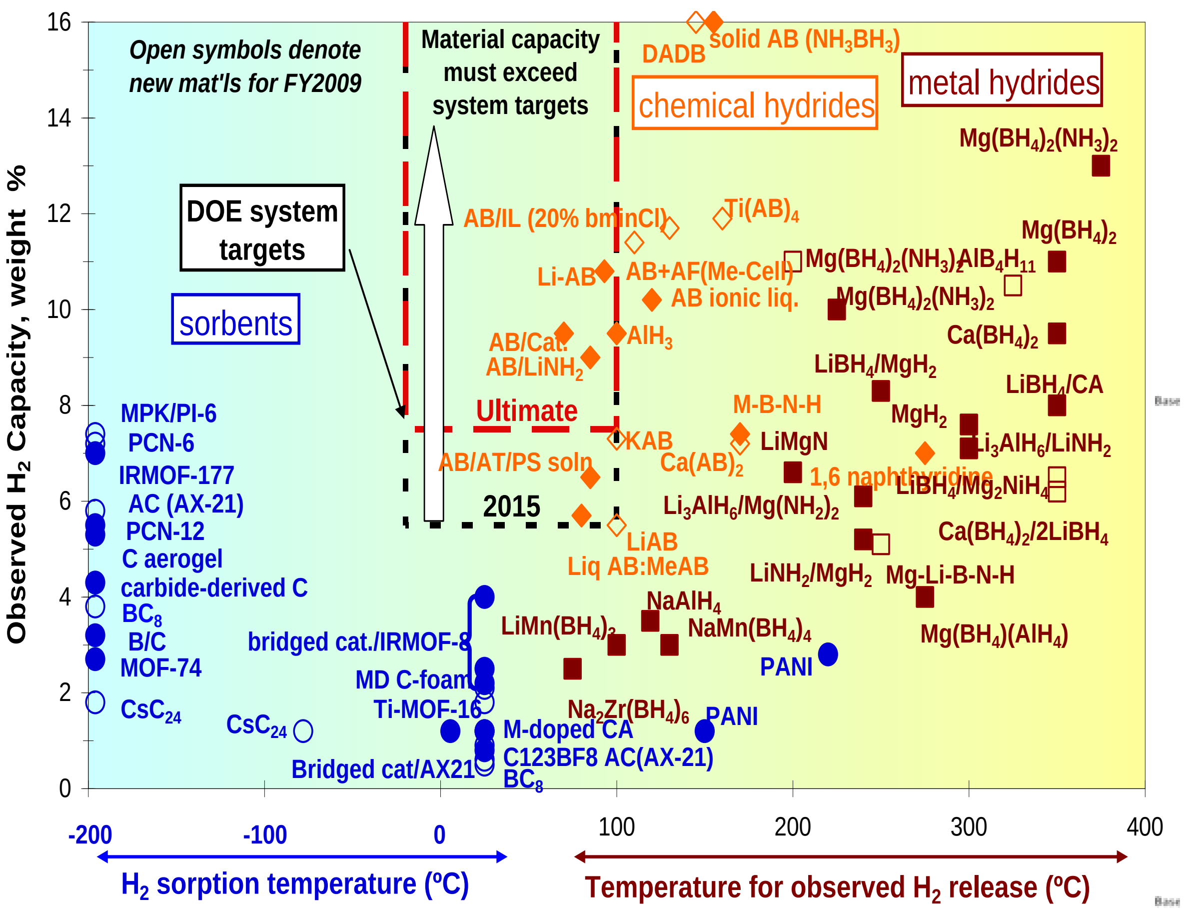
- **Increased hydrogen yield by 65%**
- **Reduced production cost to an estimated $4.65/gge delivered**

Progress - Hydrogen Storage

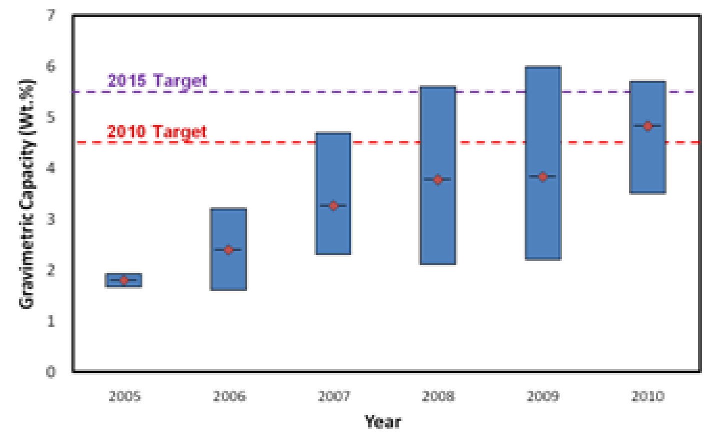
U.S. DEPARTMENT OF ENERGY

Tanks can achieve 430 mile range. Focus is on materials R&D but meeting all weight, volume, performance and cost requirements is still challenging.

Developed > 420 new materials with potential to store hydrogen at low to moderate pressures



Projected Capacities for Complete 5.6-kg H_2 Storage Systems



- **Validated cryosorbents achieving >8.5 wt.% H_2 storage** (Texas A&M, SwRI)
- **Identified potential pathways to reduce carbon fiber and tank cost**

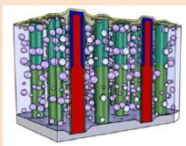
Collaborations

U.S. DEPARTMENT OF ENERGY

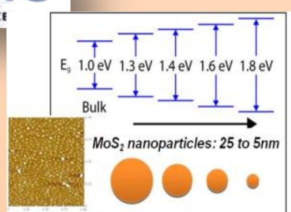
Examples of Cross-Office Collaborative Successes

Advancing fundamental science knowledge base

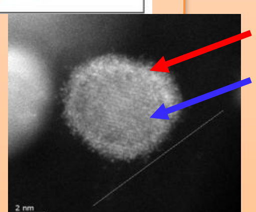
Solar to Fuels Hub



Nanowire based solar fuels generation (CalTech)



Bandgap tailoring (Stanford)



Mechanistic understanding of catalysts

Pt monolayer

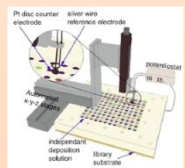
Pd core

Biological H_2 production

Materials-based H_2 storage

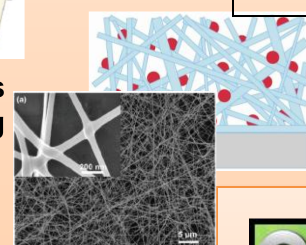
Applied RD&D of innovative technologies

High Throughput Processes (UCSB)



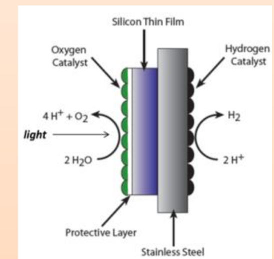
Standard protocols and benchmarking

Working Groups PEC, Biological, High T Membranes, Storage Systems



Nano-catalyst support scaffold (Stanford)

Using ARPA-E developed catalyst in water splitting device



Midwest Optoelectronics

ARPA-E: Focus on creative, high-risk transformational energy research

Alkaline Membranes

Sun Catalytix

Developing novel catalysts (high risk/high impact)

Progress - Technology Validation

U.S. DEPARTMENT OF ENERGY

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)

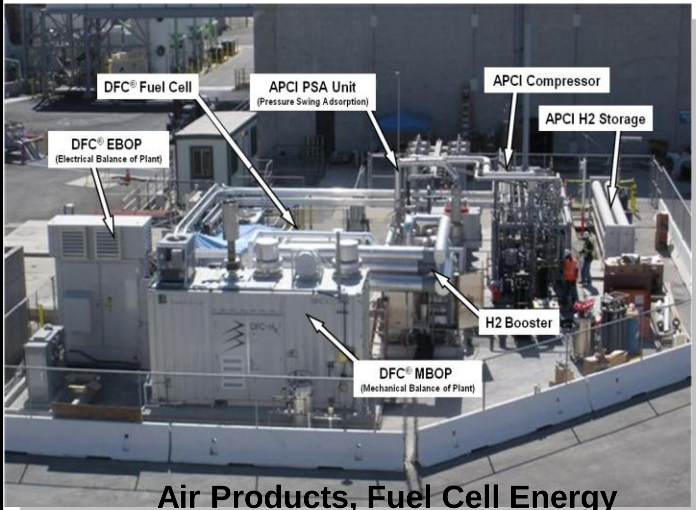
- H_2 fuel cell buses have a 42% to 139% better fuel economy when compared to diesel & CNG buses

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



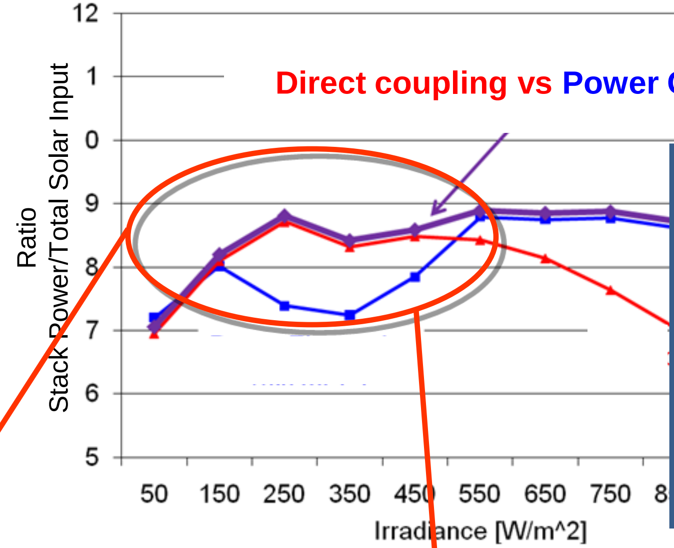
Air Products, Fuel Cell Energy

Hydrogen & Fuel Cells for Energy Storage

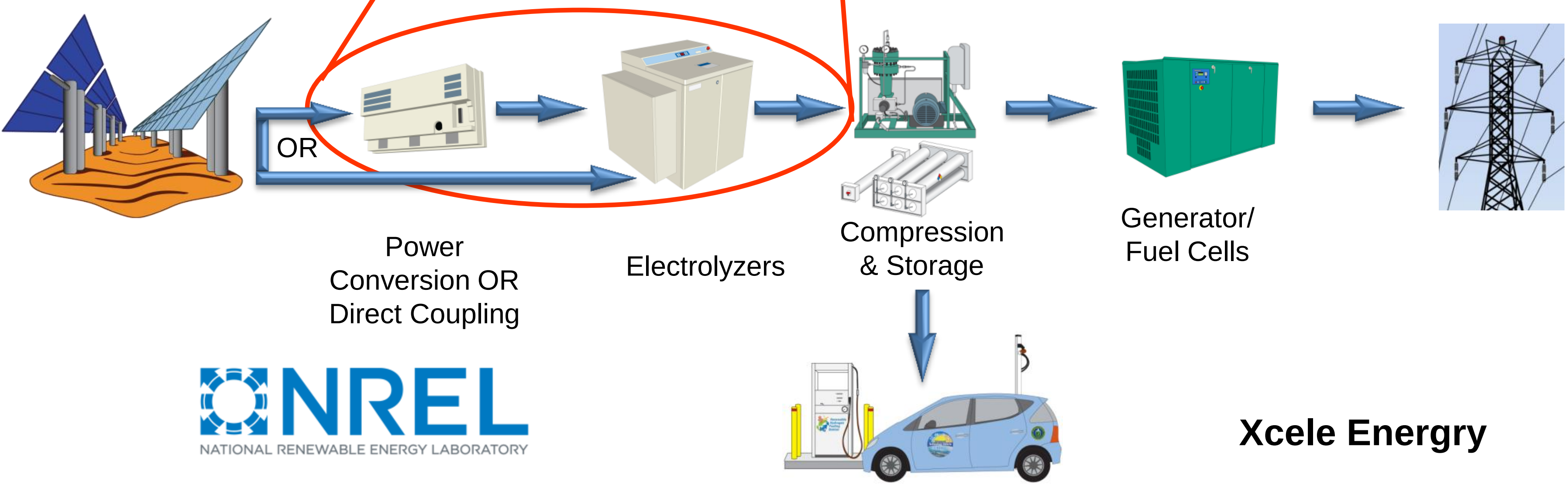
U.S. DEPARTMENT OF ENERGY

Improved efficiency of renewable H_2 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 H_2 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**



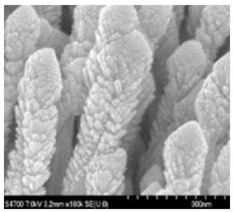
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Xcele Energry

DOE – DOT Collaborations

U.S. DEPARTMENT OF ENERGY

DOE and DOT support the development and deployment of fuel cell technology



Applied R&D
Reduced cost (80% since 2002)
Improved performance

DOE RD&D

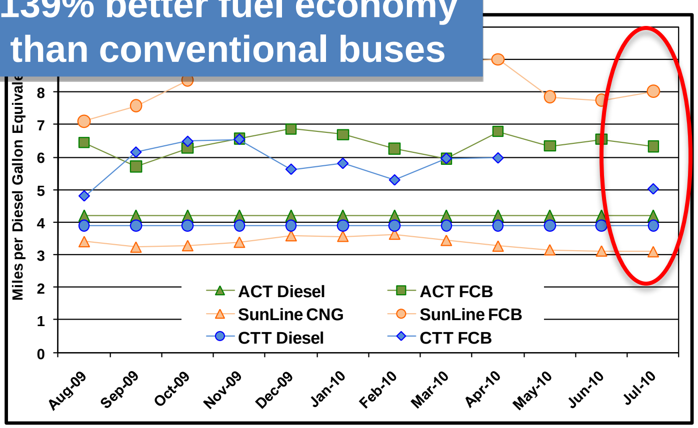
Data Collection & Validation

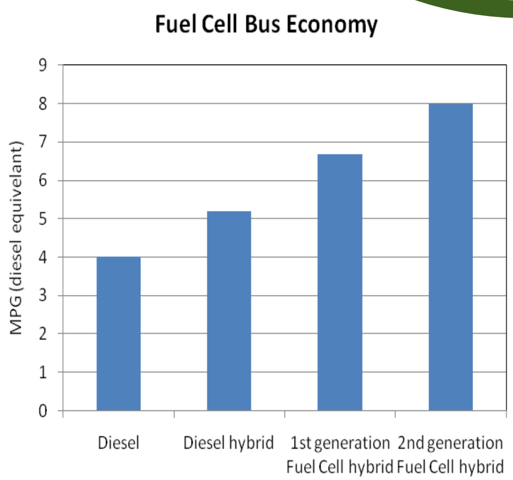
NREL HSDC
NREL's Hydrogen Secure Data Center

National Bus Program
($49 million for 4 years)

DOT Deployment

Fuel Cell buses: 42% to 139% better fuel economy than conventional buses





Projections based on the typical diesel baseline of 4 mpg in an average transit duty cycle

Accomplishments

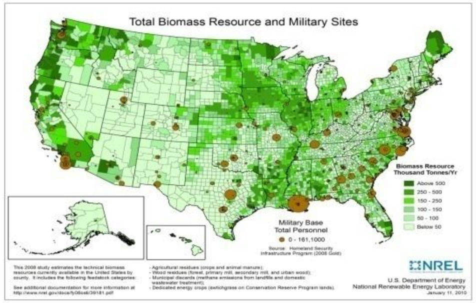
Demonstrated:

- Doubled fuel economies (8 mpg, >2X compared to diesel buses)
- 41% increase in average miles between roadcall with new fuel cell system (~8,500 MBRC)
- Demonstrated more than 8,000 hr fuel cell durability

DOD-DOE Memorandum of Understanding

U.S. DEPARTMENT OF ENERGY

Strengthen coordination and partnerships between DOE and DOD.

Workshops Held	Outcomes & Next Steps	Impact
Waste-to-Energy	DOD-DOE working group formed to identify opportunities.	
Aviation APUs	Industry working group established	
Shipboard APUs	Bio/logistics fuels reforming	

634,000 million BTUs potential energy savings using waste-to-energy CHP[2]

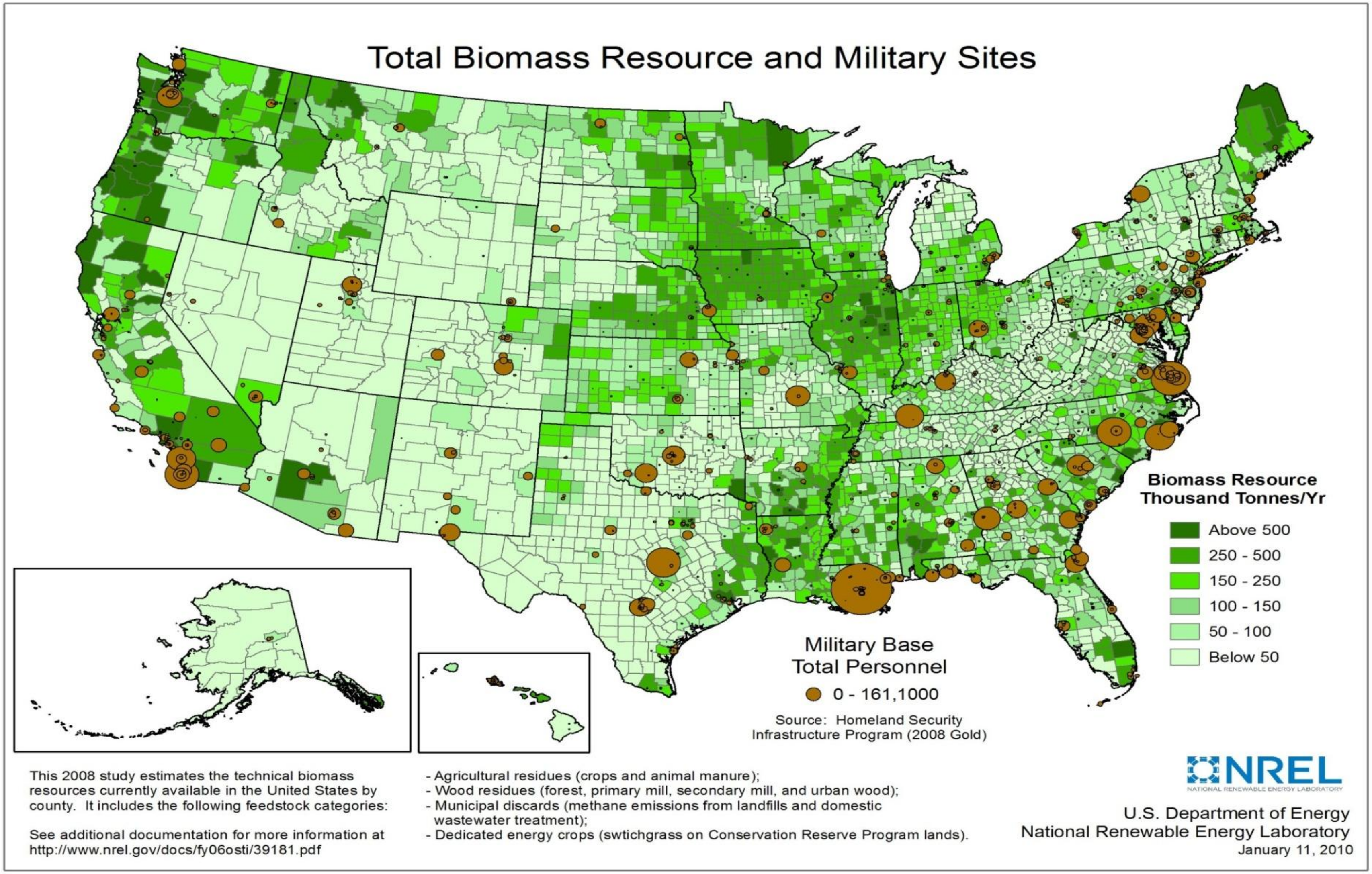
Potentially reduce NOx emissions by ~900-2,200 tons/yr for aircraft & 1,200-2,000 tons/yr for GSE[2]

Shipboard fuel cells capable of saving ~11,000-16,000 bbls/ship/yr[2]

[1]FCHEA, http://www.fchea.org/index.php?id=14, [2] DOD Estimates

Potential Resources near DOD Sites

U.S. DEPARTMENT OF ENERGY



Progress – Market Transformation & Recovery Act

U.S. DEPARTMENT OF ENERGY

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

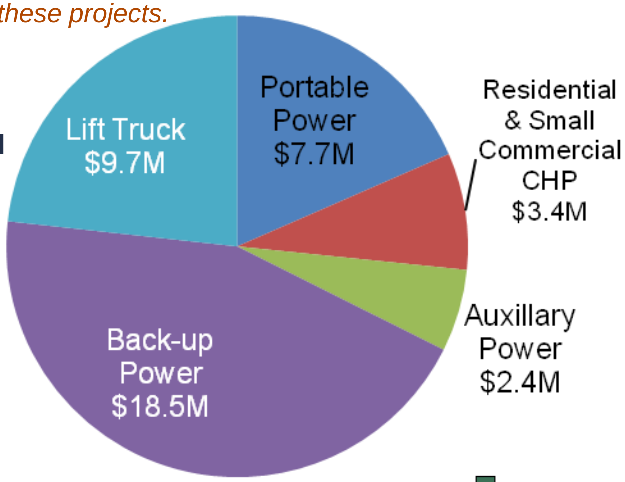
FROM the LABORATORY to DEPLOYMENT:

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

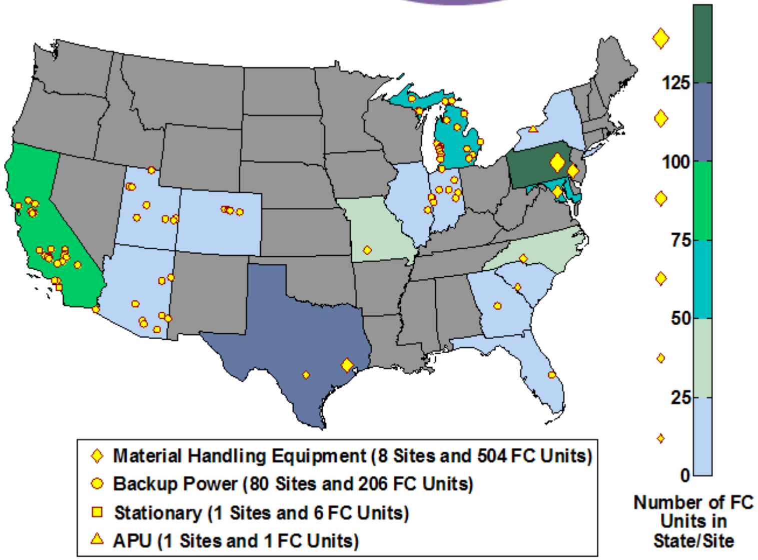
DOE: $42 M

Cost-share: $54 M

Total: $96 M.

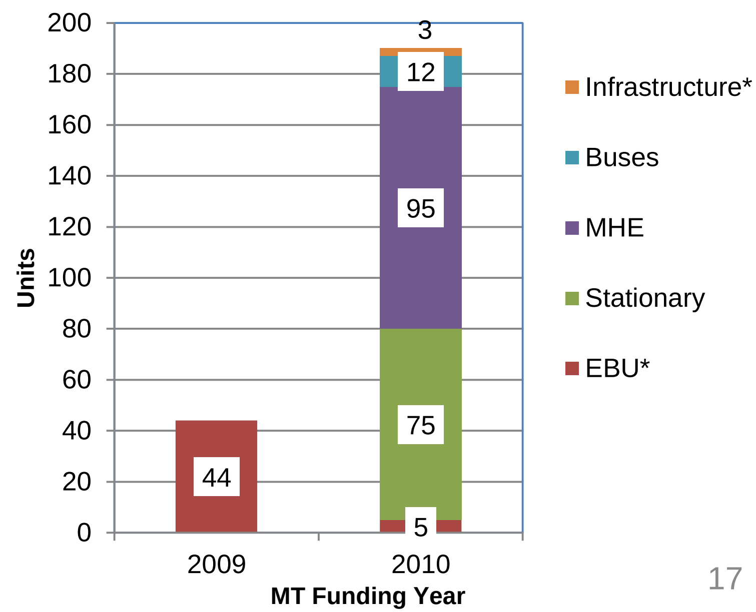


- **Forklifts**
  - FedEX Freight East, GENCO, Nuvera Fuel Cells, Sysco Houston
- **Back-up Power**
  - Plug Power, Inc., ReliOn, Inc., Sprint Nextel
- **Portable Power**
  - Jadoo Power, MTI MicroFuel Cells, Univ. of N. Florida
- **Auxiliary Power**
  - Delphi Automotive



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

Market Transformation Hydrogen and Fuel Cell Deployments*

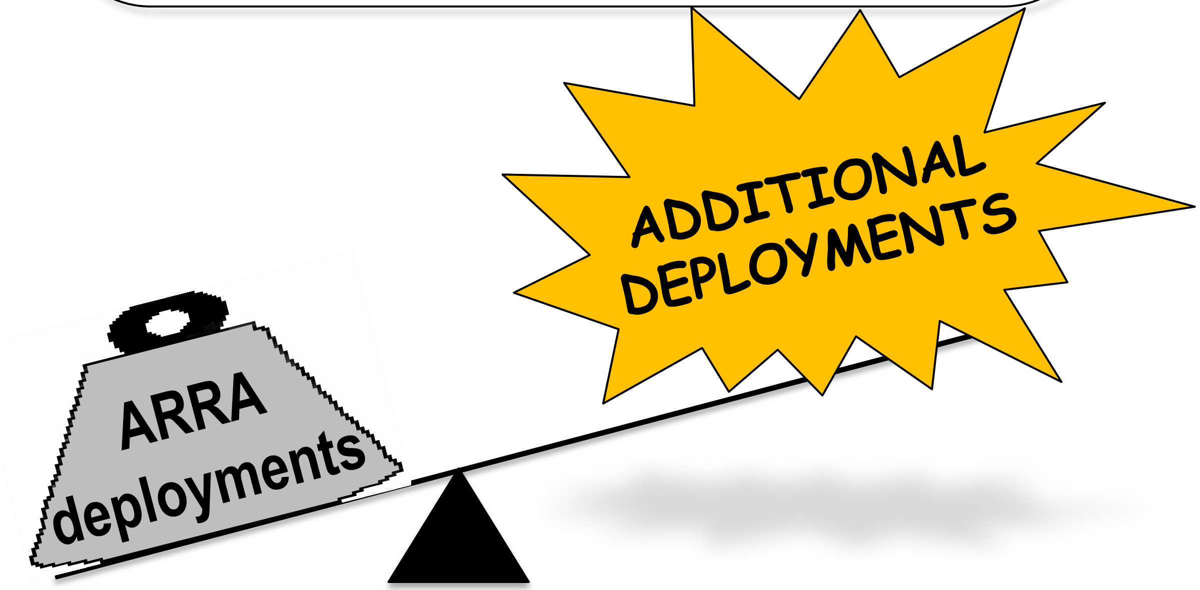


Accomplishments

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

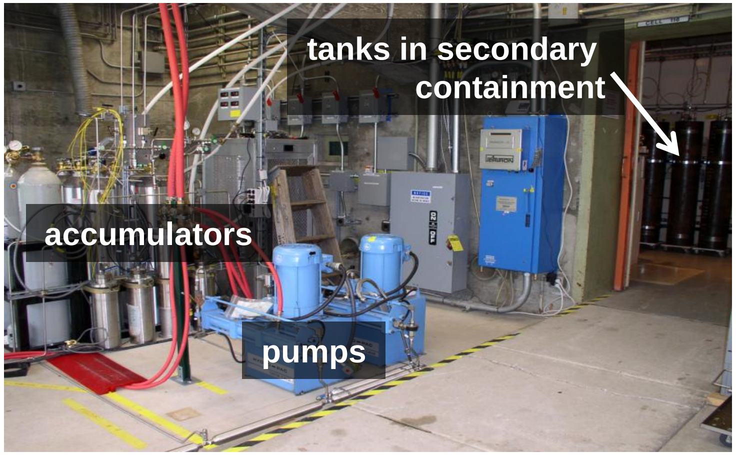
*Average projected hours to 10% voltage drop of all the fleets with a max fleet project of more than 9,500 hours. 25% of systems have more than 2,300 operation hours and one fleet averages more than 2,6000 operation hours.

U.S. DEPARTMENT OF ENERGY

Safety R&D and Codes & Standards

- Exceeded 34,000 hydrogen pressure cycles in steel storage tanks
- Quantified effect of barrier walls leading to potential for up to 50% reduction in separation distances
- Expanded web-based first responder training (17,000 visits)

Tanks with engineered defects are projected to exceed expected life



Sandia National Lab

Education and Outreach

- Developed and disseminated information to educate key stakeholders
- Reached > 8,500 teachers
- Measured up to 220% increase in knowledge level in 2 years

Fuel Cell Technologies Post-doc Program

– Up to five positions available to conduct applied research at universities, national laboratories, and other research facilities

– **Applications are due June 30, 2011**

http://www1.eere.energy.gov/education/postdoctoral_fellowships/

Example - The Case for Fuel Cell Forklifts

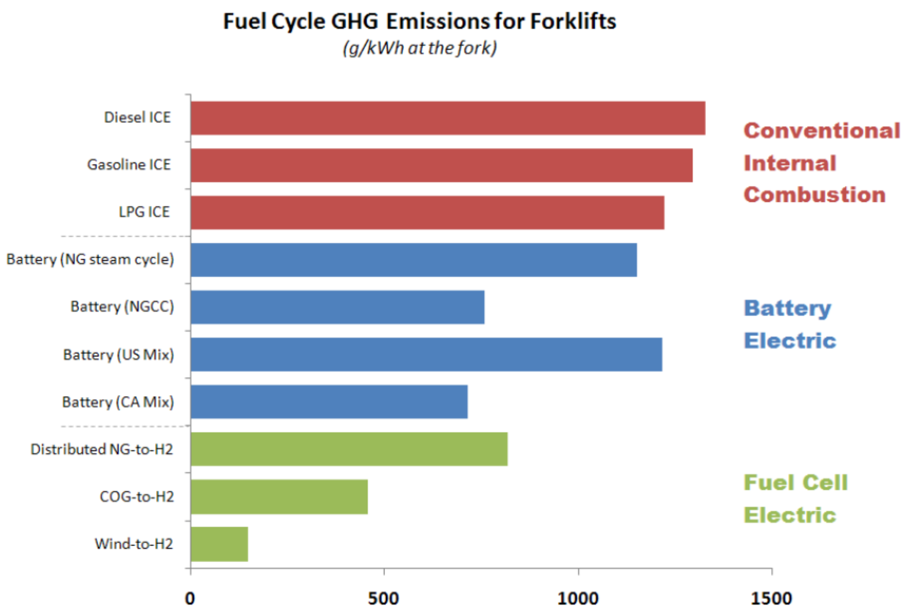
U.S. DEPARTMENT OF ENERGY

Fuel cell forklifts offer several advantages compared to conventional fork lift technology

Preliminary Analysis

Compared to conventional forklifts, fuel cell forklifts have:

- **1.5 X lower maintenance cost**
- **8 X lower refueling/recharging labor cost**
- **2 X lower net present value of total system cost**



Preliminary Analysis: Comparison of PEM Fuel Cell- and Battery-Powered Forklifts

Time for Refueling/ Changing Batteries	4-8 min/day	45-60 min/day (for battery change-outs) 8 hours (for battery recharging & cooling)
Labor Cost of Refueling/Recharging	$1,100/year	$8,750/year
NPV of Capital Costs	$12,600 ($18,000 w/o incentives)	$14,000
NPV of O&M Costs (including fuel)	$52,000	$128,000

Published Fact Sheets & Case Studies

Employment Impacts of Early Markets

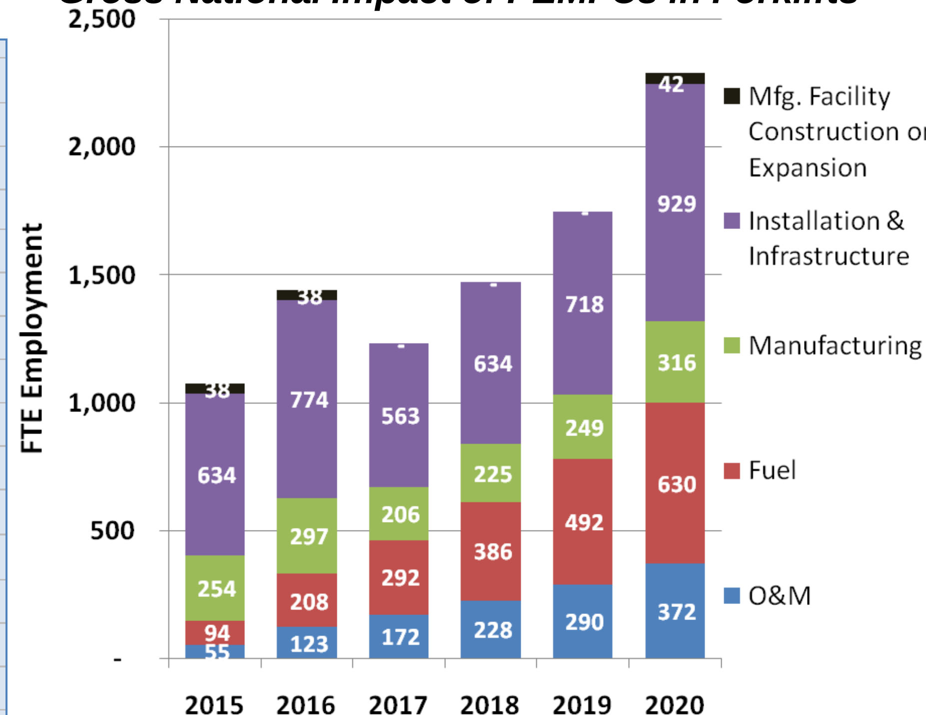
U.S. DEPARTMENT OF ENERGY

Developed user-friendly tool to calculate economic impacts

REQUIRED USER INPUT FIELDS	
Select State or Region	NE
Type of Fuel Cell	PEMFC
Application	Stationary - Backup
Average Size of Manufactured Fuel Cell	5
Fuel Cells Manufactured by Year	2000
Annual Fuel Cell Production (kW/year)	10,000
Time Frame (years)	5
OPTIONAL USER INPUT FIELDS	
Existing Fuel Cell Production Capacity (kW/year)	0
Additional Manufacturing Capacity to be Constructed (kW/year)	10,000
Sales Price ($/kW)	$2,000
Production Cost ($/kW, initial)	$1,301
Progress Ratio	0.97
Production Volume for Initial Cost	10,000
Scale Elasticity	-0.2
Full Scale Production Level (kW/year)	25,000
Annual Rate of Technological Progress	2%
Average Production Cost Over Time Frame ($/kW)	$1,098
Installation Cost ($/kW)	TBD
Operations & Maintenance Cost ($/kW, annual)	TBD

Preliminary Analysis

Gross National Impact of PEMFCs in Forklifts



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

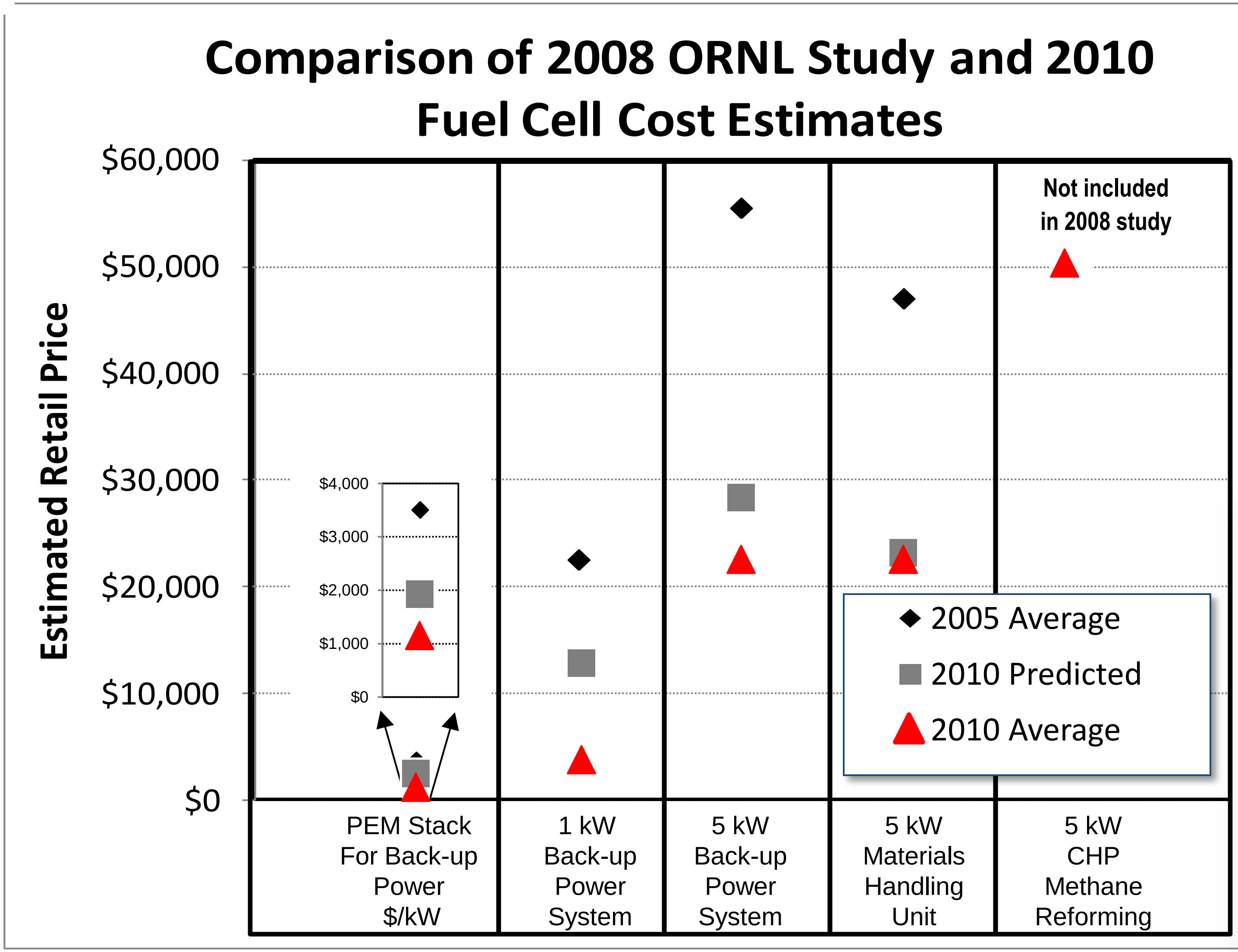
Technology/Market Assumptions:

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

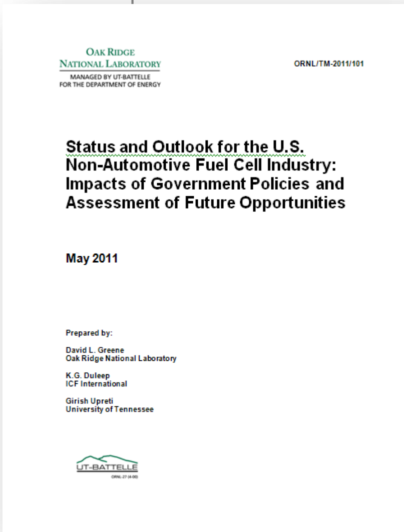
Argonne National Lab/RCF

Early Market Cost Reduction Analysis

U.S. DEPARTMENT OF ENERGY



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



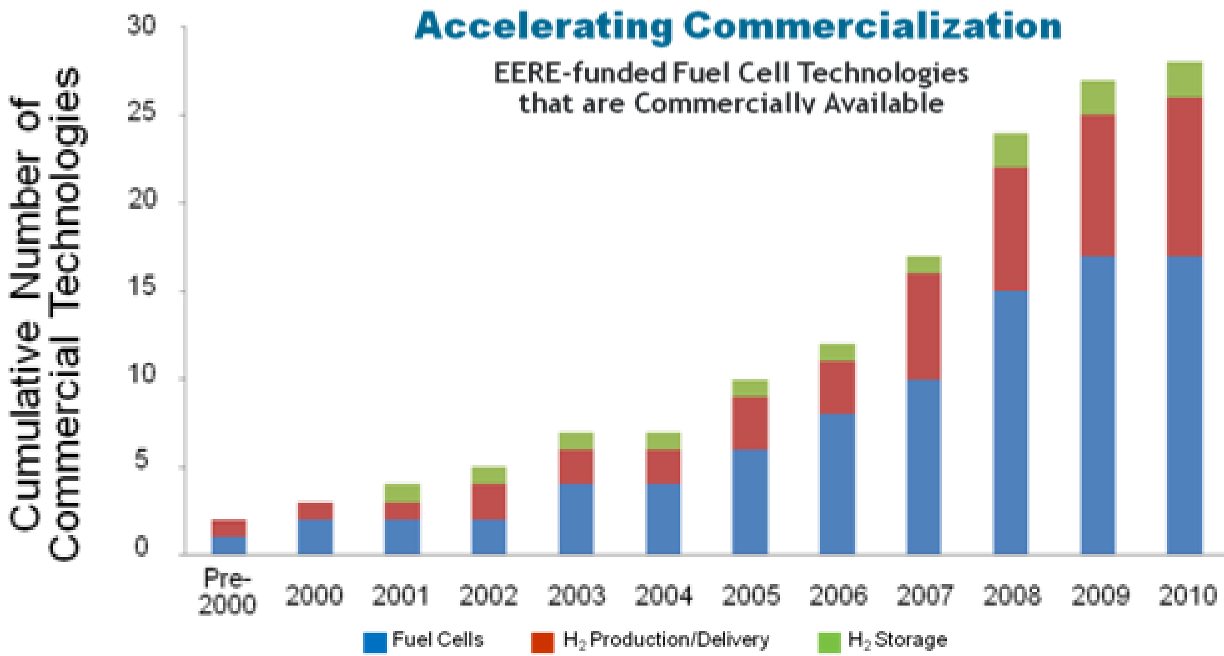
2005 and 2010 averages based on estimates supplied by OEMs. 2010 predicted assumed government procurements of 2,175 units per year, total for all market segments. Predictions assumed a progress ratio of 0.9 and scale elasticity of -0.2.

ORNL

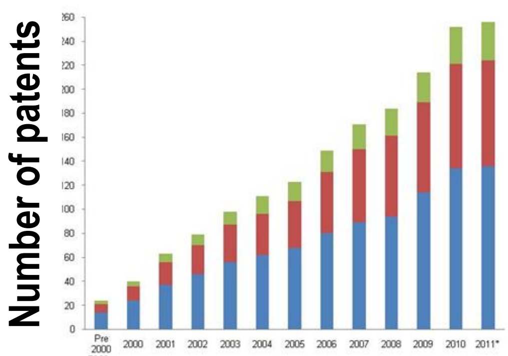
Assessing Program Impact - Commercialization

U.S. DEPARTMENT OF ENERGY

DOE funding directly led to ~30 hydrogen and fuel cell technologies in the market.



Source: Pacific Northwest National Laboratory
http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/pathways_success_hfcit.pdf



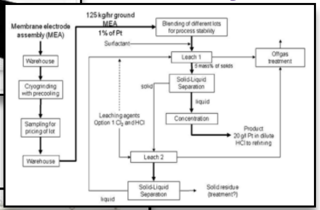
256 PATENTS resulting from EERE-funded R&D:

- 136 fuel cell
- 88 H_2 production & delivery
- 32 H_2 storage

Examples

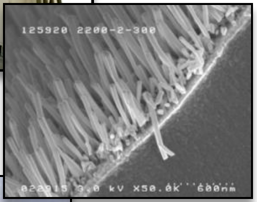
DuPont

BASF Catalysts

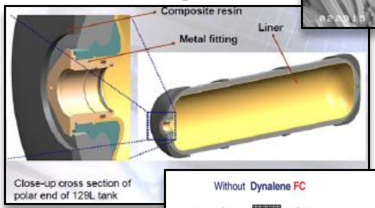


Proton

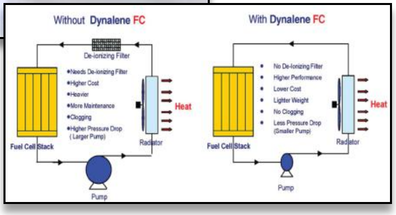
3M



Quantum Technologies

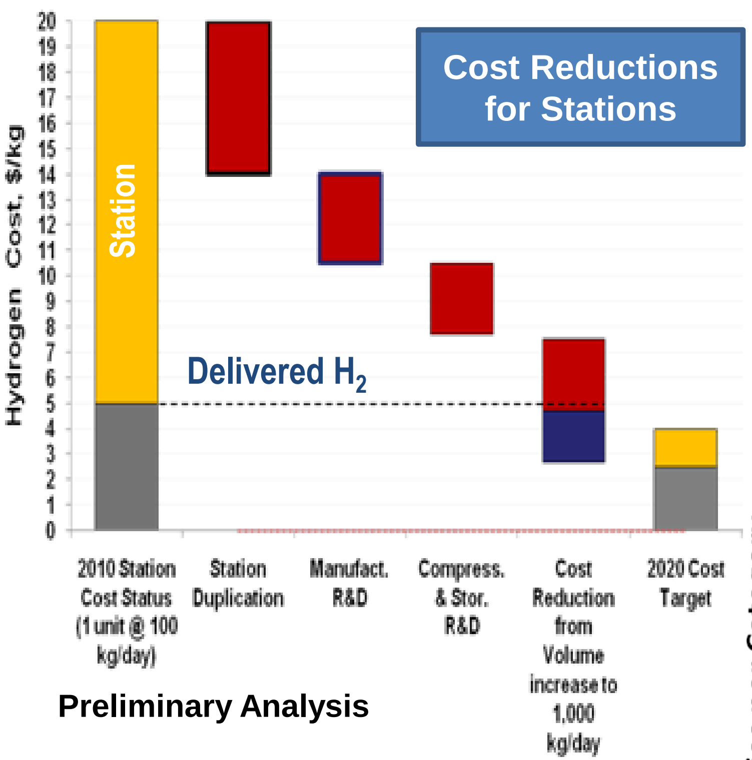


Dyanlene, Inc.



Additional Analysis - Hydrogen Infrastructure

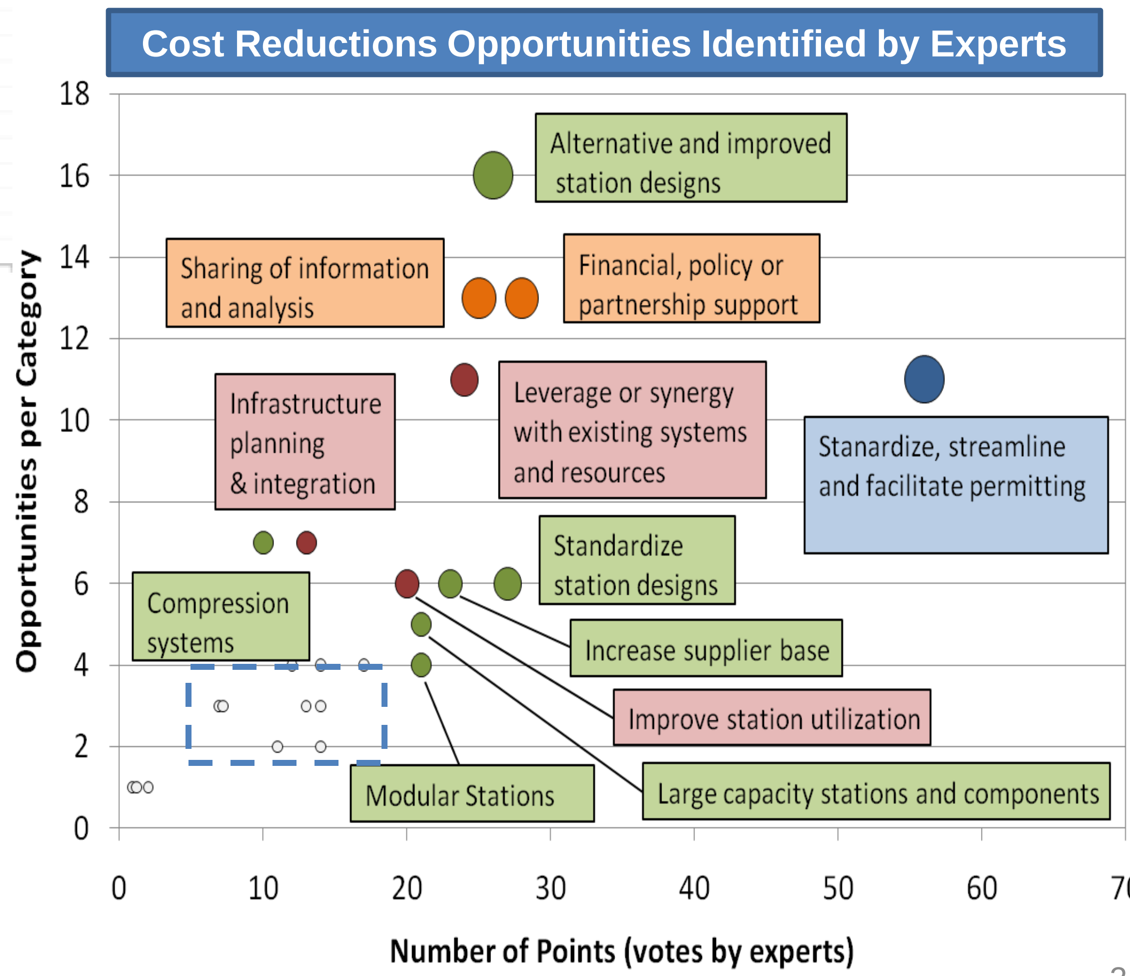
U.S. DEPARTMENT OF ENERGY



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 H_2 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.

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



Announcements

U.S. DEPARTMENT OF ENERGY

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&oppId=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

U.S. DEPARTMENT OF ENERGY

FTA United States Department of Transportation Federal Transit Administration

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

Acknowledgements

U.S. DEPARTMENT OF ENERGY

Federal Agencies

- DOC
- DOD
- DOE
- DOT
- EPA
- GSA
- DOI
- DHS
- NASA
- NSF
- USDA
- 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

External Input

- Annual Merit Review & Peer Evaluation
- H2 & Fuel Cell Technical Advisory Committee
- National Academies, GAO, etc.

DOE Hydrogen & Fuel Cells Program

Industry Partnerships & Stakeholder Assn's.

- Tech Teams (USCAR, energy companies- FreedomCAR & Fuel
- 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 H_2 & 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)**

***P&D** = Production & Delivery; **S** = Storage; **FC** = Fuel Cells; **A** = Analysis; **SC&S** = Safety, Codes & Standards; **TV** = Technology Validation, **MN** = Manufacturing*

Thank you

Presidential Awardees

- ***Professor Susan Kauzlarich –UC Davis Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring***
- ***Presidential Early Career Awards***
  - ***Dr. Jason Graetz –BNL***
  - ***Dr. Craig Brown – NIST***

For more information, please contact
Sunita Satyapal
Program Manager

Sunita.Satyapal@ee.doe.gov

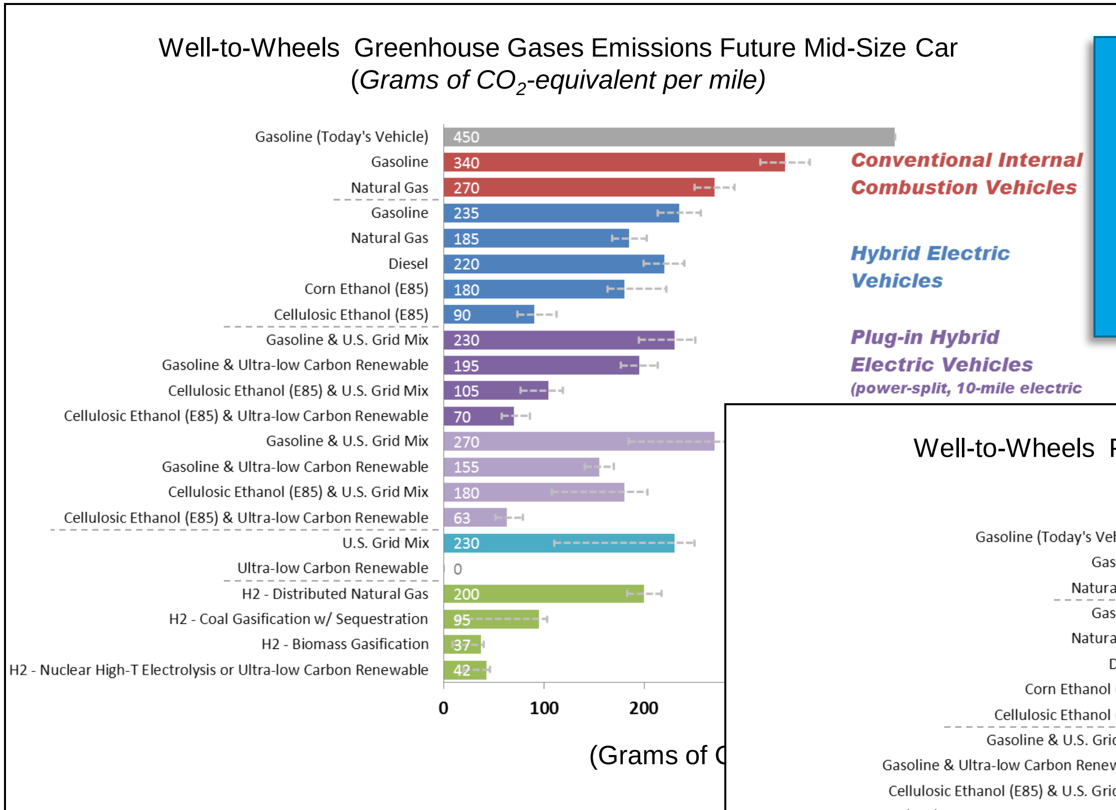
Hydrogenandfuelcells.energy.gov

Hydrogen.energy.gov

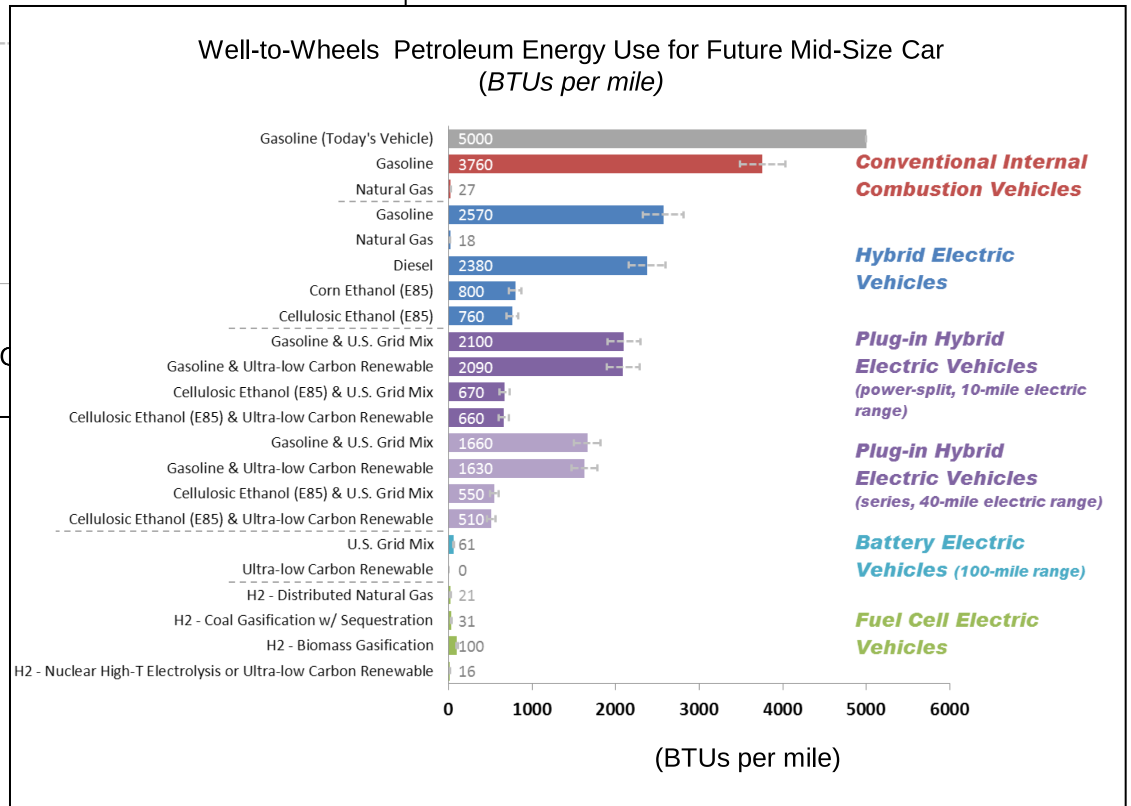
Additional Information

Systems Analysis — *WTW Updates*

U.S. DEPARTMENT OF ENERGY



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.

Key Participants – Hydrogen Production

U.S. DEPARTMENT OF ENERGY

Analysis & Testing
- ORNL
- TIAX
- PNNL
- UH
- SNL
- ANL

Bio-derived Liquids
- ANL
- PNNL
- NREL

Electrolysis
- Giner Electrochemical
- Avalence
- Proton Energy
- ORNL
- NREL

Membranes
- Media and Process Technology
- ASU
- Pall Corporation
- ORNL

Biomass Gasification
- UTRC
- GTI
- NETL

Solar High Temperature Thermochemical H_2 Production
- SNL
- ANL
- SAIC
- U of CO, Boulder

Photoelectrochemical H_2 Production
- LANL
- LLNL
- Midwest Optoelectronics
- MV Systems
- Stanford University
- NREL

Biological H_2 Production
- UC Berkeley
- J. Craig Venter
- NREL

Key Participants – Hydrogen Delivery

U.S. DEPARTMENT OF ENERGY

Analysis
- ANL
- NREL
- PNNL

Carriers
- Air Products
- PNNL

Forecourt Compression/Storage
- AC Transit
- Fuel Cell Energy
- NASA
- ORNL

H_2 Liquefaction & Delivery
- Gas Equipment Engineering Corporation
- Linde Corporation
- LLNL
- Praxair
- Promethius Energy

Pipelines & Pipeline Compression
- ANL
- Concepts NREC
- DOT
- I2CNER
- MITI
- NASA
- NIST
- ORNL
- Secat
- SNL
- SRNL
- University of Illinois

Sub-program Review
- BP
- Chevron
- Exxon-Mobil

Key Participants – Hydrogen Storage

U.S. DEPARTMENT OF ENERGY

Metal Hydrides

- HRL Laboratories
- UTRC
- CalTech
- Stanford
- Pittsburgh/Ga. Tech
- Hawaii/UNB
- Illinois
- Ohio State
- Nevada-Reno
- Utah
- Northwestern
- Brookhaven
- NIST
- Jet Propulsion Lab
- Oak Ridge
- Savannah River
- Sandia

Hydrogen Sorbents

- Air Products
- CalTech
- Duke U.
- Texas A&M
- Michigan
- North Carolina
- Penn State
- Rice
- Missouri-Columbia
- UCLA
- Northwestern
- Argonne
- Oak Ridge
- Lawrence Livermore
- NIST
- NREL

Chemical Hydrogen Storage Materials

- Dow
- U.S. Borax
- Penn State
- Alabama
- California-Davis
- Missouri-Columbia
- Pennsylvania
- Oregon
- Washington
- Los Alamos
- Pacific Northwest
- Idaho

System Engineering

- Ford
- General Motors
- Lincoln Composites
- UTRC
- Hawaii Hydrogen Carriers
- Oregon State
- CalTech
- L'Université du Québec à Trois-Rivières
- Savannah River
- Jet Propulsion Lab
- Los Alamos
- NREL
- Pacific Northwest

Testing, Analysis, Physical Storage and Novel Concepts

- Air Products and Chemicals
- UTRC
- Gas Technology Institute
- Hawaii Hydrogen Carriers
- H2 Technology Consulting LLC
- Hydrogen Education Foundation
- Southwest Research Institute
- SUNY – Syracuse
- UC Berkeley
- UC Santa Barbara; UNLV
- Quantum Technologies
- Argonne
- Savannah River
- Lawrence Livermore
- Sandia
- Oak Ridge
- Pacific Northwest
- NREL
- Purdue
- U. of Arkansas
- GM
- TIAX
- SiGNa

Key Participants – Fuel Cells

U.S. DEPARTMENT OF ENERGY

Testing and Technical Assessments
- LANL
- Directed Technologies
- TIAX
- NREL
- ANL
- ORNL
- NIST

Bipolar Plates
- TreadStone Technologies
- ORNL
- ANL

Catalysts & Supports
- BNL
- PNNL
- 3M
- UTC
- LBNL
- ANL
- LANL
- General Motors
- Northeastern University
- University of South Carolina
- Illinois Institute of Technology
- NREL

Durability
- Ballard
- LANL
- Plug Power
- UTC
- ANL
- Nuvera Fuel Cells
- University of Connecticut

Membranes
- Giner Electrochemical Systems
- Oak Ridge National Laboratory
- FuelCell Energy
- University of Central Florida
- 3M
- Vanderbilt University
- Colorado School of Mines
- Case Western Reserve University
- LANL
- Sandia National Laboratory
- Ion Power
- University of Southern Mississippi
- Kettering University

Balance of Plant
- W. L. Gore & Associates
- Stark State College
- Dynalene

Portable Power
- Arkema Inc.
- University of North Florida
- LANL
- NREL

Stationary Power
- Intelligent Energy
- Acumentrics
- Versa Power Systems
- UTC
- University of Akron
- Colorado School of Mines
- Stark State College

Transport
- SNL
- LBNL
- Nuvera Fuel Cells
- Giner Electrochemical Systems
- General Motors
- Rochester IT
- LANL
- CFD

Impurities and Fuel Processors
- NREL
- University of Connecticut
- Clemson University
- University of Hawaii
- DuPont
- Rolls Royce

Key Participants – Manufacturing R&D and Education

U.S. DEPARTMENT OF ENERGY

Manufacturing R&D

Electrode Desposition
- BASF

High Pressure Storage
- Quantum
- PNNL

MEA Manufacturing
- ORNL
- RPI
- Gore

GDL Fabrication
- Ballard Material Products

Testing of FC Stacks
- UltraCell
- PNNL
- LLNL

Measurement of FC Stacks
- NIST
- NREL
- LBNL

Education

State & Local Government Projects
- Virginia Clean Cities
- Technology Transition Corporation
- Houston Advanced Research Center
- South Carolina Hydrogen and Fuel Cell Alliance
- Clean Energy States Alliance
- Connecticut Center for Advanced Technology, Inc.
- Ohio Fuel Cell Coalition

Middle Schools & High Schools
- National Energy Education Development Project
- UC-Berkeley Lawrence Hall of Science

University Projects
- Humboldt State Univ.
- University of Central Florida/UNC-Charlotte
- Cal State-LA
- Michigan Tech (MTU)
- Univ. of North Dakota
- Hydrogen Education Foundation

Early Adopters
- Carolina Tractor

Analysis
- Argonne National Lab
- RCF Consulting

Key Participants – Safety, Codes & Standards; Technology Validation; and Systems Analysis

U.S. DEPARTMENT OF ENERGY

Safety, Codes & Standards

- LANL
- LLNL
- NASA
- NIST
- NREL
- PNNL
- ORNL
- SNL
- U.S. Dept. of Commerce
- U.S. Dept. of Transportation
- Regulatory Logic

Acknowledgements: SCS works with many other international and domestic stakeholders, including auto OEMs, energy providers, governmental agencies, NGOs, CDOs, and SDOs.

Technology Validation

- Air Products & Chemicals, Inc.
- CA Fuel Cell Partnership
- Daimler
- General Motors Corp.
- Mercedes Benz North America
- NREL
- Shell Hydrogen

Systems Analysis

- ANL
- LANL
- LLNL
- NREL
- ORNL
- PNNL
- RCF Economic & Financial Consulting, Inc.
- SNL
- UC Davis

Key Participants – Market Transformation

U.S. DEPARTMENT OF ENERGY

Industry

- Boeing
- BMW
- Excel Energy
- First Energy
- Ford Motor
- GM
- HELCO
- Price Choppers
- Walmart

Other Federal Agencies

- Army - CERL
- Environmental Protection AGency
- Federal Aviation Administration
  Federal Transit Administration Navy - ONR
- Defense Logistics Agencey - TARDEC
- NASA
- U.S. Department of Transportation
- U.S. Department of Defense
- U.S. Department of Interior - National Park Service
- U.S. Department of Commerce

Federal Labs

- ANL
- LANL
- LLNL
- NREL
- ORNL
- SNL

State Governments

- California
- Connecticut
- Hawaii
- New York
- South Carolina

NGOs

- American Gas Association
- Electric Power Research Institute
  Fuel Cell and Hydrogen Energy Association
- Green Communities
- US Clean Heat and Power Assocation

Key ARRA Participants

U.S. DEPARTMENT OF ENERGY

Data Collection & Analysis

- NREL

Fuel Cell Developers

- Altergy
- Delphi
- Jadoo Power
- MTI MicroFuel Cells
- Nuvera Fuel Cells
- Plug Power, Inc.
- ReliOn, Inc.
- University of North Florida

Fuel Cell End-Users

- AT&T
- City of Folsom, CA
- Coca Cola
- Fort Irwin
- GENCO
- H-E-B
- Kimberly Clark
- NASCAR
- PG&E
- Sempra Energy customers
- Sprint Nextel
- Sysco Houston
- Sysco Philadelphia
- University of California - Irvine
- Warner Robins Air Force Base
- Wegmans
- Whole Foods Market

Hydrogen Providers

- Air Products & Chemicals, Inc.
- Linde
- Nuvera Fuel Cells