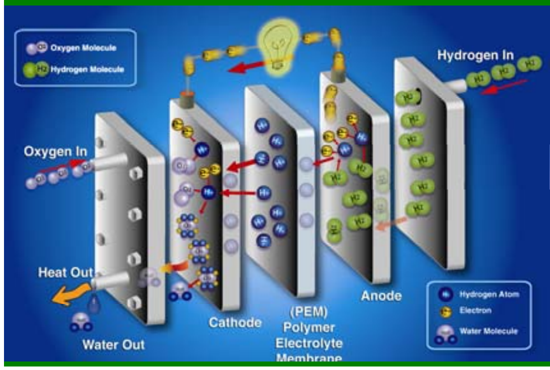
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



Overview of Hydrogen and Fuel Cell Activities

Dr. Sunita Satyapal

Program Manager

Hydrogen and Fuel Cells Program

Fuel Cell Technologies Program

U.S. Department of Energy

HTAC Meeting

October 14, 2010

Arlington, VA

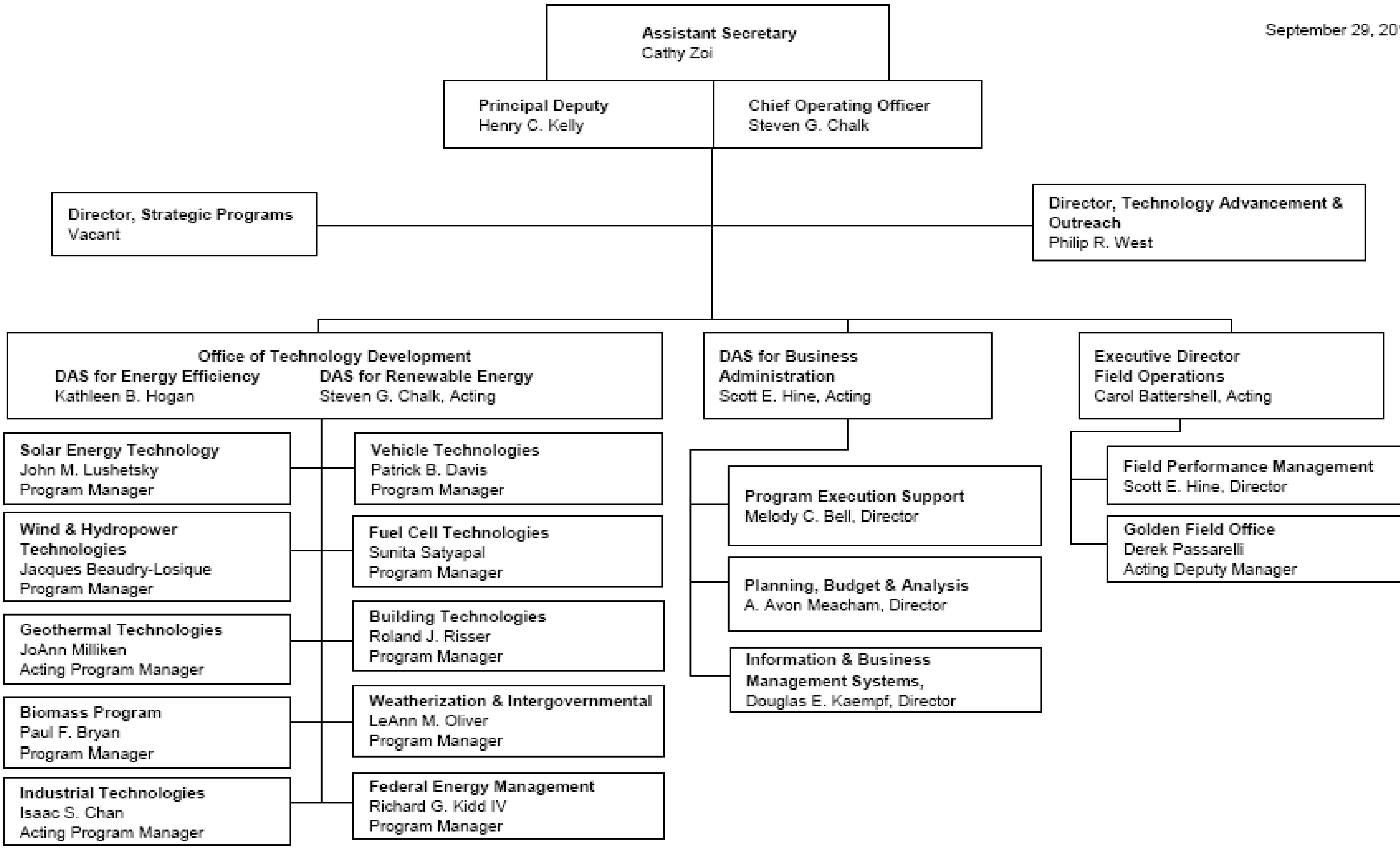
Agenda

- **DOE FY 2010 Updates**
  - Organizational Changes
  - RD&D Progress
  - Analysis & Key Publications
- **Program Plan**
  - Draft for HTAC Input
- **FY11 Budget Update**
- **Additional Information**
  - Upcoming Workshops
  - SBIR Update
  - FreedomCar & Fuel Partnership Review

Source: US DOE 10/2010

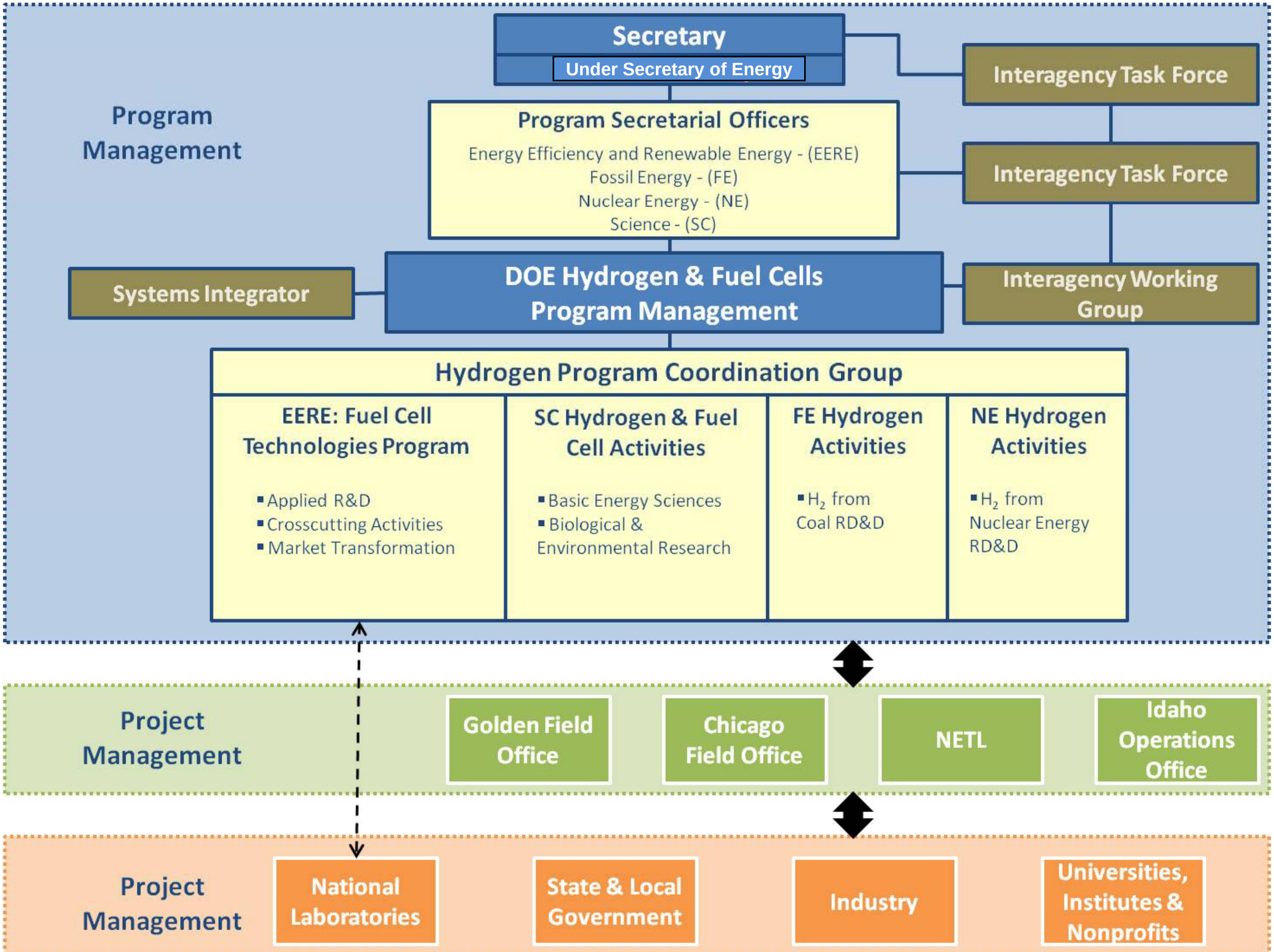
EERE Organizational Chart

Energy Efficiency & Renewable Energy



Source: US DOE 10/2010

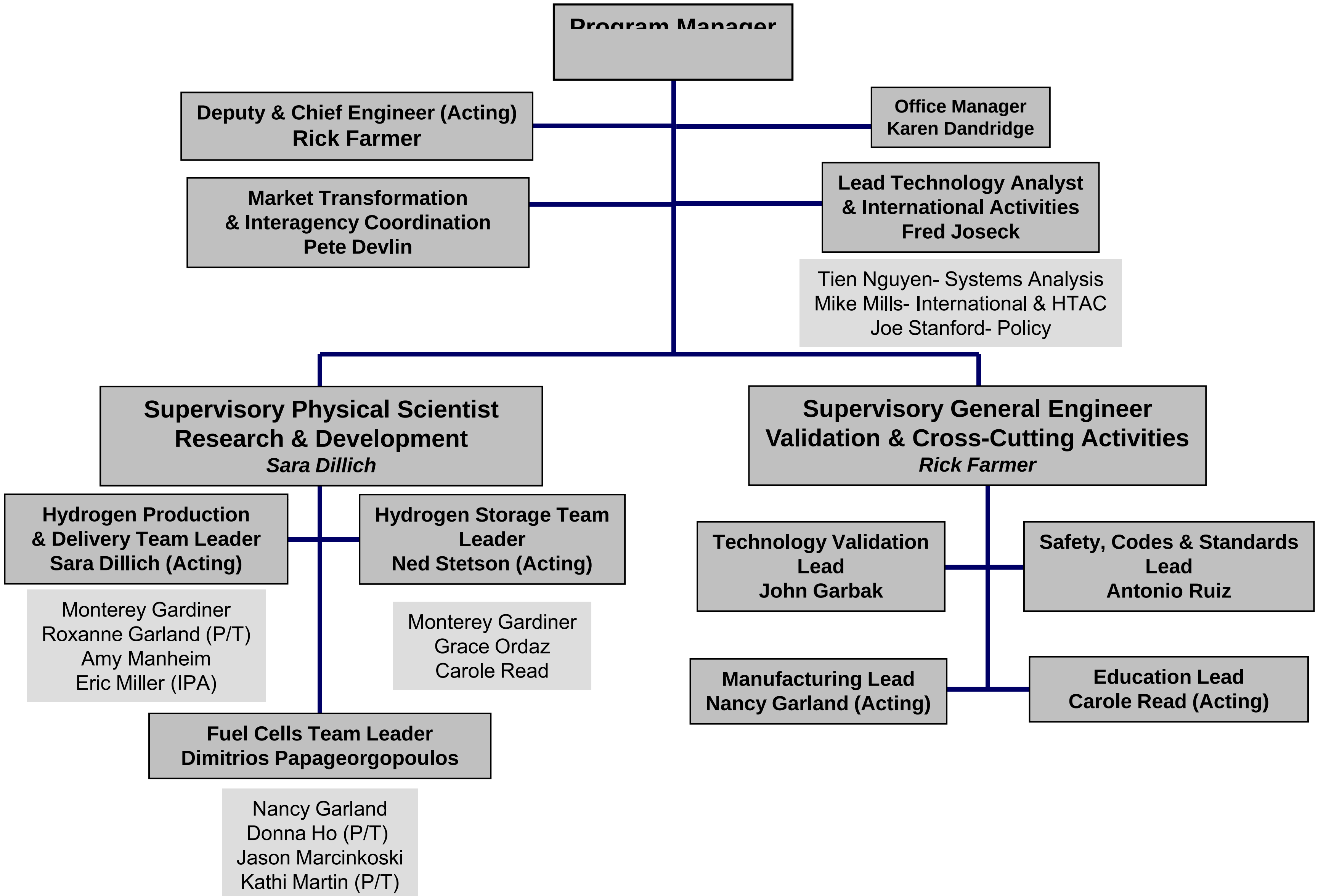
Program Management



Source: US DOE 10/2010

FCT Program Organizational Chart

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



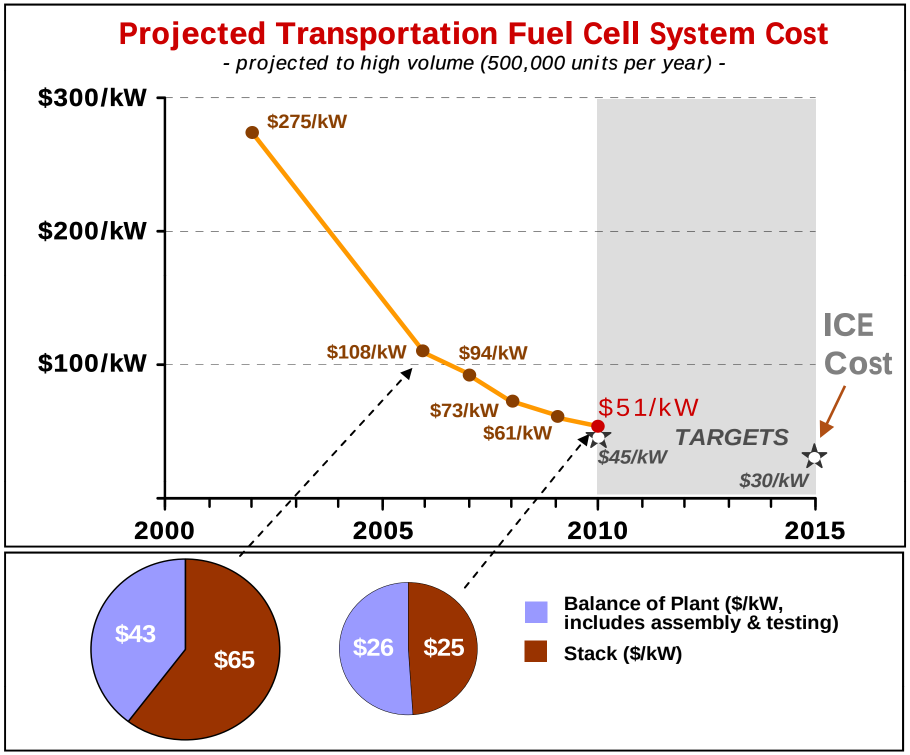
Source: US DOE 10/2010

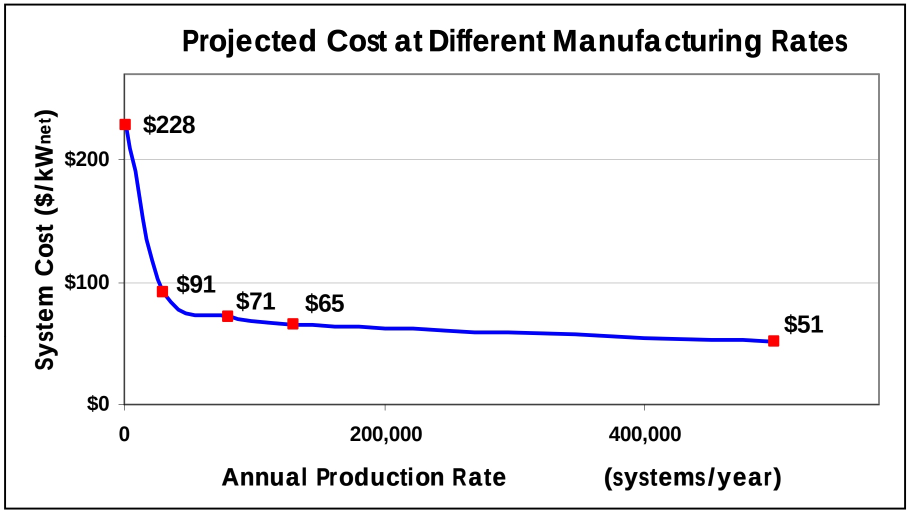
Fuel Cell R&D — Progress: Cost

Projected high-volume cost of fuel cells has been reduced to $51/kW (2010)*

- ***More than 15% reduction since 2009***
- ***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).*

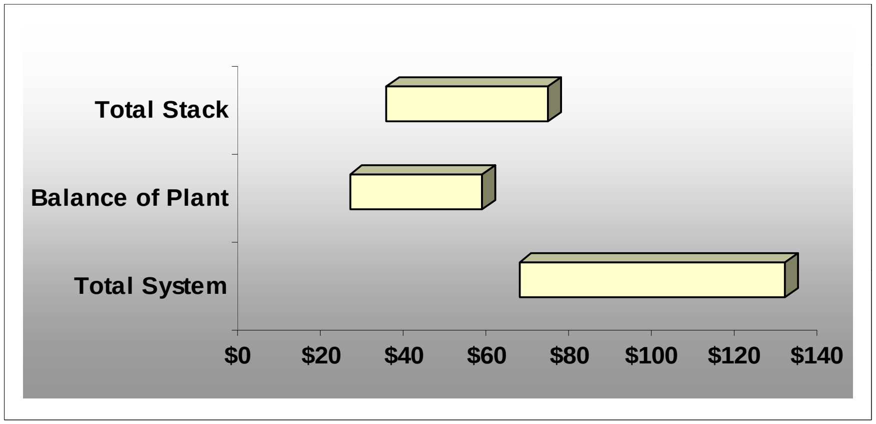
***Panel found $60 – $80/kW to be a "valid estimate": http://hydrogendoedev.nrel.gov/peer_reviews.html*

Source: US DOE 09/13/2010

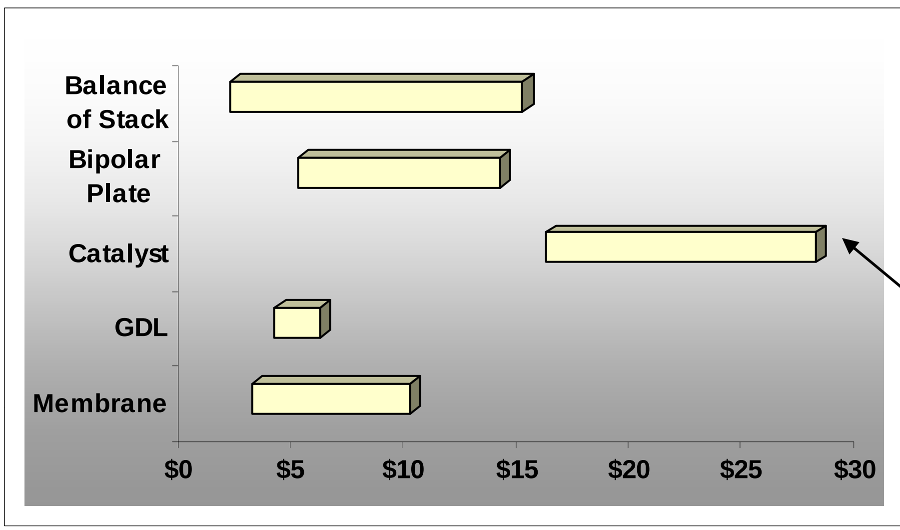
Stakeholder Cost Analyses

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

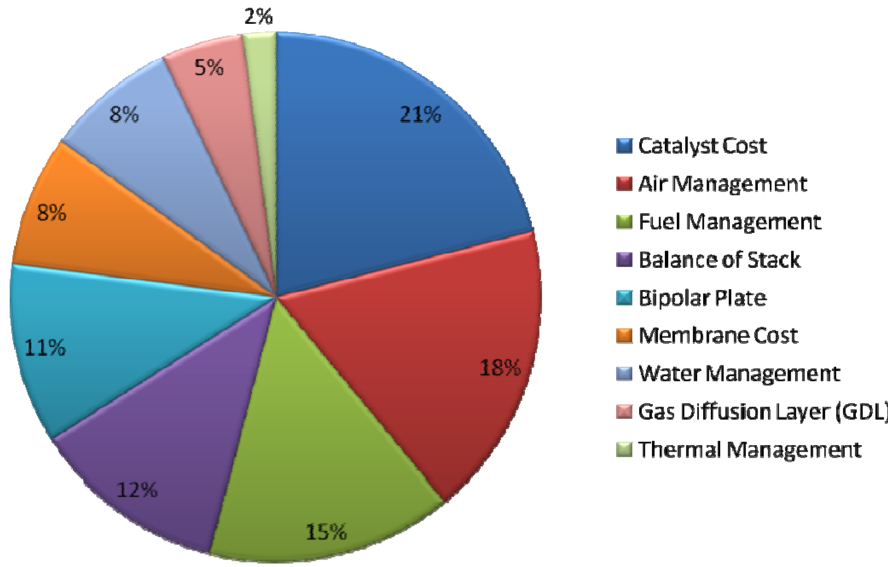
Representatives from the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) compiled fuel cell cost estimates for automotive applications to identify potential R&D focus areas



Cost range for 500,000 – 1M units/year: system status



Cost range for 500,000 units/year: stack status



Example of cost breakdown from China IPHE reference (500,000 units)

- **Range of cost estimates varies widely for some components**
- **Catalyst cost reduction is clearly required**

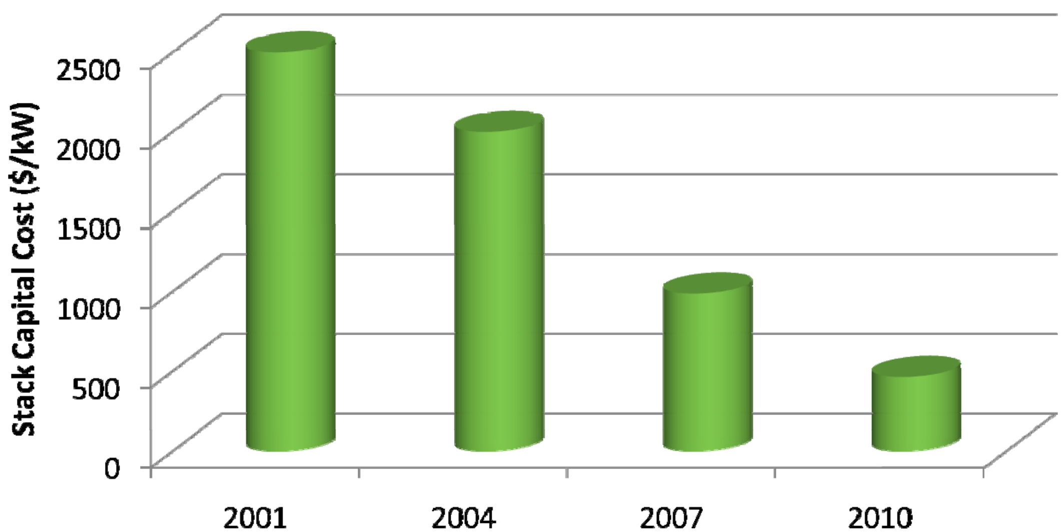
Source: US DOE 10/2010

Ref: www.iphe.net/docs/Resources/IPHE%20Fuel%20Cell%20Cost%20Comparison%20Report.pdf

R&D Progress - Examples

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

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

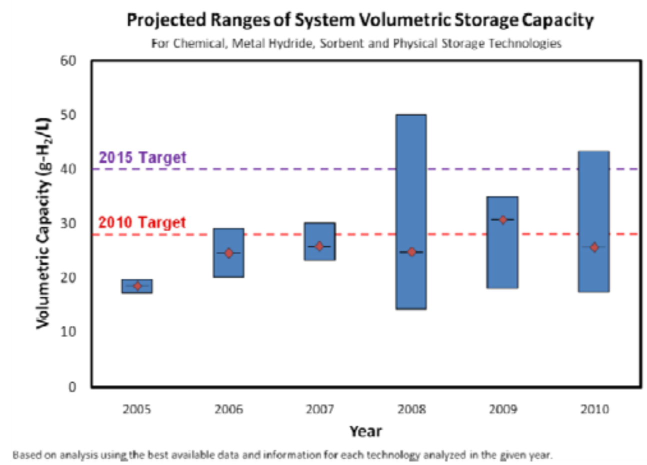


Source: Giner Electrochemical Systems, LLC
[2] Total cost of delivery hydrogen ($/kg) in H2A Model Rev. 2.0 is $5.20 (Cost of delivery in Rev. 1.0.11 is $0.69; Rev 2.0, $1.92

- Demonstrated complete conversion to gas containing hydrogen during liquid phase reforming of a woody biomass slurry (with inexpensive base metal catalyst). (UTRC)
- 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.)

Hydrogen Storage: **Continued to identify storage materials (>400 to date) & assess potential to increase system capacities**

Projected Capacities for Complete H_2 Storage Systems



Safety, Codes and Standards

Provided technical data and incorporated risk-informed approach that enabled updated separation distances in the 2010 NRPA code.

Technology Validation

U.S. DEPARTMENT OF ENERGY

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

Buses

- DOE is evaluating real-world bus fleet data (DOT collaboration)
  - H_2 fuel cell buses have a 39% to 141% better fuel economy when compared to diesel & CNG buses

Forklifts

- Forklifts at Defense Logistics Agency site have completed more than 18,000 refuelings

Recovery Act

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

Source: US DOE 09/2010

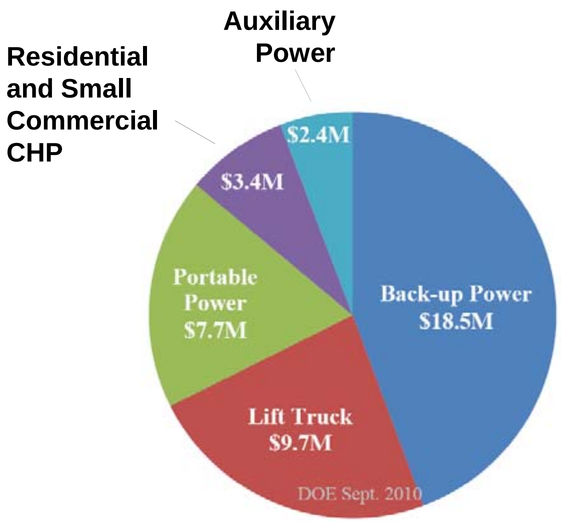
Recovery Act Fuel Cell Funding & Projects

U.S. DEPARTMENT OF ENERGY

DOE announced more than $40 million from the American Recovery and Reinvestment Act to fund 12 projects, which will deploy up to 1,000 fuel cells — to help achieve near term impact and create jobs in fuel cell manufacturing, installation, maintenance & support service sectors.

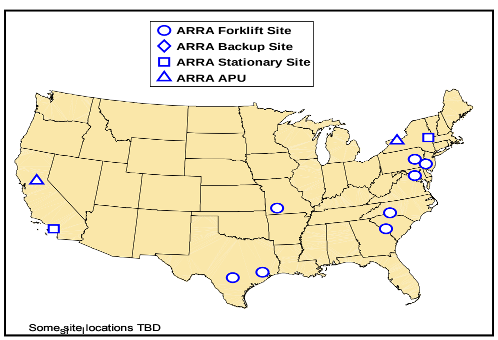
FROM the LABORATORY to DEPLOYMENT:

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



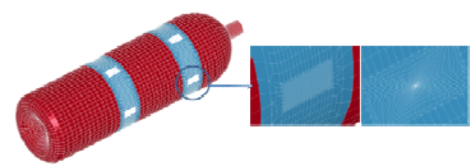
COMPANY	AWARD	APPLICATION
Delphi Automotive	$2.4 M	Auxiliary Power
FedEx Freight East	$1.3 M	Lift Truck
GENCO	$6.1 M	Lift Truck
Jadoo Power	$2.2 M	Portable
MTI MicroFuel Cells	$3.0 M	Portable
Nuvera Fuel Cells	$1.1 M	Lift Truck
Plug Power, Inc. (1)	$3.4 M	CHP
Plug Power, Inc. (2)	$2.7 M	Back-up Power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

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



Reporting deployment and performance metrics to inform goals and targets for FC RD&D.

Real-life field testing of portable power units by end users to improve future fuel cell designs

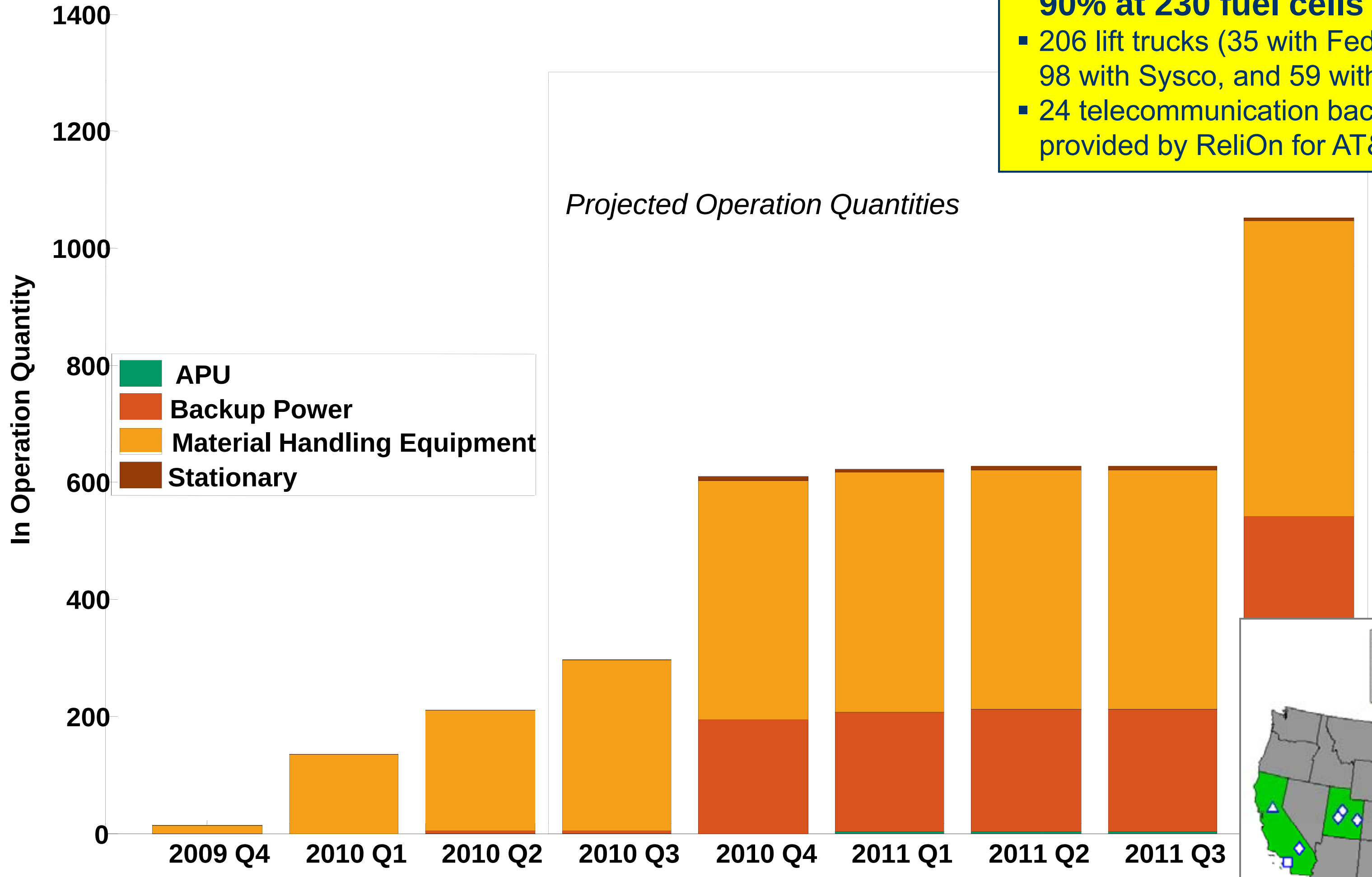


Partnering in studies of cyclic fatigue of steel tanks to provide technical basis for codes & standards development to enable commercial acceptance of fuel cell systems. Emphasizes importance of safety, codes & standards subprogram

Source: US DOE 10/2010

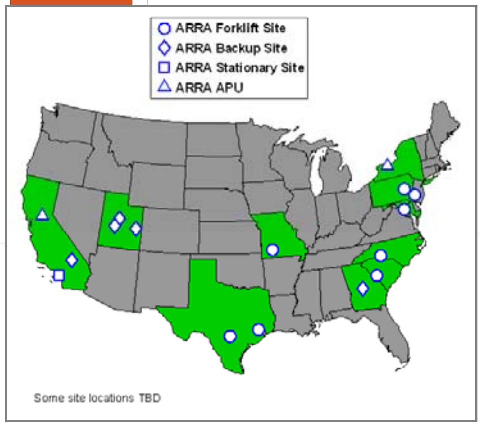
ARRA Fuel Cell Deployments

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.



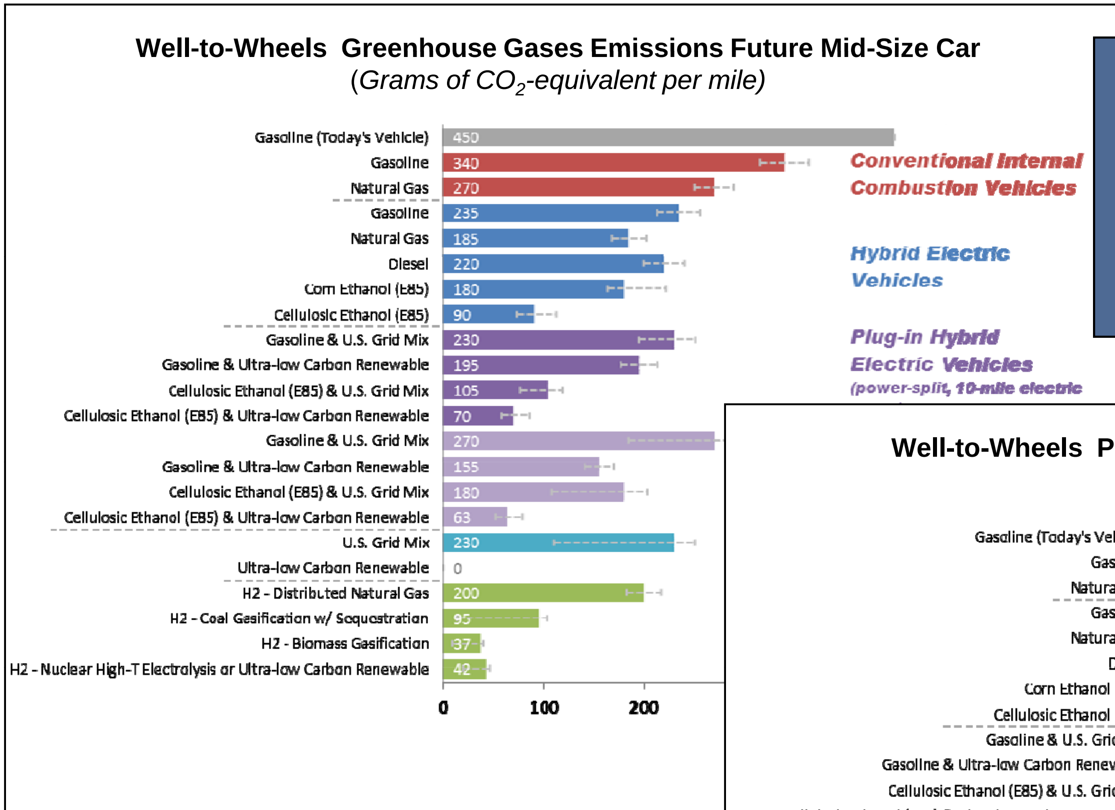
From National Renewable Energy Laboratory

U.S. Fuel Cell Deployments Using Market Transformation and Recovery Act Funding

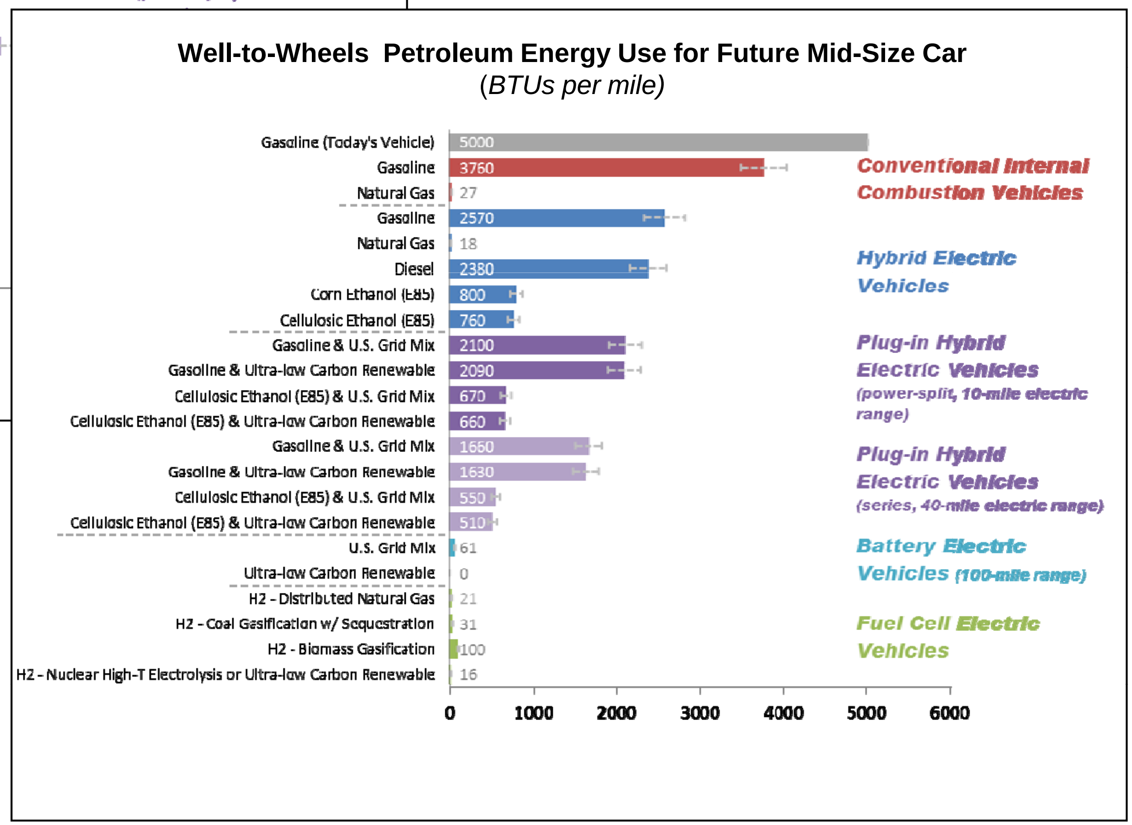
Source: US DOE 09/2010

Systems Analysis — *WTW Updates*

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



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



Analysis details to be published October, 2010

Assumptions at: http://hydrogen.energy.gov/program_records.html

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.

Source: US DOE 10/2010

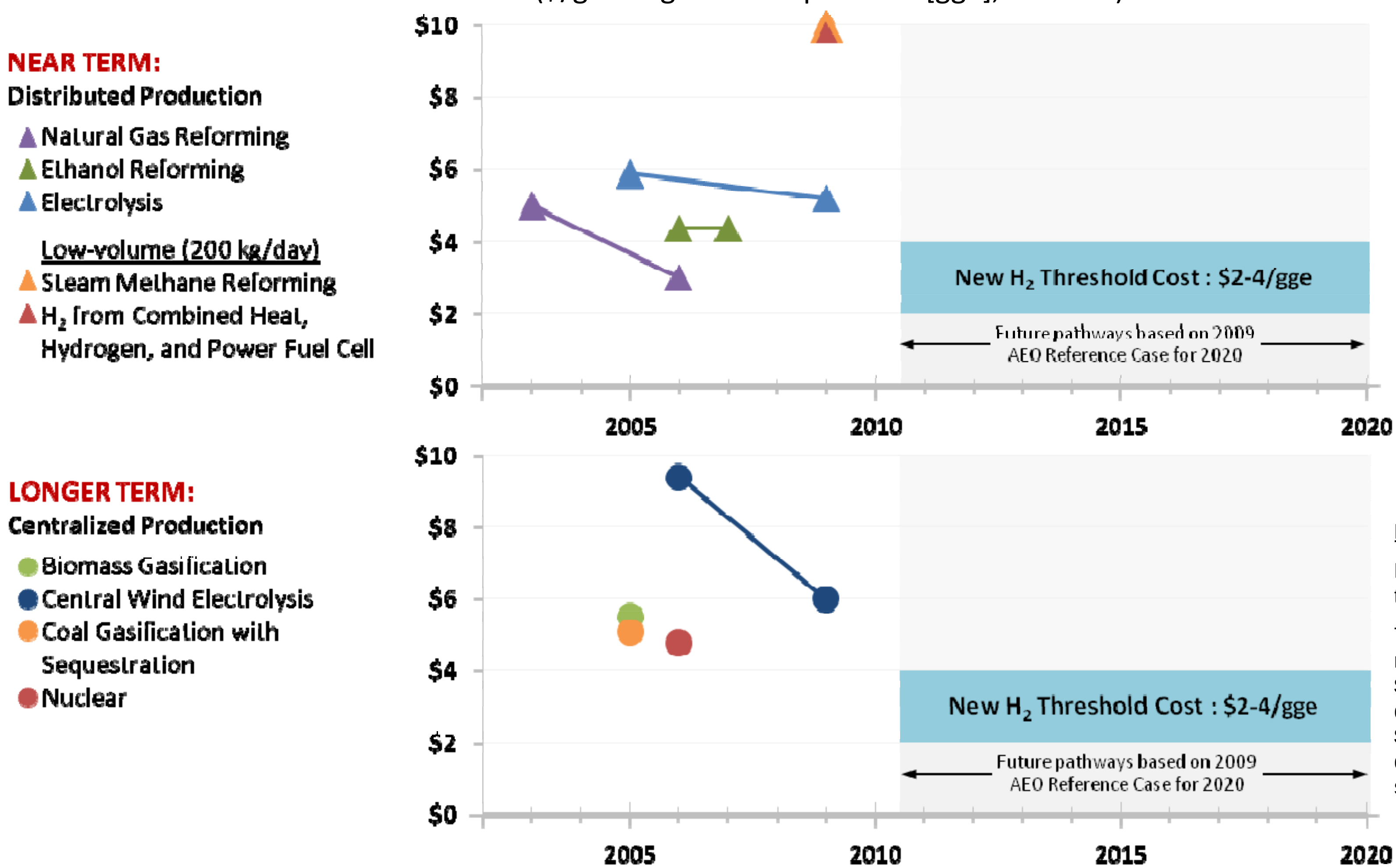
Hydrogen Threshold Cost Analysis

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

($/gallon gasoline equivalent [gge], untaxed)



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.

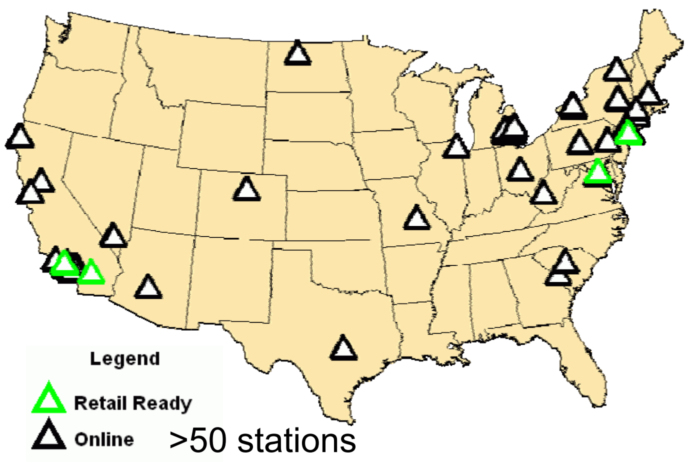
Systems Analysis

U.S. DEPARTMENT OF ENERGY

We are assessing the costs and benefits of various technology pathways and identifying key technological gaps, by conducting:

Life-cycle analysis, Emissions analysis, Environmental analysis, Systems integration analysis

Hydrogen fuel cell vehicles are being introduced in the U.S. over the next 5 years



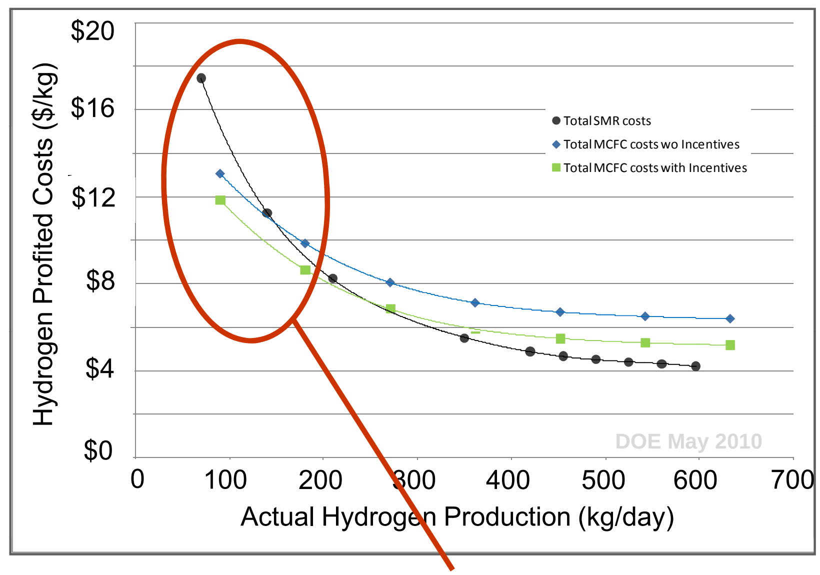
Industry Survey Results* from the CA Fuel Cell Partnership

	Phase 1 (hundreds) 2011	Phase 2 (thousands) 2012-14	Phase 3 (tens of thousands) 2015-17
Pass. vehicles	710	4,300	49,600
Buses	15	20-60	150

* For details, see full report at:
http://www.cafcp.org/hydrogen-fuel-cell-vehicle-and-station-deployment-plan

Assessing Novel Pathways for H_2 Production

(e.g. cost of combined hydrogen, heat and power)



In cases where there is a low demand for hydrogen in early years of fuel cell vehicle deployment, CHHP may have cost advantages over on-site SMR production.

Source: US DOE 09/2010

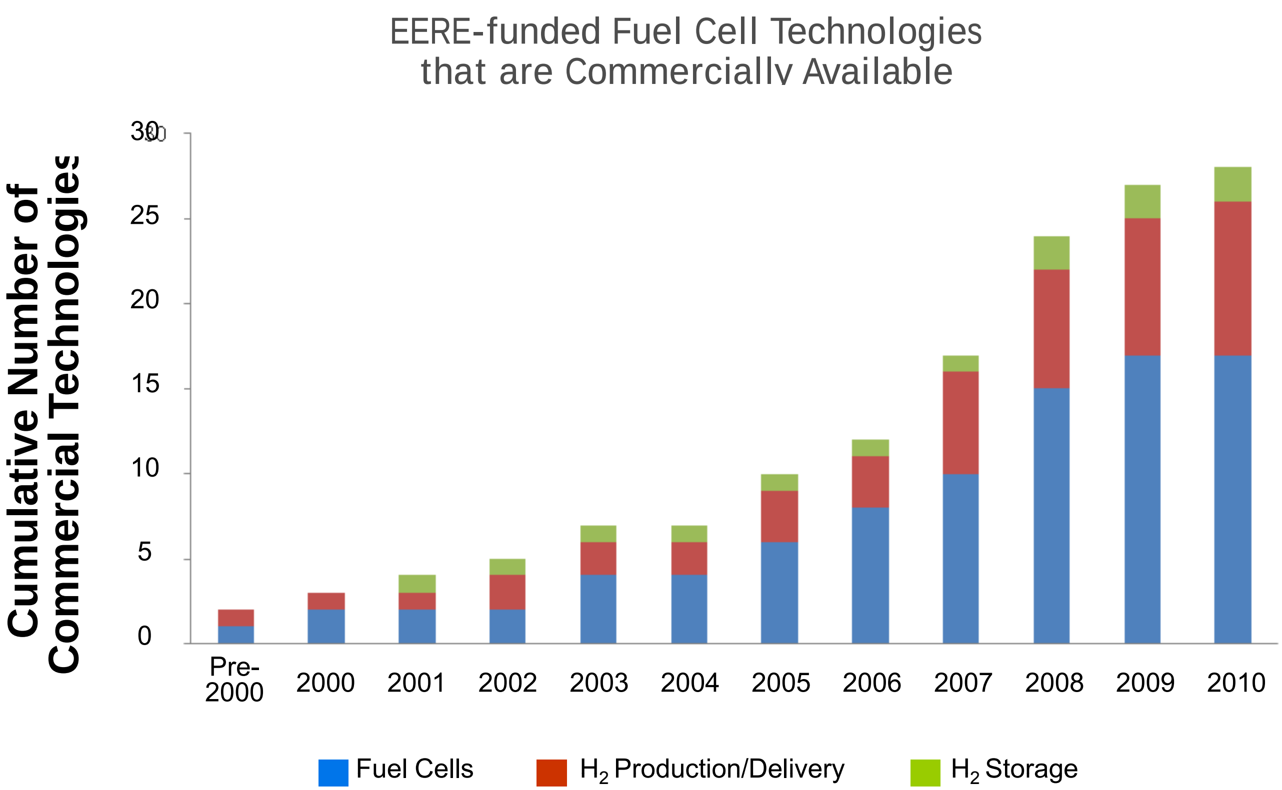
Source: Fuel Cell Power Model

Assessing the Program-*Commercializing Technologies*

U.S. DEPARTMENT OF ENERGY

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

Accelerating Commercialization



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

Source: US DOE 09/2010

198 PATENTS resulting from EERE-funded R&D:

– 99 fuel cell

– 74 H_2 production and delivery

– 25 H_2 storage

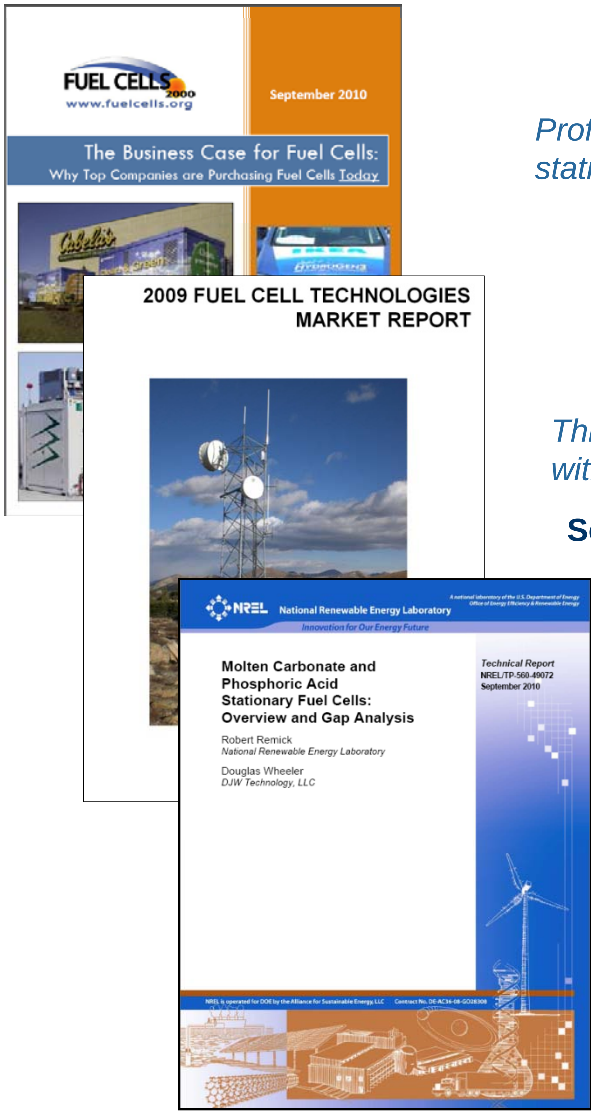
60% are actively used in:

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

Key Reports Recently Published

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



Source: US DOE 09/2010

The Business Case for Fuel Cells: Why Top Companies are Purchasing Fuel Cells Today

By FuelCells2000, http://www.fuelcells.org

Profile of 38 companies who have ordered, installed, or deployed fuel cell forklifts, stationary fuel cells or fuel cell units.

See report: http://www.fuelcells.org/BusinessCaseforFuelCells.pdf

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).

See report: http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/48219.pdf

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.

See report: http://www.nrel.gov/docs/fy10osti/49072.pdf

Fuel Cell Today 2009 Market Analysis

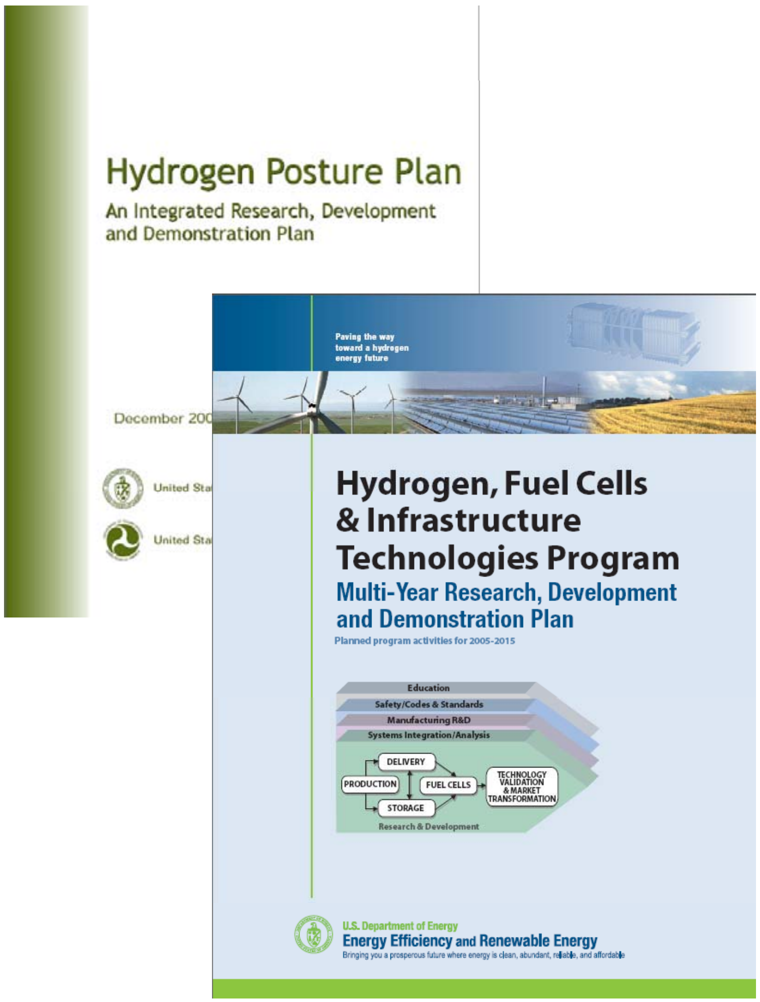
The report describes sales of fuel cells in US and worldwide.
October 2010

Source: US DOE 10/2010

Program Plan

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

Describes the planned research, development, and demonstration 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 will be made available for stakeholder public comment

Source: US DOE 10/2010

Outline of Program Plan

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

Introduction

Why Hydrogen and Fuel Cells?

The Hydrogen and Fuel Cells Program: Mission, Goals, and Strategy

1. Hydrogen and Fuel Cell Applications: Benefits and Challenges

1.1 Advantages of Fuel Cells and Hydrogen

1.2 Potential Impacts of the Widespread Use of Hydrogen and Fuel Cells

1.3 Key Challenges

1.4 The Way Forward

2. The Program: Plans and Key Milestones

2.1 Guiding the Program: Systems Analysis & Systems Integration

2.2 Advancing the Technologies

2.3 Driving Technical Progress through Crosscutting Efforts

2.4 Overcoming Institutional & Economic Barriers

2.5 Key Milestones

3. The Program's Strategic Direction

3.1 Organization & Partnerships

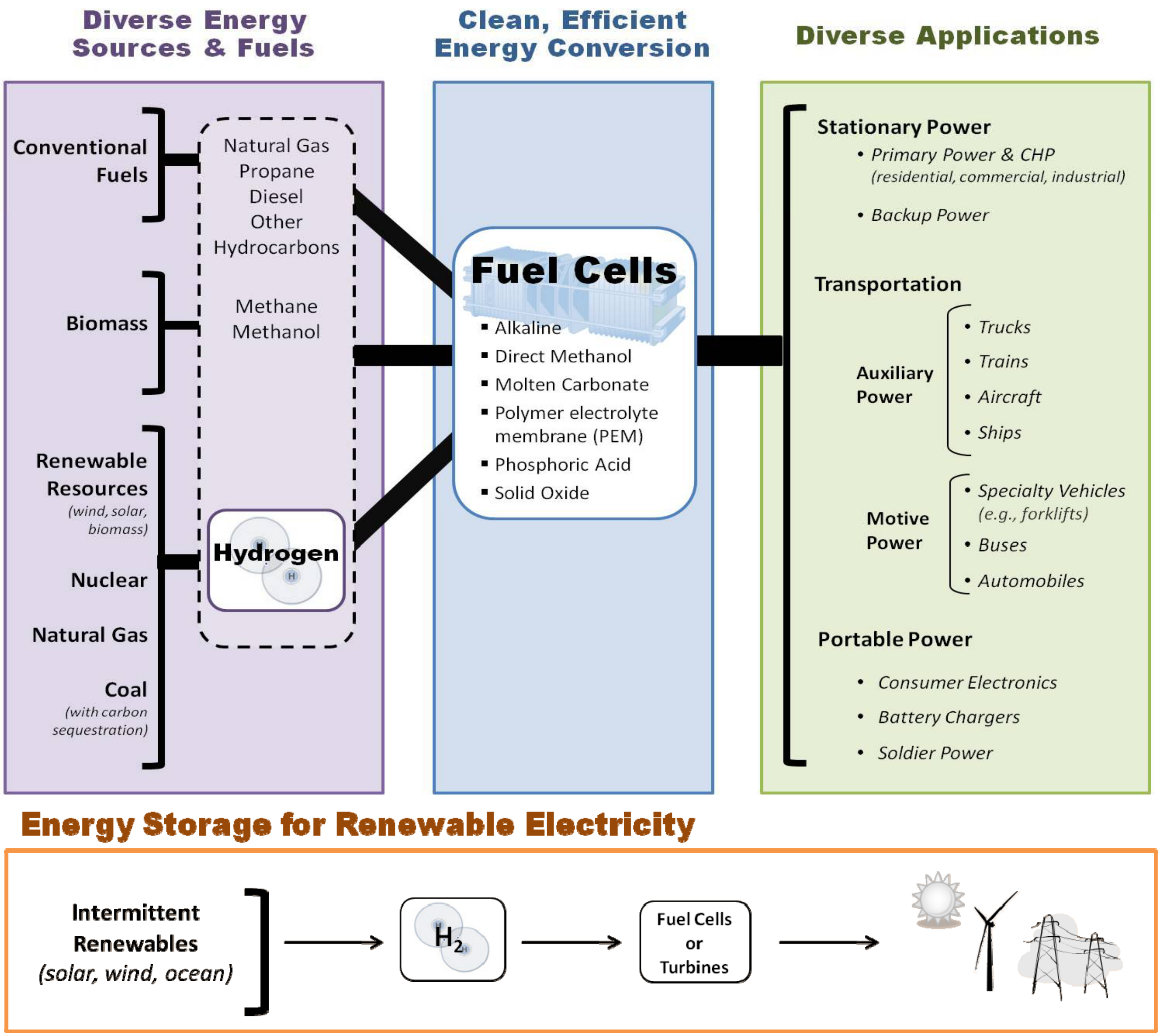
3.2 Program Implementation

3.3 Federal, State, and International Collaboration & Coordination

Source: US DOE 10/2010

Fuel Cells: Addressing Energy Challenges

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



Source: US DOE
10/2010

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.**

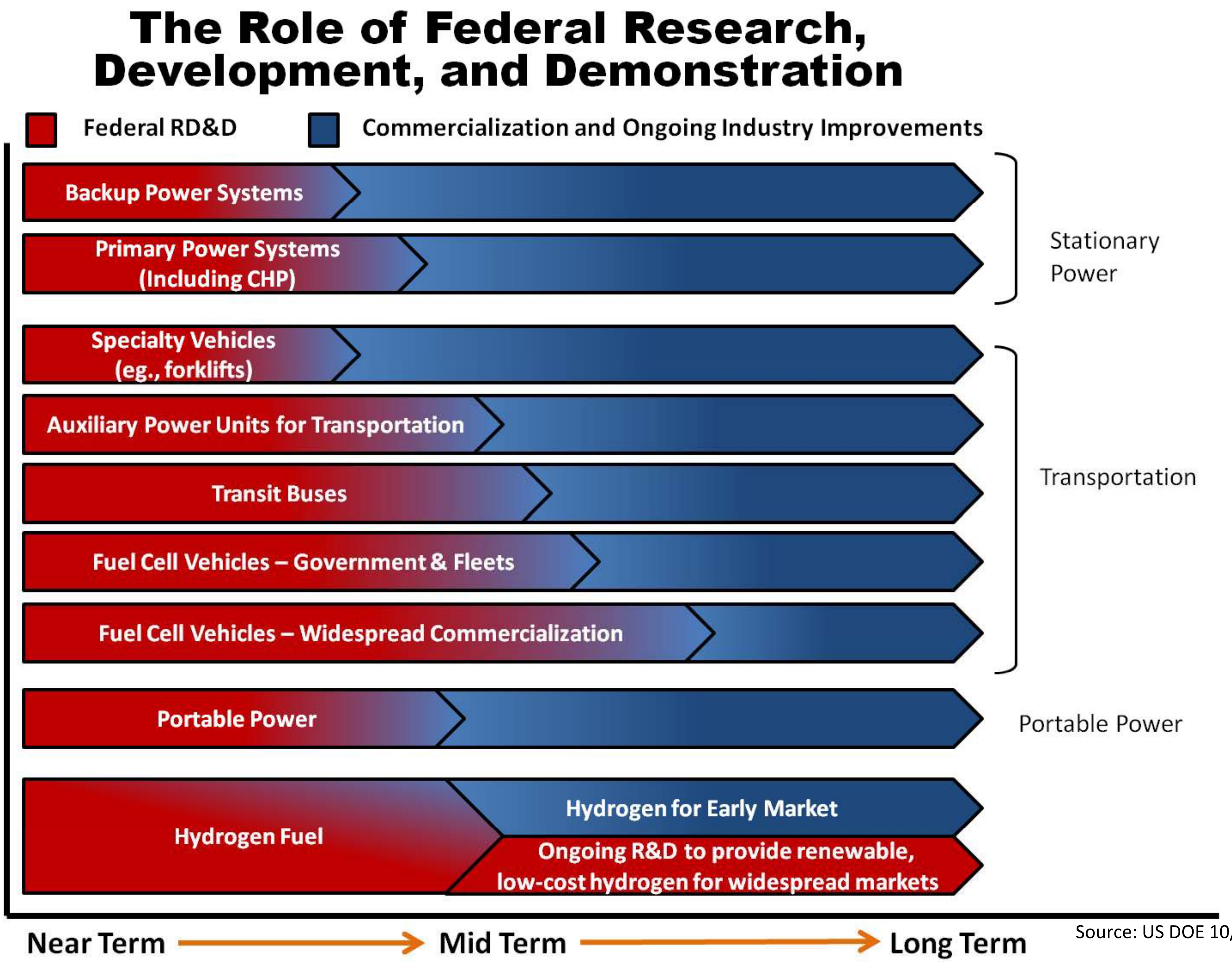
Key Goals **: Develop hydrogen and fuel cell technologies for:**

1. Early markets such as stationary power (prime and back up), lift trucks, and portable power in the 2010 – 2012 timeframe,
2. Mid-term markets such as residential combined-heat-and-power systems, auxiliary power units, fleets and buses, in the 2012 to 2015 timeframe, and
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

RD&D Timeline

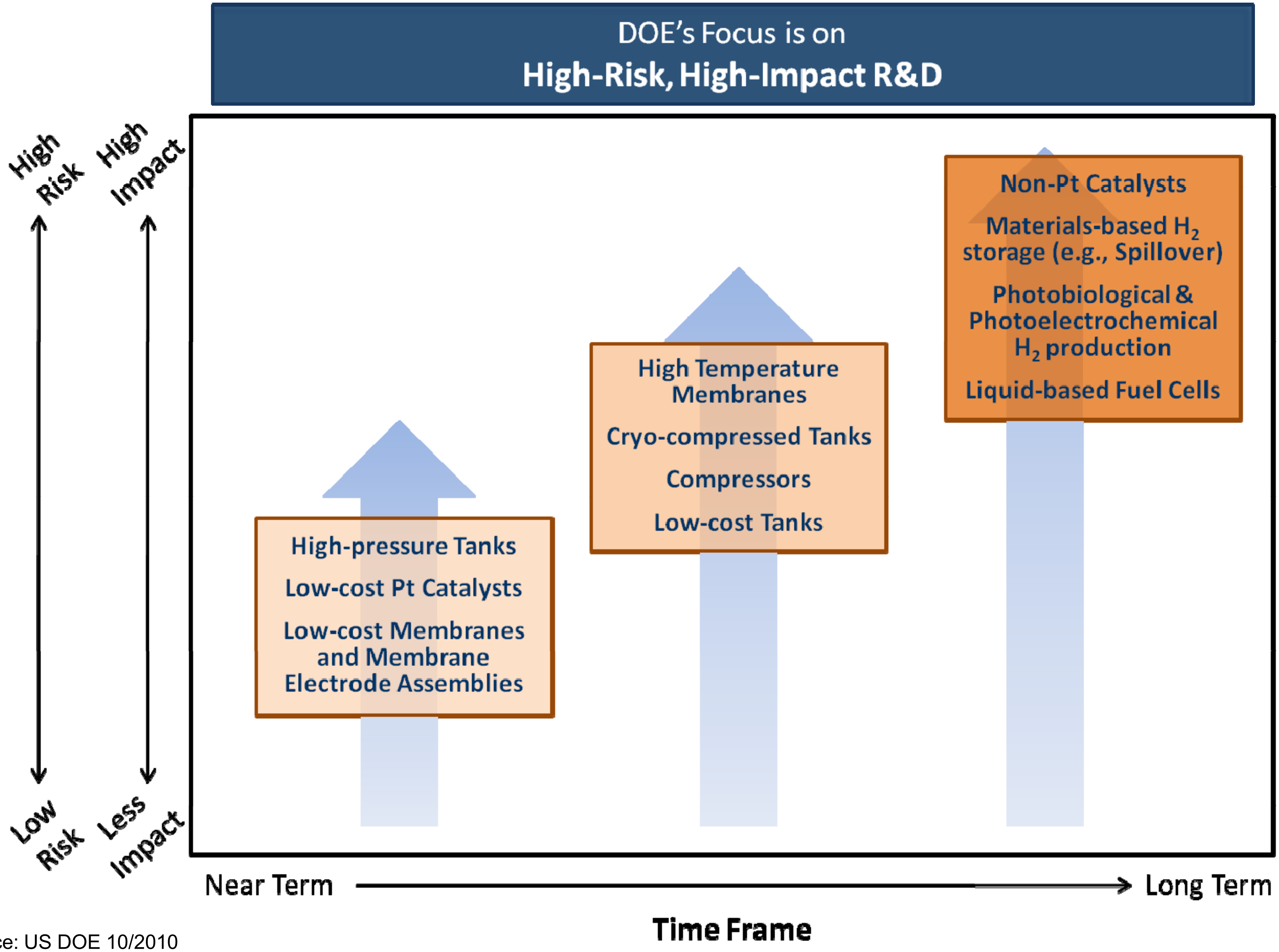
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



Source: US DOE 10/2010

Program R&D – Federal Role

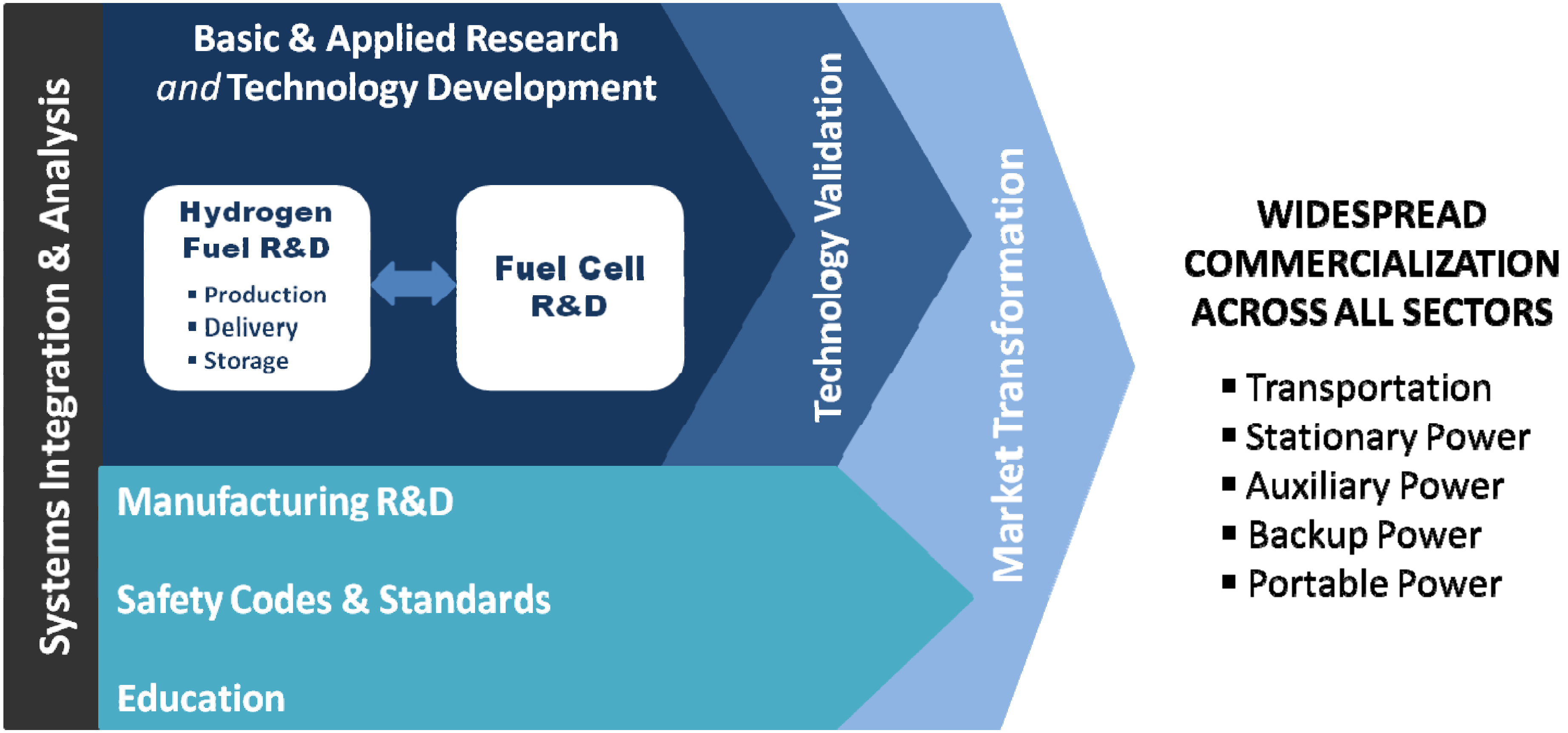
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



Source: US DOE 10/2010

Current Program Structure

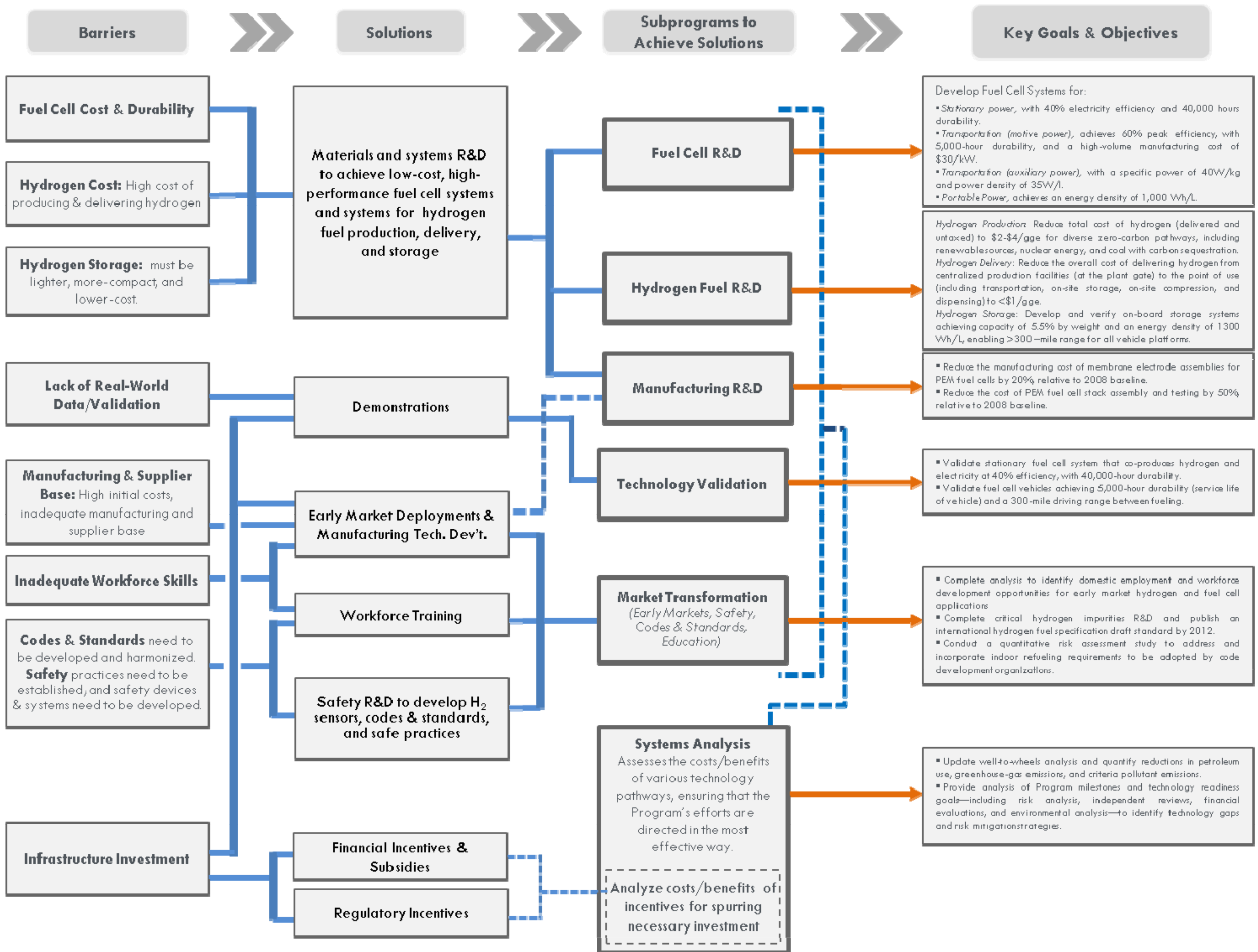
The Program is an integrated effort, structured to address all the key challenges and obstacles facing widespread commercialization.



The Program includes activities within the Offices of Energy Efficiency & Renewable Energy, Fossil Energy, Nuclear Energy, and Science.

Source: US DOE 10/2010

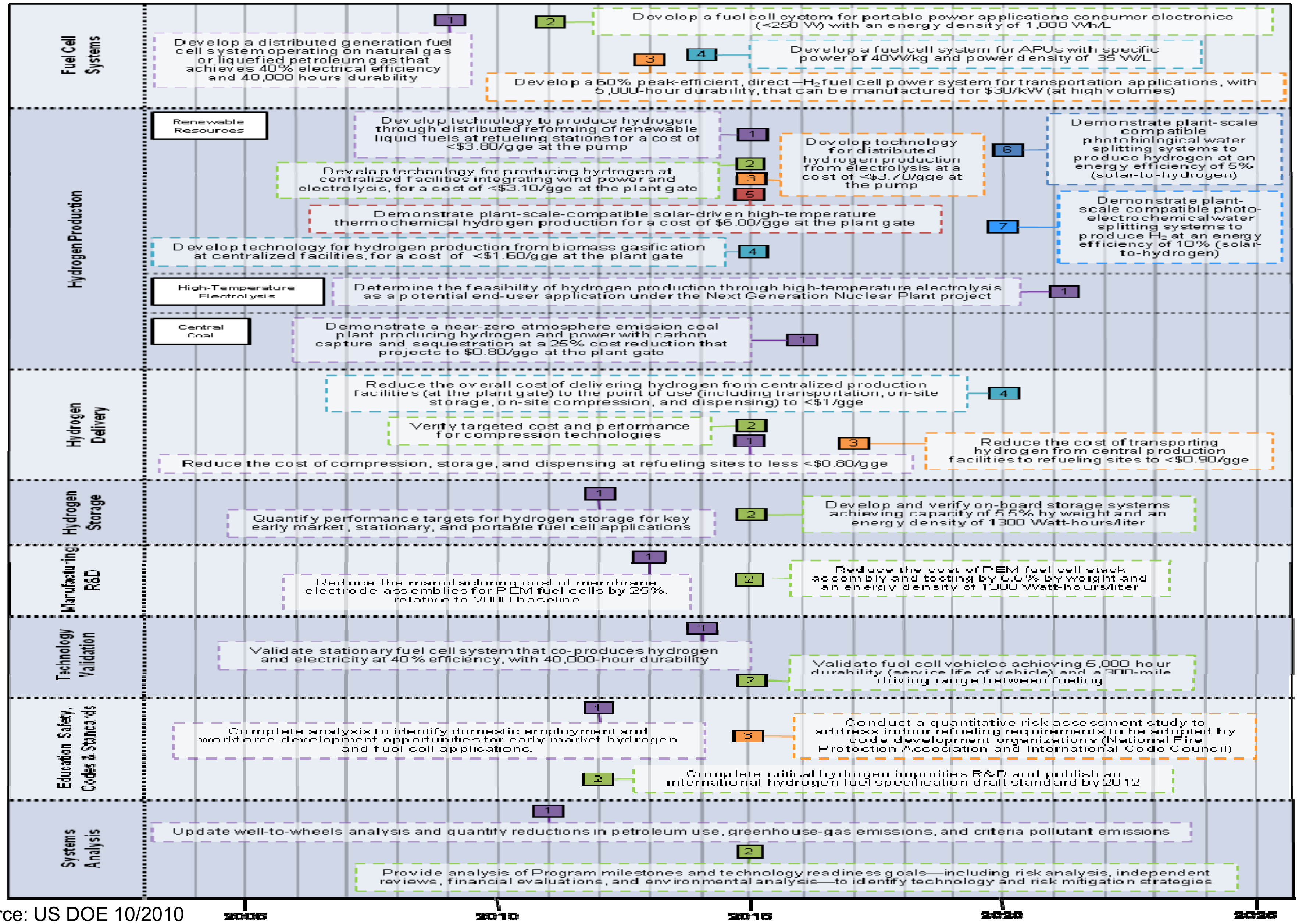
Program Strategy



Source: US DOE 10/2010

Key Milestones (see hardcopy)

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



Source: US DOE 10/2010

Collaborations

Federal Agencies

- DOC
- DOD
- DOEd
- 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 the Hydrogen Economy – 16 countries, 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
- National Hydrogen Association
- U. S. Fuel Cell Council
- 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
Argonne A, FC, P&D
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
Lawrence Berkeley FC, A
Lawrence Livermore P&D, 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*

* Office of Energy Efficiency and Renewable Energy

Source: US DOE 10/2010

Next Steps & Projects Underway

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

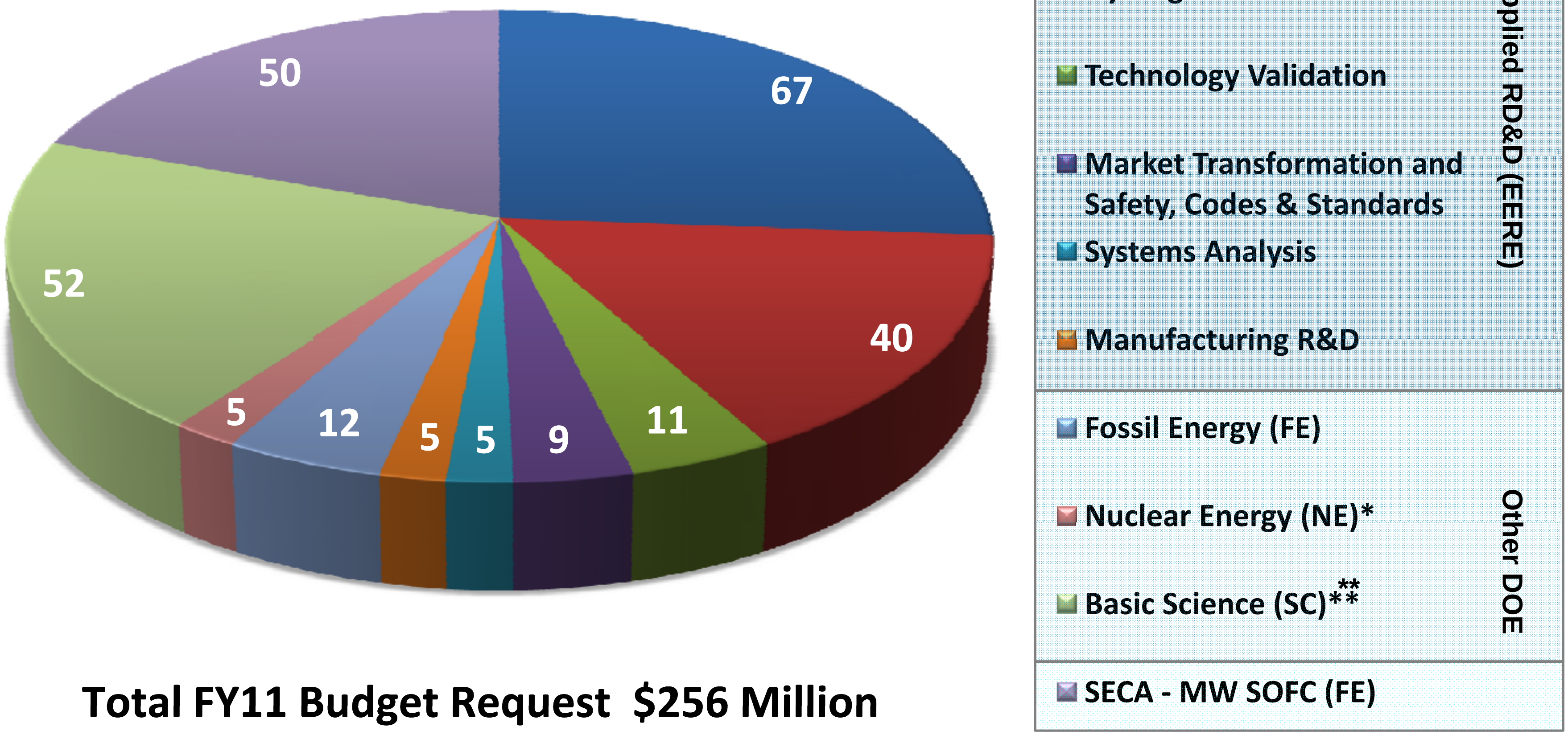
- Infrastructure
  - Analysis, workshops to identify options
- Market Analysis
  - Assessment of manufacturing capacity
  - Impact of tax credits, grants, ARRA
  - Market & employment analysis
- Interagency Coordination
  - DOD-DOE MOU
  - Interagency Task Force & action plan

FY 2011 Budget Update

Total DOE FY11 Budget Request

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

Total DOE Hydrogen and Fuel Cell Technologies FY11 Budget Request (in millions of US$)



Total FY11 Budget Request $256 Million

*NE: $5M represents FY10 funding

**SC Includes BES and BER

Source: US DOE 09/2010

EERE H_2 & Fuel Cells Budgets

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

Funding *($ in thousands)*						
Key Activity	**FY 2008**	**FY 2009[3]**	**FY 2010**	**FY 2011 *Request***	**FY 2011 House**	**2011 Senate**
Fuel Cell Systems R&D[1]	-	-	-	67,000	67,000	67,000
Fuel Cell Stack Component R&D	42,344	61,133	62,700	-	-	
Transportation Systems R&D	7,718	6,435	3,201	-	-	
Distributed Energy Systems R&D	7,461	9,750	11,410	-	-	
Fuel Processor R&D	2,896	2,750	171	-	-	
Hydrogen Fuel R&D[2]	-	-	-	40,000	40,000	47,000
Hydrogen Production & Delivery R&D	38,607	10,000	15,000	-	-	
Hydrogen Storage R&D	42,371	57,823	32,000	-	-	
Technology Validation	29,612	14,789[4]	13,097	11,000	11,000	20,000
Market Transformation	0	4,747	15,026	0	0	20,000
Safety, Codes & Standards	15,442	12,238[4]	8,839	9,000	9,000	9,000
Education	3,865	4,200[4]	2,000	0	0	1,000
Systems Analysis	11,099	7,520	5,556	5,000	5,000	5,000
Manufacturing R&D	4,826	4,480	5,000	5,000	5,000	5,000
Total	**$206,241**	**$195,865**	**$174,000[5]**	**$137,000**	**$137,000**	**$174,000**

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 FY 2009 Recovery Act funding of $42.967M not shown in table
4 Under Vehicle Technologies Budget in FY 2009
5 Includes SBIR/STTR funds to be transferred to the Science Appropriation; all prior years shown exclude this funding

Source: US DOE 10/2010

DOE H_2 & Fuel Cells Budgets: *FY07 – FY11*

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	Funding *($ in thousands)*					
	FY 2008 Approp.	**FY 2009** Approp.	**FY 2010** Approp.	**FY 2011** Request	**FY 2011** House Marks	**FY 2011** Senate Marks
EERE Hydrogen & Fuel Cells	206,241	195,865	174,000[2]	137,000	137,000	174,000
Fossil Energy (FE)[1]	21,773	26,400	~26,400	12,000[3]	12,000	12,000[5]
Nuclear Energy (NE)	9,668	7,500	5,000	TBD**	TBD**	TBD**
Science (SC)	36,484	38,284	~38,284	~38,000[4]	~38,000[4]	~38,000[4]
DOE TOTAL	**276,481**	**268,049**	**~243,684**	**TBD**	**TBD**	**TBD**

[1] All FE numbers include funding for program direction.

[2] Includes SBIR/STTR funds to be transferred to the Science Appropriation; other years shown exclude this funding.

[3] Includes coal to hydrogen and other fuels. FE also plans $50M for SECA in FY11. Senate and House marks also $50M.

[4] Estimated funding for hydrogen- and fuel cell–related projects; exact funding to be determined. The Office of Science also plans ~$14M for hydrogen production research in the Office of Biological and Environmental Research in FY11.

[5] Senate mark was $20M, request was $12M. Specific language was received regarding coal and biomass to liquids research and an assumption that most of ht extra funds will go this area.

** Funding will come from the Next Generation Nuclear Power funding and will be determined later.

Source: US DOE 10/2010

Additional Information

Fuel Cell Technology Program Upcoming Workshops

Hydrogen Production, Delivery, and Storage

Production

- PEC workshop on EERE/BES Partnerships (TBD)
- Biological workshop on EERE/BES Partnerships (TBD)
- STCH discussion of down-select report and future directions (TBD)

Delivery

- Joint storage and delivery interface discussion with industry partners currently interested in refilling station design compatible with advanced storage concepts (TBD)

Storage

- Workshop to develop roadmap for lower cost compressed H_2 storage activities (Q2, FY 2011)
- Workshop to identify key R&D issues for cryo-compressed H_2 storage (Q2, FY 2011)
- Follow-up workshops on hydrogen sorbents (TBD)
- Workshops on interface issues between the infrastructure and on-board storage (TBD)
- Workshops to develop roadmap/strategies for future storage materials R&D

Education

- Stakeholder updated roadmap workshop planned in October

Manufacturing

- Stationary Manufacturing R&D FY11 (TBD)

Fuel Cells

- Reversible fuel cells (TBD)
- AFC workshop: Status, prospects and R&D needs (TBD)

Safety, Codes and Standards

- Insurability of Hydrogen and FC Technologies (Spring-Summer 2011)
- Collaborative Safety R&D (March 2011, Japan)
- Assessment of Sensor Technology and Targets (Summer-Fall 2011)
- FC Systems and Components Certification and Qualification (Nov 5, 2011, SNL, CA)

Systems Analysis

- Infrastructure workshop on station cost identification and identification of R&D gaps (TBD)
- Workshop tentatively planned for NHA (TBD)

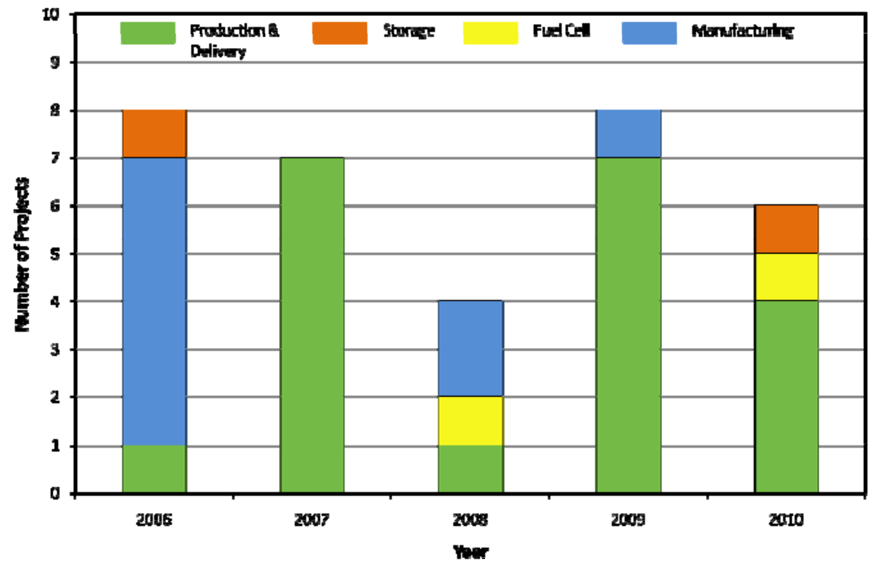
Source: US DOE 10/2010

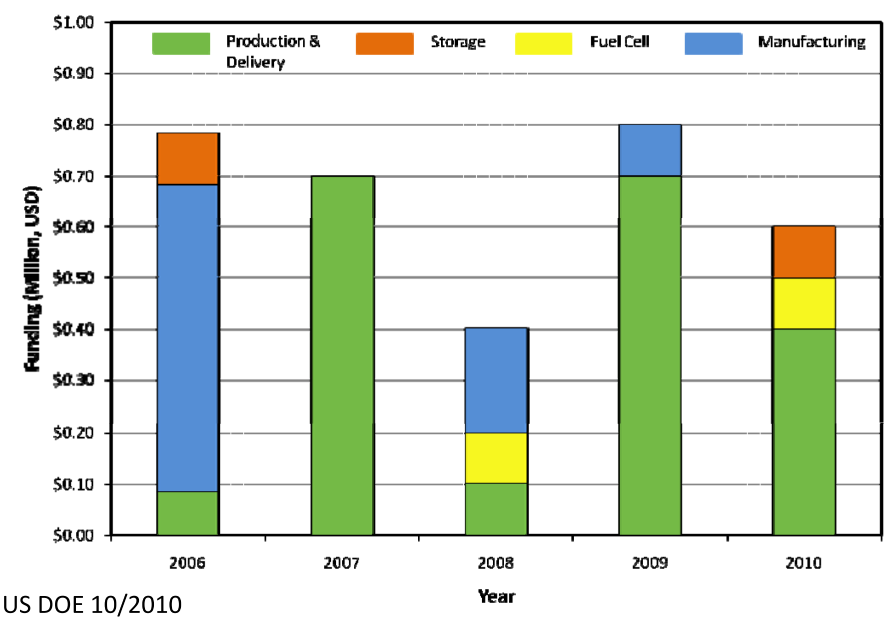
New Hires Planned

- **DOE Fuel Cell Team Member Job to be posted soon**
  - Check www.usajobs.gov and http://www1.eere.energy.gov/hydrogenandfuelcells/index.html for more information
- Additional capabilities (potential new hires) solicited:
  - Financial/market/policy & analysis expertise
  - Safety, codes and standards support
  - Hydrogen fuel R&D
  - Chief Engineer

Summary of SBIR Activities

FCT Program Phase 1 SBIR Projects 2004 – 2010





Total of 41 Projects and $4.08 Million in Funding

Production & Delivery:
- 23 Projects
- Hydrogen Production, Hydrogen Production Process Intensification, Hydrogen Compression & Liquefaction, Hydrogen Home Fueling Analysis & Hydrogen Dispensing

Storage:
- 2 Projects
- Advanced Materials for Hydrogen Storage

Fuel Cells:
- 7 Projects
- Fuel Cell Coolants &Membranes, Bio-Fueled Solid Oxide, Innovative Fuel cell Concepts & Balance of Plant

Manufacturing:
- 9 Projects
- Hydrogen Production Equipment, Hydrogen Storage Containers, Proton Exchange Membrane (PEM) Fuel Cells & Bipolar Plates

Source: US DOE 10/2010

FCT Program Phase 2 SBIR Projects 2005 – 2010

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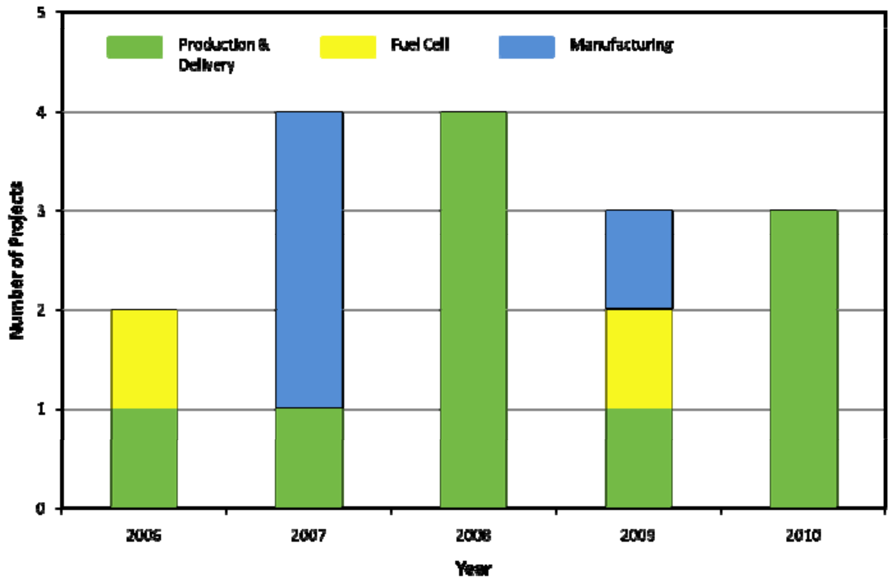

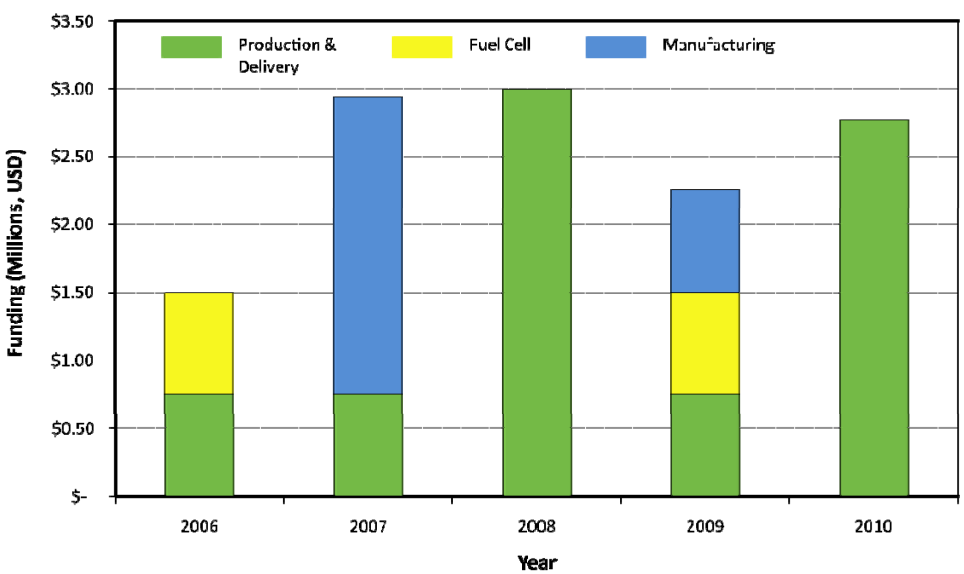

Source: US DOE 10/2010

Total of 17 Projects & $13.2 Million in funding

Production & Delivery

- Hydrogen Compression Technology
  - Mohawk Innovative Technology (2 projects)
  - Fuelcell Energy
- Hydrogen Production
  - Genesis Fueltech
  - Physical Optics Corporation
  - Synkera Technologies Inc.
  - H_2 Pump, LLC
  - Proton Energy Systems
  - Giner Electrochemical Systems, LLC
- Hydrogen from Waste
  - Directed Technologies, Inc.

Fuel Cells

- Fuel Cell Systems Coolants and Membranes
  - Advanced Fluid Tech Inc., Dab Dynalene Heat Trans
- Dimensionally Stable High Performance Membrance
  - Giner Electrochemical Systems, Loc
- Bio-Fuel Solid Oxide Fuel Cell
  - Innovatek, Inc.

Manufacturing

- Manufacturing of Hydrogen Storage Containers
  - Innosense, Loc
- Manufacturing of Proton Exchange Membrane (PEM) Fuel Cells
  - Nanotek Instruments, Inc.
  - Scribner Associates Incorporated
- Manufacturing of Bipolar Plates
  - Faraday Technology, Inc.

FCT Program Phase III SBIR Projects

New FY 2010 SBIR Phase III Projects

- Advanced Materials for Fuel Cell Technologies
  - Dynalene Inc. (Whitehall, PA); $1 Million
    - *Large Scale Testing, Demonstration, and Commercialization of the Nanoparticle-based Fuel Cell Coolant*
  - Giner Electrochemical Systems Inc (Newton, MA); $1.5 Million
    - *Dimensionally Stable High Performance Membrane*
- Bio-Fueled Solid Oxide Fuel Cells
  - InnovaTek Inc. (Richland, WA); $2.2 Million
    - *Power Generation from an Integrated Biomass Reformer and Solid Oxide Fuel Cell*
  - TDA Research Inc. (Wheat Ridge, CO); $1.9 Million
    - *Bio-fueled Solid Oxide Fuel Cells*

- Continuing Phase "III" Projects
  - Fuel Cell Energy, Inc. – Electrochemical Hydrogen Compression
  - Mohawk Innovative Technology, Inc. – Centrifugal Hydrogen Compression

DYNALENE Tomorrow's Solutions Flow Through Us   GINER   INNOVATEK   TDA Research

FY11 Phase I SBIR Technical Topics

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FY11 DOE SBIR FOA is currently open, FCT Program Topics are:

Topic 3: Hydrogen and Fuel Cells

- Subtopic 3a Reducing the Cost of High Pressure Hydrogen Storage Tanks
- Subtopic 3b – Fuel Cell Balance-of-Plant
- Subtopic 3c – Hydrogen Odorant Technology
- Subtopic 3d – Demonstration of Alternative-Fuel Cells as Range Extenders for Battery-Powered Airport Group Support Equipment (GSE)
- Subtopic 3e – Other: In addition to the specific subtopics listed above, the DOE invites grant applications in other areas relevant to this Topic.

FY11 DOE SBIR Phase I FOA will close on 11/15/2010
Link to FY11 Funding Opportunity Announcement (FOA):
http://science.doe.gov/sbir/Solicitations/FOA_2011_Phase_I.pdf

Source: US DOE 10/2010

National Academies' Review of FreedomCAR and Fuel Partnership

The committee recognizes

"three primary alternative pathways" for reducing petroleum consumption and greenhouse gas emissions in the transportation sector:

1) *improved ICE vehicles coupled with greater use of biofuels,*
2) *expanded use of PHEVs and BEVs, and*
3) *hydrogen fuel cell vehicles.*

The report reflects the committee's overall opinion that the Partnership is "effective in progressing toward its goals," observing that "there is evidence of solid progress in essentially all areas …"

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Crosscutting Activities

SUBJECT AREA	RECOM. #	RECOMMENDATION TEXT
Safety	2-1	The Partnership should establish a program to address all end-to-end safety aspects in addition to the existing codes and standards work. This work should be based on the pathways work and should include production, distribution, dispensing, and the vehicles. It should apply to all six alternative fuels and their associated vehicle types, including the use of high-voltage electricity on many of these vehicles.
Safety	2-2	The Partnership should generate and act on a failure modes and effects analysis of the full pressure vessel assembly, which includes the attached components and the human interface at the pump. Accelerated laboratory tests need to be run to identify failure/degradation modes of the pressure vessel and the mechanisms leading to failure. A nondestructive test program needs to be developed to assess pressure vessel integrity, which should serve both as a tool for quality control and as a means of checking for damage in service. The work on the analysis of worldwide natural gas and hydrogen incidents should continue. An R&D program should be established to develop a new generation of pressure-relief devices that can protect the storage tank from localized fire.
Safety	2-3	The hydrogen compatibility (including embrittlement) program should be continued. The Partnership should have experts in hydrogen embrittlement review the operating conditions and materials in the high-pressure delivery and refueling stations for potential problem areas, including welds and nonmetallic materials.
Safety	2-4	The Partnership should establish an emergency response R&D program with the involvement of emergency responders and research organizations to do fundamental work on the response to incidents involving alternative fuels. High-voltage batteries and electrical systems should also be included.
Safety	2-5	The Partnership should fully integrate the DOT safety efforts into the safety and the codes and standards aspects of the FreedomCAR and Fuel Partnership. All relevant parts of the DOT should be included: those involving passenger vehicles, trucks, the hydrogen bus program, pipelines and hazardous materials, fuel delivery trailers, and others. Alternative fuels should be included. The DOE and the Partnership's Executive Steering Group should consider adding a high-level DOT representative to the ESG.
Battery Electric and Plug-in Hybrid Electric Vehicles and the U.S. Electric Grid	2-6	The grid interaction technical team should work with state utility regulatory authorities, perhaps through the National Association of Regulatory Utility Commissioners, to ensure that the incentives provided by state regulations mesh well with the national interest in vehicle deployment, reduced oil consumption, and lower greenhouse gas emissions.
Battery Electric and Plug-in Hybrid Electric Vehicles and the U.S. Electric Grid	2-7	The grid interaction technical team should continue to encourage and, where appropriate, facilitate the ongoing development of open-architecture standards for smart-vehicle/smart-grid interconnections currently being developed by the Institute of Electrical and Electronics Engineers and the Society of Automotive Engineers. In doing so, the technical team should encourage participation from the purveyors of smart grid systems and battery suppliers as well as from the electric utility industry.
Battery Electric and Plug-in Hybrid Electric Vehicles and the U.S. Electric Grid	2-8	Standards for the reuse of electric vehicle batteries should be developed under leadership of the grid interaction technical team, and training materials for the use of these standard should be developed in parallel.

Key Recommendations

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

Crosscutting Activities (Continued)

SUBJECT AREA	RECOM. #	RECOMMENDATION TEXT
Persisting Trends in Automotive Innovation: Implications for the FreedomCAR and Fuel Partnership. (Manufacturing)	2-9	The Partnership should consider including manufacturing processes among the precompetitive R&D programs. Because its funding originates in the United States, the Partnership should emphasize the technologies and methods most capable of realizing advanced vehicle production in the United States, to the extent that this is feasible.
Persisting Trends in Automotive Innovation: Implications for the FreedomCAR and Fuel Partnership. (Standards)	2-10	As the basic platform of the automobile becomes more modular, interface standards will be required to enable greater competition among technology alternatives. While specific interface standards have been discussed elsewhere in this report, the Partnership should also consider conducting a more general review of areas in which industry-wide standards could accelerate the pace of innovation and lower its cost.
Persisting Trends in Automotive Innovation: Implications for the FreedomCAR and Fuel Partnership. (Inclusive Innovation Architecture)	2-11	The Partnership should seek out and implement methods to allow new, nontraditional suppliers-especially, emerging entrepreneurial companies-to participate in the innovation process. The Small Business Innovation Research (SBIR) program can become a highly productive source of innovation, and the Partnership should review its linkages with this program and strengthen them where appropriate.
Environmental Impacts of Alternative Pathways	2-12	The Partnership should undertake a review of the state of methods and case studies that have been carried out on environmental impacts related to the technologies under development. This review would answer some remaining open questions and help direct systems studies so as to maximize their efforts to characterize the environmental impacts of different fuel pathways.
Environmental Impacts of Alternative Pathways	2-13	The Partnership should strengthen the links between the systems analysis teams and the technical teams. In particular, technology goals and targets should include consideration of priorities established in systems analysis, and systems analysis should be conducted on emerging technologies indentified by the technical teams.
Environmental Impacts of Alternative Pathways	2-14	The Partnership should consider incorporating the broader scope of a “cradle-to-grave” analysis rather than a “source (well)-to-wheels” approach in program planning from production to recycling in order to better consider total energy consumption, total emissions, and the total environmental impact of various energy/vehicle pathways and technologies.

Key Recommendations

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

Vehicle Subsystems

SUBJECT AREA	RECOM. #	RECOMMENDATION TEXT
Advanced Combustion, Emissions Control, and Hydrocarbon Fuels	3-1	The DOE should continue to support financially, be active in, and work to further enhance the collaborations among the national laboratories, industry, and academia in order most effectively to direct research efforts to areas where enhanced fundamental understanding is most needed to improve internal combustion engine and after treatment power-train performance.
Advanced Combustion, Emissions Control, and Hydrocarbon Fuels	3-2	The DOE should continue to support the development and dissemination of the open-source-code computational fluid dynamics program KIVA. This tool is critical to integrating the new understanding of combustion and emission processes into a framework that allows it to be used to guide further research and identify fuel and engine operating conditions that will maximize reductions in fuel consumption over the entire operating range of the engine.
Advanced Combustion, Emissions Control, and Hydrocarbon Fuels	3-3	The advanced combustion and emission control technical team should engage with the biofuels research community to ensure that the biofuels research which the team is conducting is consistent with and leverages the latest developments in the field of biofuels R&D.
Advanced Combustion, Emissions Control, and Hydrocarbon Fuels	3-4	As the vehicle mix within the on-the-road light-duty vehicle fleet is likely to change with the implementation of the new fuel economy standards, the advanced combustion and emission control technical team should interface with the system modeling technical team to make sure that their research programs are consistent with the changing demands for the optimal matching of the engine operational regimes, power management, and emission control that will be imposed on the internal combustion engine and hybrid power trains as the vehicle characteristics evolve.
Fuel Cell Subsystem	3-5	As the auto companies begin to down-select technologies for fuel cell vehicles, they must focus their limited R&D resources on development engineering for the platform selected and move into the competitive (as distinct from precompetitive) arena. The only way that alternative fuel cell systems and components can receive sufficient attention to mitigate the overall program risk is for the precompetitive program, sponsored largely by the DOE, to support them. Thus, the DOE should increase its focus on precompetitive R&D related to both the fuel cell stack and the balance of plant-the other components of the fuel cell system required for successful operation, such as controls, fuel storage, instrumentation, and so forth – to develop alternatives to the down-selected technologies.
Fuel Cell Subsystem	3-6	The DOE should incorporate more of that advanced, most recent, nonproprietary OEM system configuration specifications in the various systems and cost models for fuel cell power plants. Systems configurations no longer demonstrated to be optimal should be abandoned in favor of best proven technology.
Fuel Cell Subsystem	3-7	The DOE should establish backup technology paths, in particular for stack operation modes and stack components, with the fuel cell technical team to address the case of current technology selections determined not likely to meet the targets. The DOE should assess which critical technology development efforts are not yielding sufficient progress and ensure that adequate levels of support for alternative pathways are in place.
Fuel Cell Subsystem	3-8	The DOE, with input from the fuel cell technical team, should evaluate, and in selected cases accelerate, the timing of the “go/no-go” decisions when it is evident that significant technological progress has been made and adopted by the OEMs.

Key Recommendations

Vehicle Subsystems (Continued)

SUBJECT AREA	RECOM. #	RECOMMENDATION TEXT
Onboard Hydrogen Storage	3-9	The centers of excellence are well managed and have provided an excellent approach for organizing and managing a large, diverse research activity with many participants at various locations. Measures should be taken to continue research on the most promising approaches for onboard hydrogen storage materials. The complete documentation and communication of findings should be undertaken for all materials examined for the completed R&D. Furthermore, in view of the fact that the hydrogen storage program has been in place for less than a decade, the Partnership should strongly support continuing the funding of basic research activities. Public domain contractor reports should be available through links on the DOE EERE Web site.
Onboard Hydrogen Storage	3-10	Research on compressed-gas storage should be expanded to include safety-related activities that determine cost and/or weight, such as validation of the design point for burst pressure ratio at beginning of life and end of life and evaluation of Type 3 versus Type 4 storage vessels. Furthermore, finite-element modeling of stresses and heat flow in fires, investigative work on wraps (i.e., translation efficiency), and analysis of applicability of compressed-gas storage to specific vehicle types would be beneficial.
Onboard Hydrogen Storage	3-11	The high cost of aerospace-quality carbon fiber is a major impediment to achieving cost-effective compressed-hydrogen storage. The reduction of fiber cost and the use of alternative fibers should be a major focus for the future. Systems analysis methodology should be applied to needed critical cost reductions.
Onboard Hydrogen Storage	3-12	The hydrogen storage program is one of the most critical parts of the hydrogen/fuel cell vehicle part of the FreedomCAR and Fuel Partnership-both for physical (compressed gas) and for materials storage. If should continue to be funded, especially the systems-level work in the Chemical Hydrogen Storage Engineering CoE. Efforts should also be directed to compressed gas-storage to help achieve weight and cost reductions while maintaining safety.
Onboard Hydrogen Storage	3-13	The time for charging the hydrogen storage material with hydrogen (refueling time) is a program goal (3 minutes for a 5 kg charge). Concepts beyond materials properties alone should be explored to meet this challenge for customer satisfaction, and will require coordination with the areas of production, off-board storage, and dispensing.
Onboard Hydrogen Storage	3-14	There should be an effort to anticipate hydrogen storage material property and performance requirements that will place demands on developed systems-for example, purity and response to impurities, aging and lifetime prediction, and safety in adverse environments. Linkage between the hydrogen storage and production and delivery activities should receive attention.
Onboard Hydrogen Storage	3-15	The search for suitable onboard hydrogen storage materials has been broadly based, and significant progress is reported. Nonetheless the current materials are not close to the long-range goals of the Partnership. Onboard hydrogen storage R&D risks losing out to near-term applications for future emphasis and funding. The management of a long-term/short-term joint portfolio should be given consideration.

Vehicle Subsystems (Continued)

SUBJECT AREA	RECOM. #	RECOMMENDATION TEXT
Electrochemical Energy Storage	3-16	The Partnership should revisit and modify, as necessary, the goals and targets for battery electric vehicles in view of the changing market conditions and improvements in technologies.
Electrochemical Energy Storage	3-17	The Partnership should significantly intensify its efforts to develop improved materials and systems for high-energy batteries for both plug-in electric vehicles and battery electric vehicles.
Electrochemical Energy Storage	3-18	The Partnership should conduct a study to determine the cost of recycling batteries and the potential of savings from recycled materials. A research program on improved processes for recycling advanced batteries should be initiated in order to reduce the cost of the processes and recover useful materials and to reduce potentially hazardous toxic waste and, if necessary, to explore and develop new processes that preserve and recycle a much larger portion of the battery values.
Electric Propulsion and Electrical Systems	3-19	The Partnership should continue to focus on activities to reduce the cost, size, and losses in the power electronics and electrical machines.
Electric Propulsion and Electrical Systems	3-20	The Partnership should conduct a project to evaluate the effect of battery charging on lithium-ion battery packs as a function of the cell chemistries, cell geometries, and configurations in the pack; battery string voltages; and numbers of parallel strings. A standardized method for these evaluations should be developed to ensure the safety of battery packs during vehicle operations as well as during plug-in charging.
Electric Propulsion and Electrical Systems	3-21	The Partnership should consider conducting a project to investigate induction motors as replacements for the permanent magnet motors now almost universally used for electric propulsion.
Structural Materials	3-22	The materials technical team should develop a systems-analysis methodology to determine the currently most cost-effective way for achieving a 50 percent weight reduction for hybrid and fuel cell vehicles. The materials team needs to evaluate how the cost penalty changes as a function of the percent weight reduction, assuming that the most effective mix of materials is used at each step in the weight-reduction process. The analysis should be updated on a regular basis as the cost structures change as a result of process research breakthroughs and commercial developments.
Structural Materials	3-23	The magnesium castings study is completed, and no further technical effort is anticipated by the Partnership as recommended in Phase 2 report. However, magnesium castings should be considered in completing the cost reduction recommendations listed above.
Structural Materials	3-24	Methods for the recycling of carbon-reinforced composites need to be developed.

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

Hydrogen & Biofuels

SUBJECT AREA	RECOM. #	RECOMMENDATION TEXT
Hydrogen Fuel Pathways	4-1	The DOE should broaden the role of the fuel pathways integration technical team (FPITT) to include an investigation of the pathways to provide energy for all three approaches currently included in the Partnership. This broader role could include not only the current technical subgroups for hydrogen, but also subgroups on biofuels utilization in advanced internal combustion engines and electricity generation requirements for PHEVs and BEVs, with appropriate industrial representation on each. The role of the parent FPITT would be to integrate the efforts of these subgroups and to provide an overall perspective of the issues associated with providing the required energy in a variety of scenarios that meet future personal transportation needs.
Hydrogen Production (Thermal Processes)	4-2	The DOE's Fuel Cell Technologies program and the Office of Fossil Energy should continue to emphasize the importance of demonstrated CO_2 disposal in enabling essential pathways for hydrogen production, especially for coal.
Hydrogen Production (Thermal Processes)	4-3	The Fuel Cell Technologies program should adjust its Technology Roadmap to account for the possibility that CO_2 sequestration will not enable a midterm readiness for commercial hydrogen production from coal. It should also consider the consequences to the program of apparent large increase in U.S. natural gas reserves.
Hydrogen Production (Thermal Processes)	4-4	The EERE should continue to work closely with the Office of Fossil Energy to vigorously pursue advanced chemical and biological concepts for carbon disposal as a hedge against the inability of geological storage to deliver a publicly acceptable and cost-effective solution in a timely manner. The committee also notes that some of the technologies now being investigated might offer benefits in the small-scale capture and sequestration of carbon from distributed sources.
Hydrogen Production (Thermal Processes)	4-5	The DOE should continue to evaluate the availability of biological feedstocks for hydrogen in light of the many other claims on this resource - liquid fuels, chemical feedstocks, electricity, food, and others.
Hydrogen Production (Thermal Processes)	4-6	The Partnership should prioritize the many biomass-to-biofuels-to-hydrogen process pathways in order to bring further focus to development in this very broad area.
Hydrogen Production (Thermal Processes)	4-7	The Partnership should consider conducting a workshop to ensure that all potentially attractive high-temperature thermochemical cycles have been identified, and it should carry out a systems analysis of candidate systems to identify the most promising approaches, which can then be funded as money becomes available.

Key Recommendations

Hydrogen & Biofuels (Continued)

SUBJECT AREA	RECOM. #	RECOMMENDATION TEXT
Hydrogen Production (Thermal Processes)	4-8	The EERE funding for high-temperature thermochemical cycle projects has varied widely and is very low in FY 2009. The committee believes that these centralized production techniques are important, and thus adequate and stable funding for them should be considered.
Hydrogen Production (Electrolytic Processes)	4-9	Water electrolysis should remain an integral part of the future hydrogen infrastructure development. The DOE should continue to fund novel water electrolysis materials and methods, including alternative membranes, alternative catalysts, high-temperature and –pressure operations, advanced engineering concepts, and systems analysis. Additional efforts should be placed on advanced integration concepts in which the electrolyzer is co-engineered with subsequent upstream and downstream unit operations to improve the overall efficiency of a stand-alone system.
Hydrogen Production (Electrolytic Processes)	4-10	Commercial demonstrations should be encouraged for new designs based on established electrolytic processes. For newer concepts such as high-temperature solid oxide systems, efforts should remain focused on laboratory evaluations of the potential for lifetime and durability, as well as on laboratory performance assessments.
Hydrogen Production (Electrolytic Processes)	4-11	Work on close coupling of wind and solar energy with electrolysis should be continued with stable funding. Further improvements in electrolyzers, including higher stack pressure, and in power electronics will benefit this application.
Hydrogen Production (Photolytic Processes)	4-12	The Partnership should examine the goals for the photolytic approach to producing hydrogen using microorganisms and formulate a vision with defined targets. Otherwise, this approach should be deemphasized as an active research area for hydrogen production.
Hydrogen Delivery, Dispensing, and Transition Supply	4-13	Hydrogen delivery, storage, and dispensing should be based on the program needed to achieve the cost goal for 2017. If it is not feasible to achieve that cost goal, emphasis should be placed on those areas that would most directly impact the 2015 decision regarding commercialization. In the view of the committee, pipeline, liquefaction, and compression programs are likely to have the greatest impact in the 2015 time frame. The cost target should be revised to be consistent with the program that is carried out.
Biofuels for Internal Combustion Engines	4-14	A thorough systems analysis of the complete biofuel distribution and end-use system should be done. This should include (1) an analysis of the fuel- and engine-efficiency gains possible through ICE technology development with likely particular biofuels or mixtures of biofuels and conventional petroleum fuels, and (2) a thorough analysis of the biofuel distribution system needed to deliver these possible fuels or mixtures to the end-user application.

HTAC Meeting Agenda Note

U.S. DEPARTMENT OF ENERGY

The Hydrogen and Fuel Cell Technical Advisory Committee (HTAC) was established under **Section 807 of the Energy Policy Act of 2005** to provide technical and programmatic advice to the Energy Secretary on DOE's hydrogen research, development, and demonstration efforts.

SEC. 807. TECHNICAL ADVISORY COMMITTEE.

REVIEW.—The Technical Advisory Committee shall review and make recommendations to the Secretary on the safety, economical, and environmental consequences of technologies for the production, distribution, delivery, storage, or use of hydrogen energy and fuel cells.

Agenda Items

DOE Safety Codes & Standards R&D Overview:
- Materials Compatibility
- Hydrogen Behavior & Releases
- Quantitative Risk Assessment

Codes and Standards Implémentation
- ReliOn
- Nuvera

Codes and Standards Development:
- Domestic Activities
  - Codes & Standards Development Organizations
- International Activities
  - International Organization for Standardization and UN/ECE Global Technical Regulations

Source: US DOE 10/2010

Thank you

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www.hydrogenandfuelcells.energy.gov