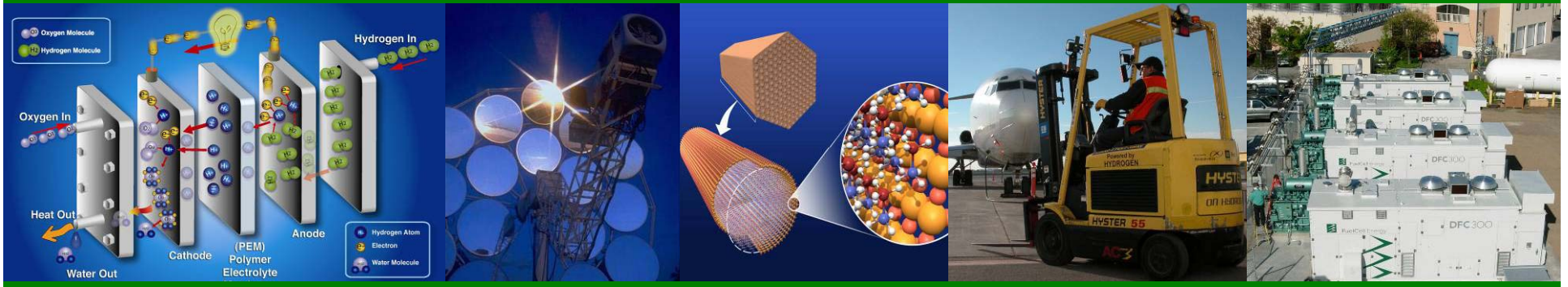




U.S. DEPARTMENT OF
ENERGY | Energy Efficiency &
Renewable Energy



DOE's Stationary Fuel Cell Demonstrations

Joseph Stanford

DOE Fuel Cell Technologies Program

Support Contractor—Sentech, Inc.

November 18, 2009

Fuel Cell Seminar & Exhibition

Palm Springs, CA

Introduction:

- The role of demonstrations in DOE's Fuel Cell Technologies Program
- Stationary technologies currently being demonstrated

Examples of Current Demonstration Projects

- Fuel Cell R&D subprogram
- Technology Validation subprogram
- Market Transformation and Recovery Act

Data Collection, Analysis, and Feedback to Stakeholders

News

- Revised targets announced
- Broad agency announcement for backup power

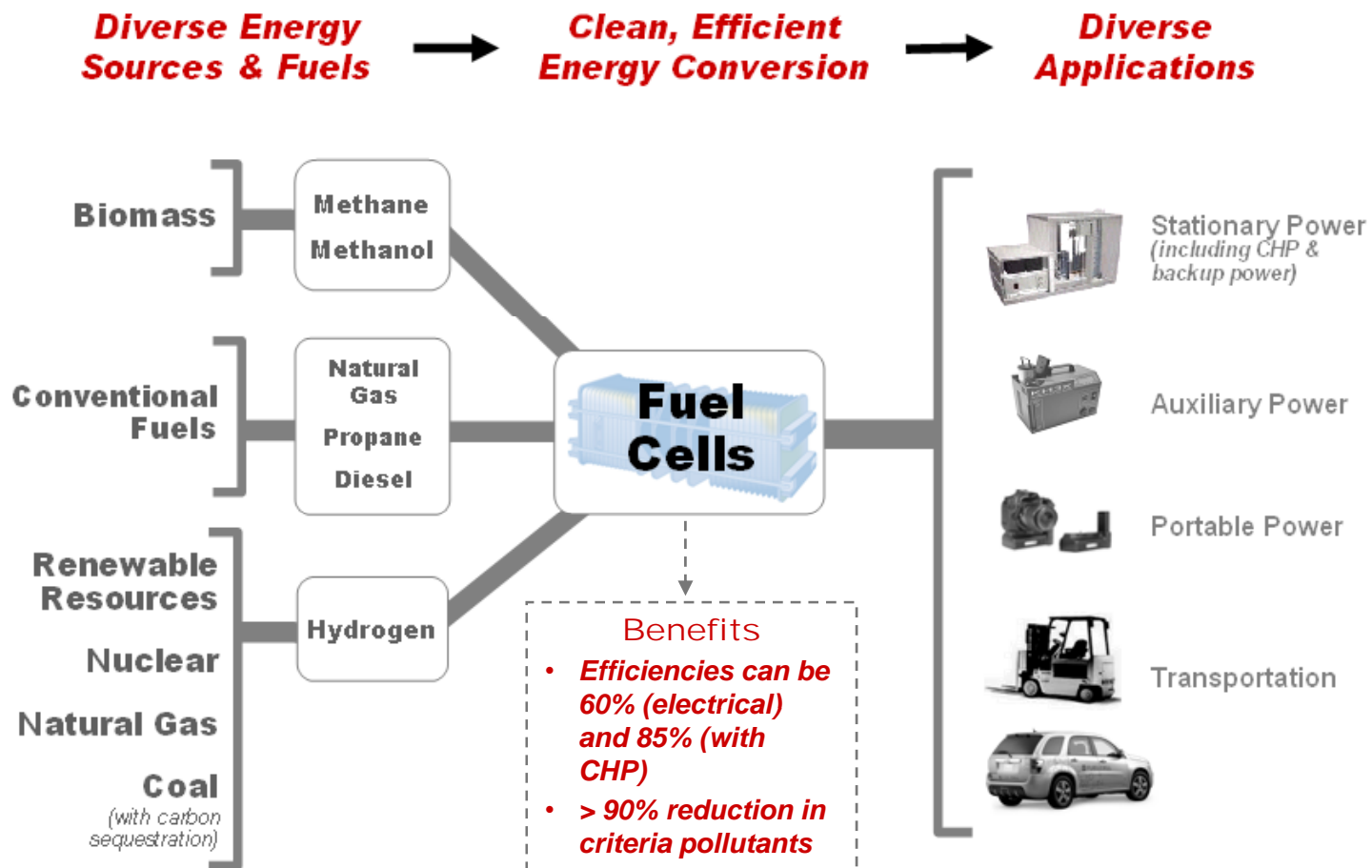
Fuel Cells: Addressing Energy Challenges

Energy Efficiency and Resource Diversity

→ **Fuel cells offer a highly efficient way to use diverse fuels and energy sources.**

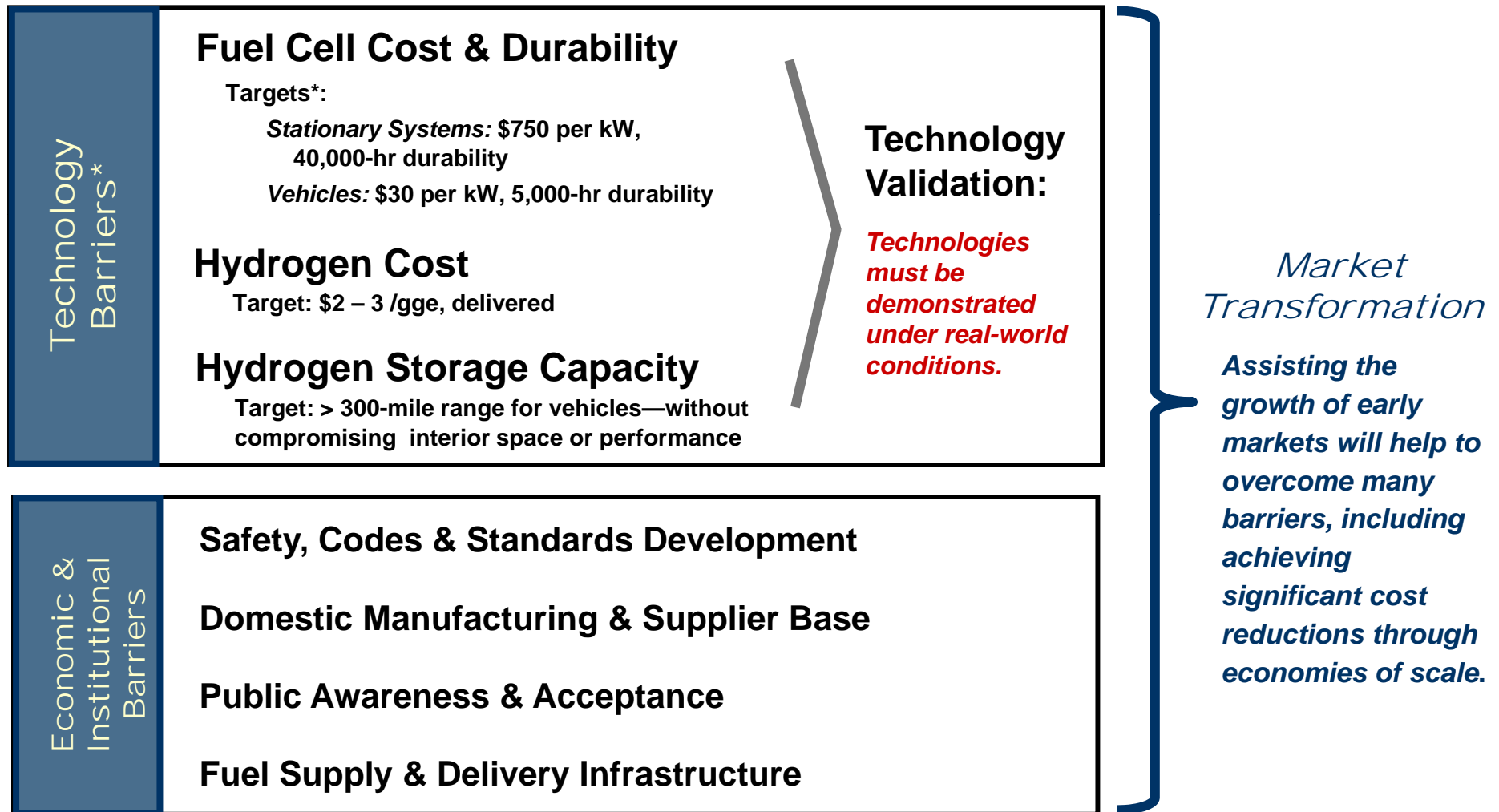
Greenhouse Gas Emissions and Air Pollution

→ **Fuel cells can be powered by emissions-free fuels that are produced from clean, domestic resources.**



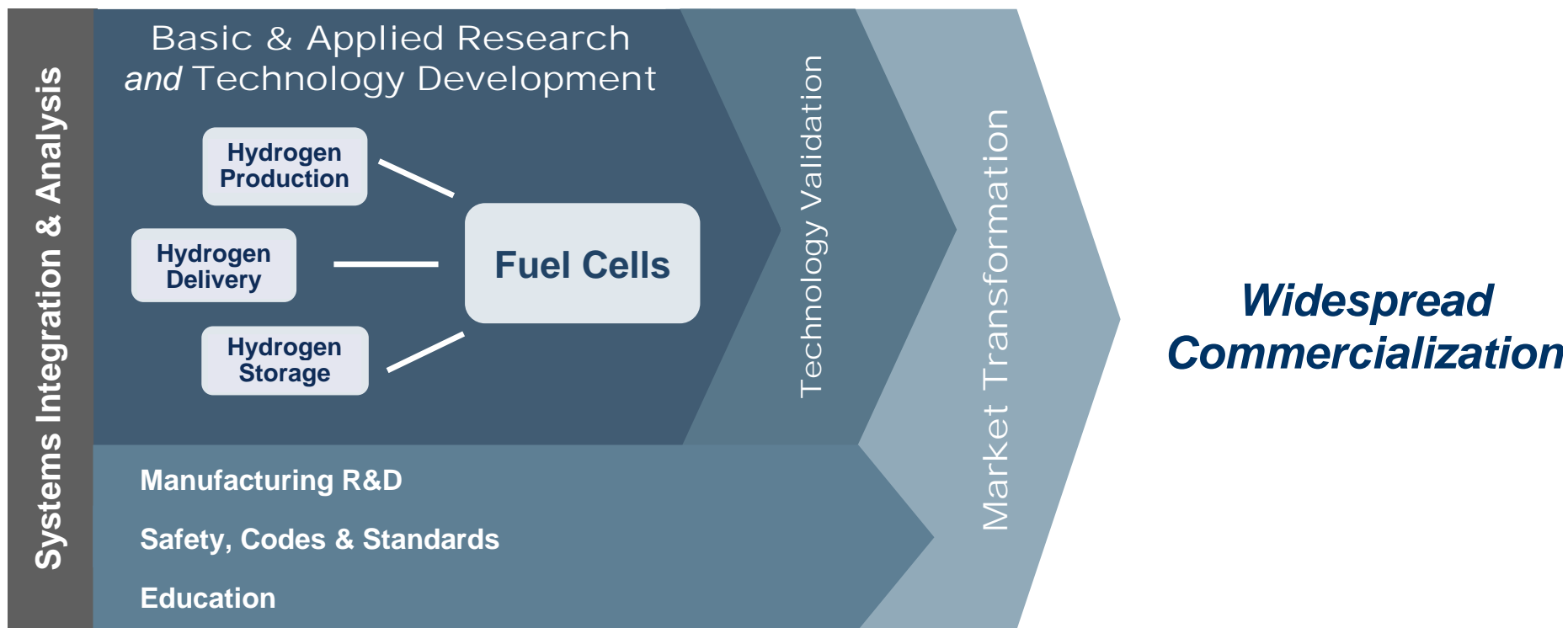
Key Challenges

*The Program is an integrated effort, structured to address the obstacles facing widespread commercialization → **real-world demonstrations are a key aspect of this effort.***



*Metrics available/under development for various applications

Program Structure



Backup Power



Expected advantages ...

- **Longer continuous run-time, greater durability than batteries** *(Battery systems usually run 4 – 8 hrs, and have to be replaced every 3 – 5 years, while fuel cell runtime is limited only by storage capacity, and they could last 15 years or more, depending on amount of actual use.)*
- **Less maintenance than batteries or generators** *(estimated routine maintenance of two hours per year for fuel cells and eight hours per year for batteries and generators)*
- **Can provide substantial cost-savings over battery-generator systems** *(nearly 25% reduction in lifecycle costs for a 5-kW, 52-hour backup-power system)*

SOURCE: *Identification and Characterization of Near-Term Direct Hydrogen Proton Exchange Membrane Fuel Cell Markets*, Battelle Memorial Institute, 2007 (www.hydrogenandfuelcells.energy.gov/fc_publications.html)

Micro-CHP



Expected advantages ...

- **Up to 85% overall efficiency**
- **25 – 35% reduction in CO₂ emissions from household energy use (and zero criteria-pollutant emissions)**
- **Overall energy costs potentially as low as 6¢/kWh—resulting in payback period as low as three years (with tax credits)**
- **Advantages over other CHP technologies:** *Less variation in efficiency across variable loads; less noise/vibration than other CHP options; low O&M requirements and less down-time*

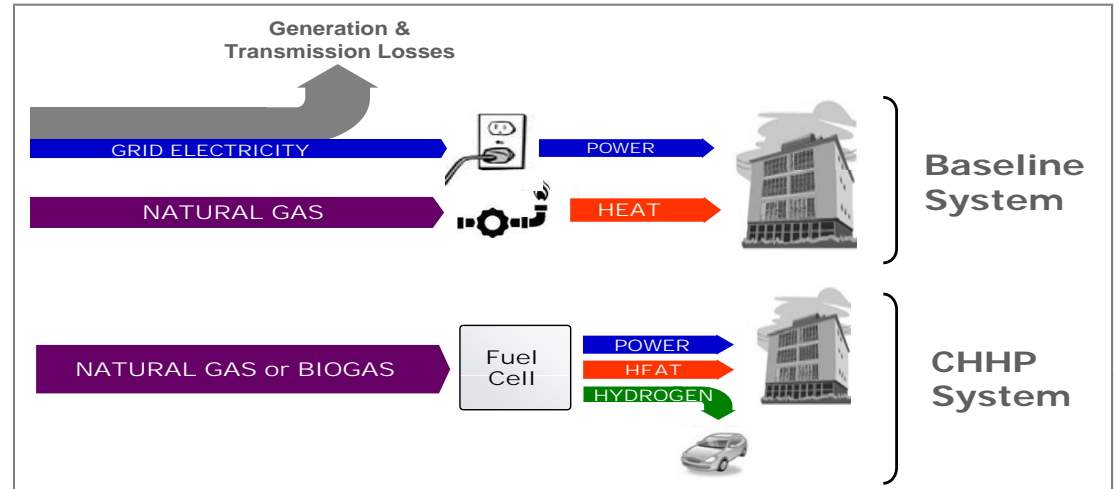
SOURCE: Internal analyses and industry communications.

Combined Hydrogen, Heat, and Power (CHHP)

CHHP Concept

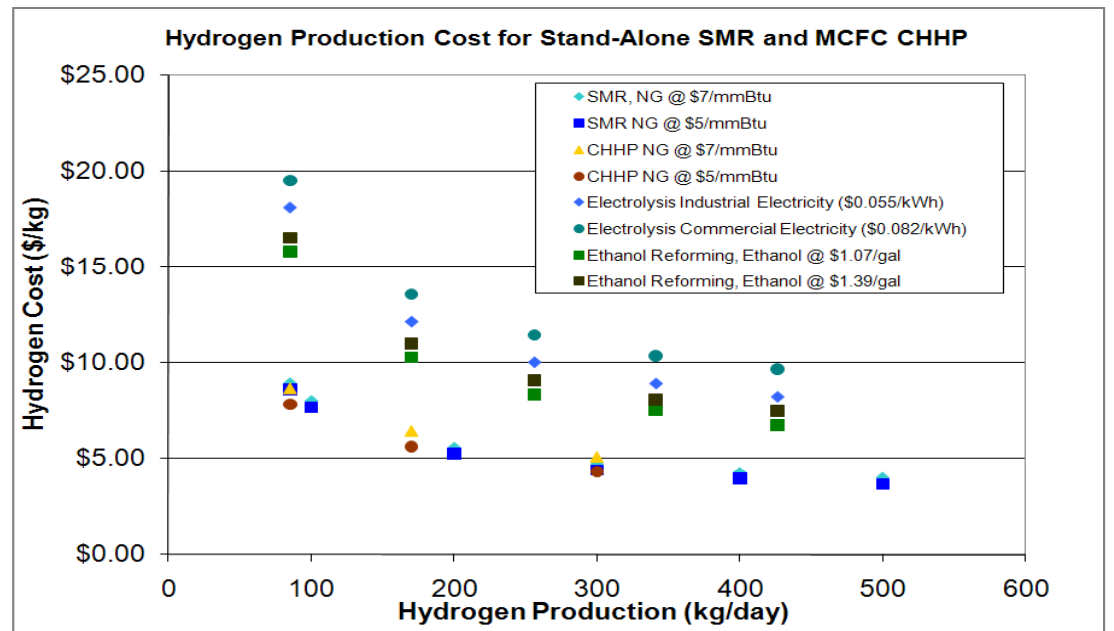
KEY ADVANTAGES:

- Help establish and initial infrastructure for refueling vehicles → *With minimal investment risk*
- Produces clean power and fuel for multiple applications
- Addresses the “stranded asset” obstacle facing early H₂ infrastructure, by spreading capital cost of H₂ production across whole CHHP system

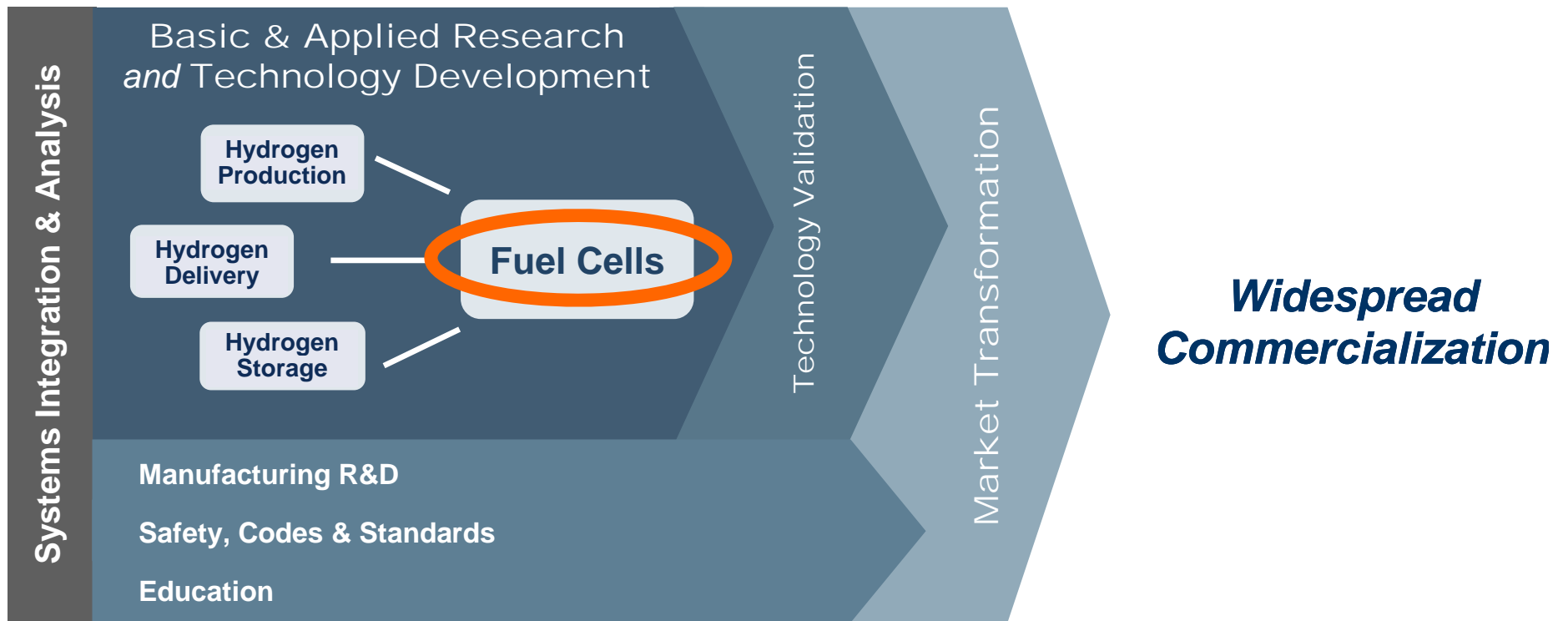


Preliminary Cost Analysis

Shows H₂ produced in CHHP systems will be competitive with stand-alone natural-gas-reforming systems



Program Structure



Examples of Stationary Demonstrations in Fuel Cell R&D Sub-Program



International Stationary Fuel Cell Demonstration – Plug Power: 5-kW; natural-gas fueled; PBI membrane—higher temperature, less susceptible to CO poisoning

- **Collaboration with E.U.**
- **Demonstration of micro-CHP for residential market**



Intergovernmental Stationary Fuel Cell Demonstration – Plug Power: 5-kW; PEM; natural-gas, LPG, ethanol

- **Will be installed at CERL's electrolyzer lab**



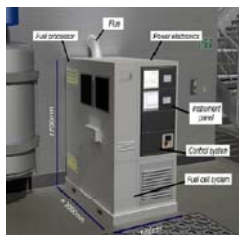
Stationary PEM Fuel Cell Power Plant Verification – UTC Power: Using 5-kW system platform to verify fundamental technologies for larger (up to 200-kW) system; natural-gas fueled; PEM

- **Reduced costs >30%**
- **Increased volumetric power density to achieve parity with similar internal combustion-based power plants**



Low-Cost Co-Production of Hydrogen and Electricity – Bloom Energy: two 25-kW SOFC systems; natural-gas fueled

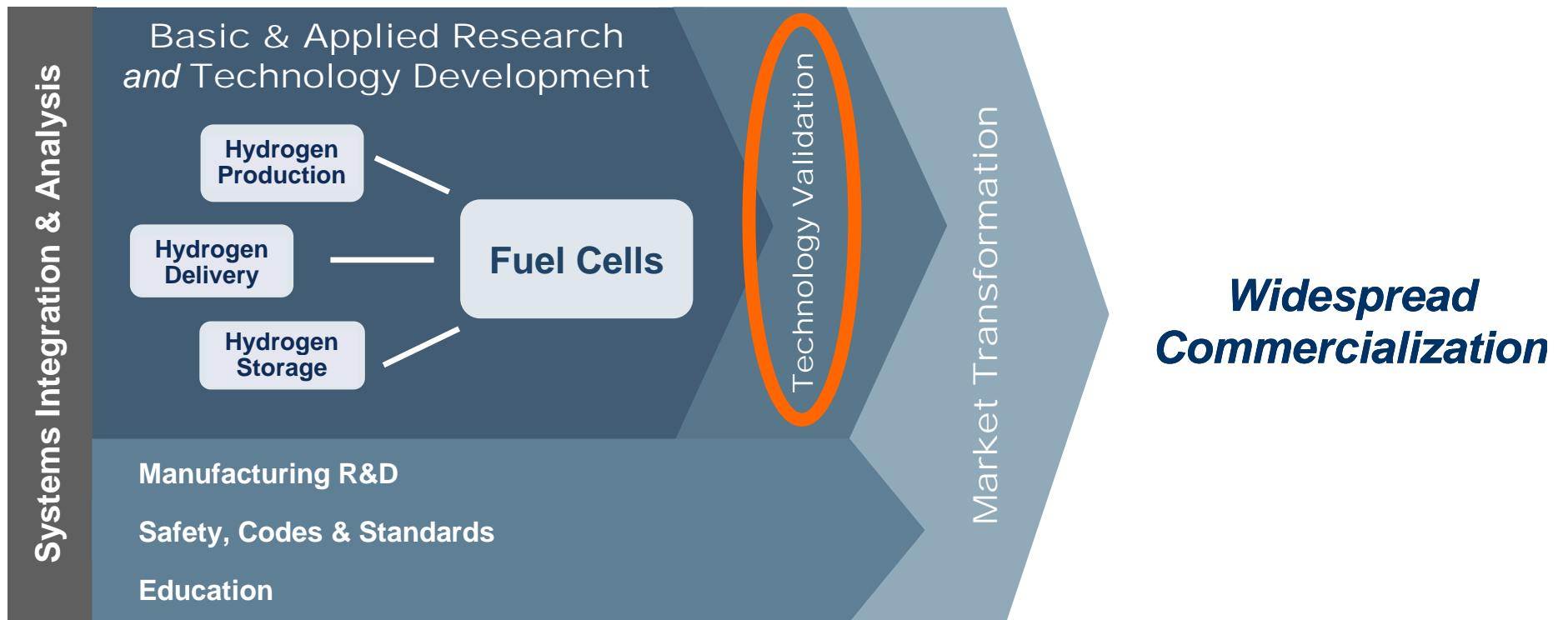
- **Peak (electric-only) efficiency of 45% demonstrated at installation in Alaska**



High-Efficiency 1- to 10-kW Stationary PEM Fuel Cell System – Intelligent Energy:

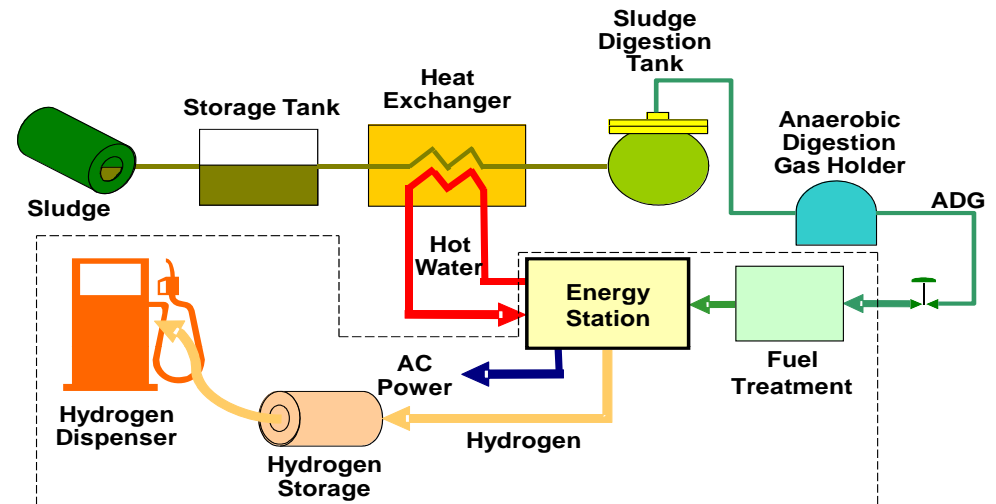
- **Completed the design of a fully integrated CHP system using Intelligent Energy's PEM fuel cell and hydrogen generation technology platforms. Testing of the fully integrated fuel cell and fuel processor has just begun.**

Program Structure



Preliminary Test Results

- Fuel cell with water-gas shift in operation > 6,000 hours
- Tri-generation results:
 - Coproduced 2 to 5 kg/hr hydrogen with > 200 kW electricity
 - Estimated hydrogen recovery at 80 to 85%
 - Product purity <0.2 ppm CO; <2 ppm CO₂
 - Operation with simulated digester gas feed
 - PSA operating map developed (cycle time vs. feed rate)
 - Implemented automated system to switch to CHP mode when hydrogen tanks are filled.



Anode Exhaust Processing and H₂ PSA

Public-Sector Partners:



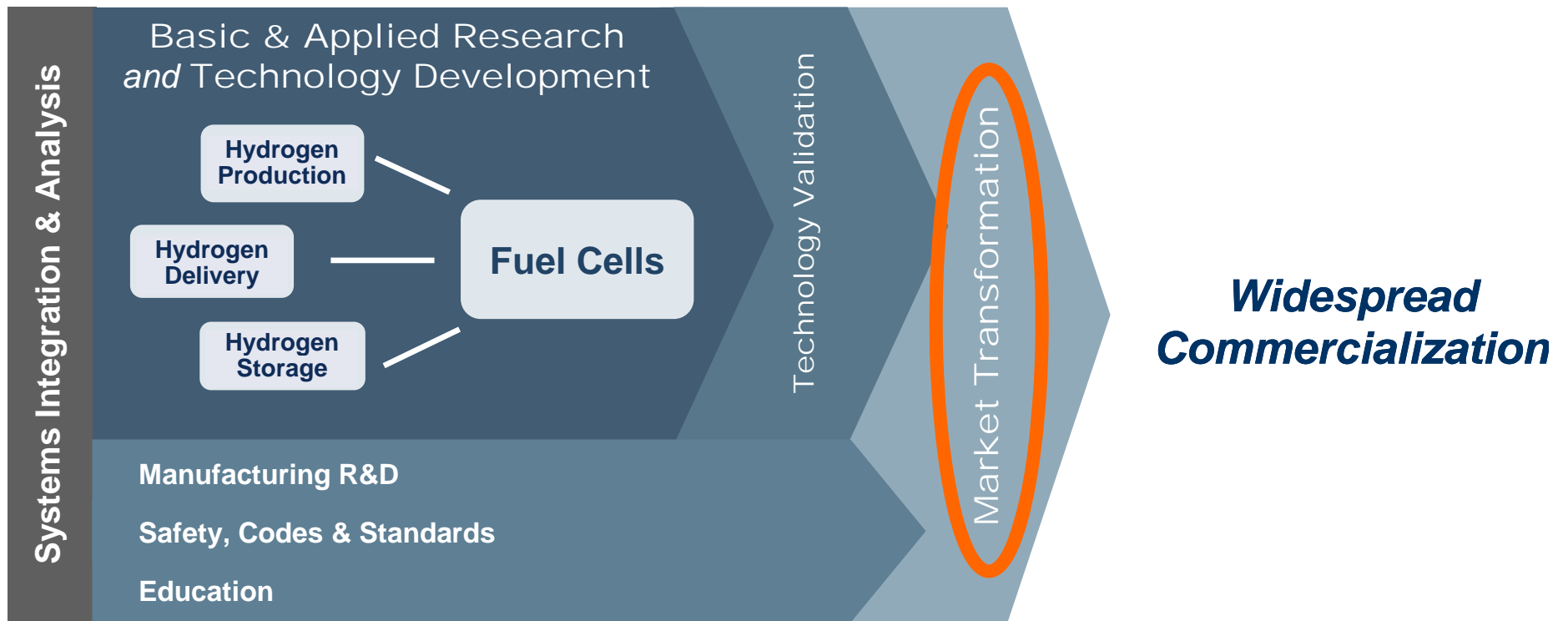
South Coast Air
Quality Management
District



California Air
Resources
Board

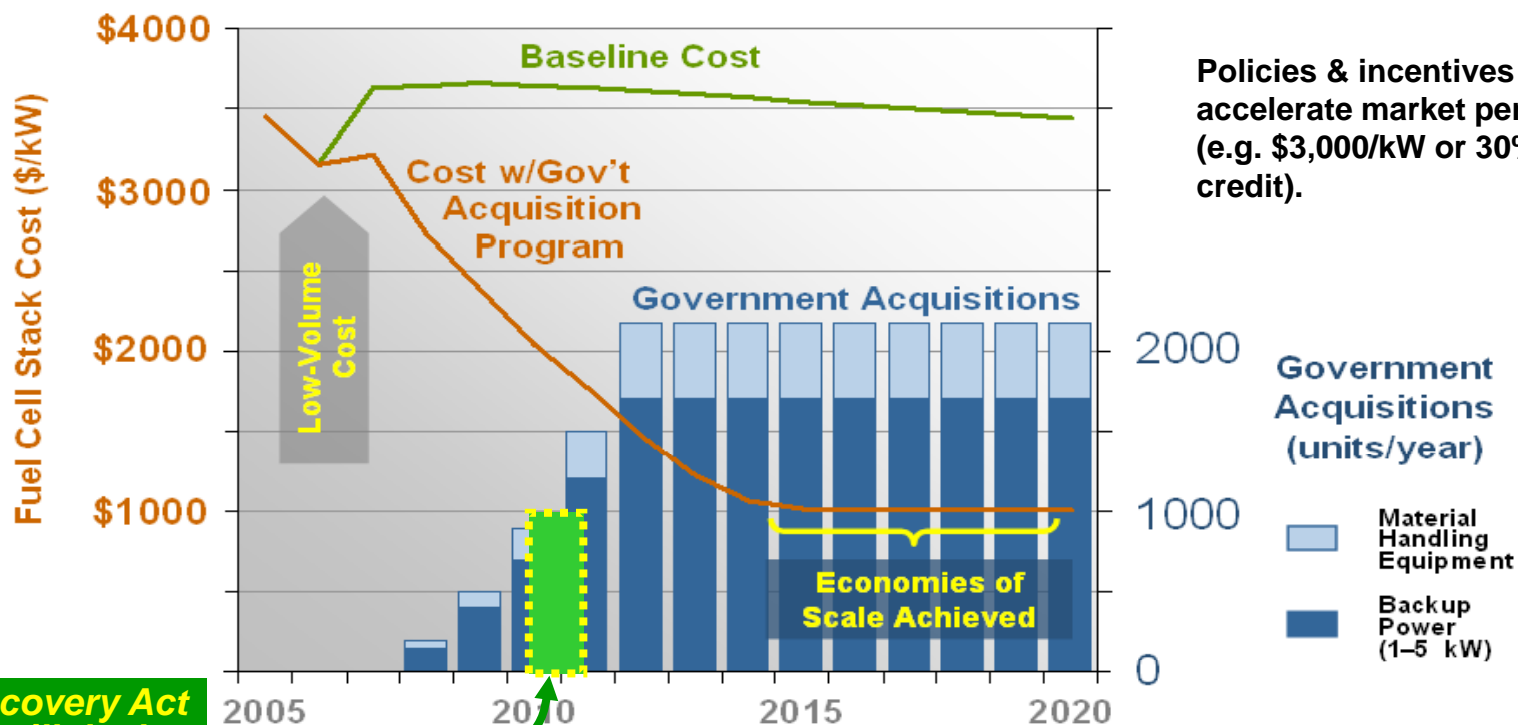


Program Structure



Government acquisitions could significantly reduce the cost of fuel cells through economies of scale, and help to support a growing supplier base.

Impact of Government Acquisitions on Fuel Cell Stack Costs (for non-automotive fuel cells)



Policies & incentives can help accelerate market penetration (e.g. \$3,000/kW or 30% tax credit).

Recovery Act funding will deploy up to 1000 fuel cells, in the private sector, by 2012.

Source: ORNL

DOE is facilitating the adoption of fuel cells across government and industry:

- 100 fuel cells are being deployed, through interagency agreements.
- More interagency agreements under development.

More than 40 backup-power fuel cells are being deployed through interagency agreements.

FY2008 — Interagency Agreements Established

Interagency agreements to deploy more than 40 backup-power fuel cells

- Fort Jackson, South Carolina – 10 fuel cells (Telecommunications Center, Energy Monitoring and Control Facility, Emergency Services Center) → **INSTALLED**
- FAA – 25 fuel cells (telecommunications infrastructure)
- Los Alamos Joint Forces Training Base, CA – 4 fuel cells (Fire Station)
- Marine Corps Logistics Base Barstow, CA – 4 fuel cells (Fire Station)



DOE intends to lead by example by deploying fuel cells at its facilities, and the Program has begun to identify opportunities.

Goals: Deploy fuel cells and quantify benefits at lab facilities; Develop DOE lab fuel cell expertise across the country.

Ideal sites: Require consistent, reliable, quiet power; would combine FC installation with planned projects.

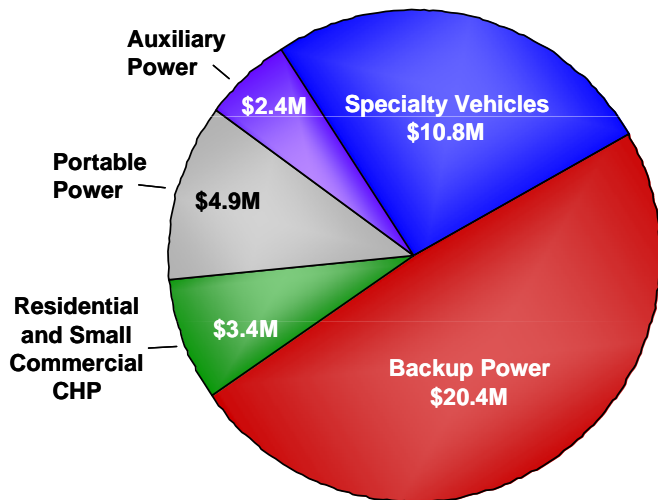
Eight feasibility studies are underway at seven locations: ANL; NRL (2 studies); ORNL; PNNL; Sandia NL; Thomas Jefferson National Accelerator Facility; and the Y-12 Site Office.

Recovery Act Deployments

DOE announced ~\$40 million from the American Recovery and Reinvestment Act to fund 13 projects to deploy more than 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.



Approximately \$72 million in cost-share proposed by industry participants—for a total of nearly \$114 million.

COMPANY	AWARD	APPLICATION
Delphi Automotive	\$2.4 M	Auxiliary Power
FedEx Freight East	\$1.3 M	Specialty Vehicle
GENCO	\$6.1 M	Specialty Vehicle
Jadoo Power	\$1.8 M	Backup Power
MTI MicroFuel Cells	\$2.4 M	Portable
Nuvera Fuel Cells	\$1.1 M	Specialty Vehicle
Plug Power, Inc. (1)	\$3.4 M	CHP
Plug Power, Inc. (2)	\$2.7 M	Backup Power
PolyFuel, Inc.	\$2.5 M	Portable
ReliOn Inc.	\$8.6 M	Backup Power
Sprint Comm.	\$7.3 M	Backup Power
Sysco of Houston	\$1.2 M	Specialty Vehicle

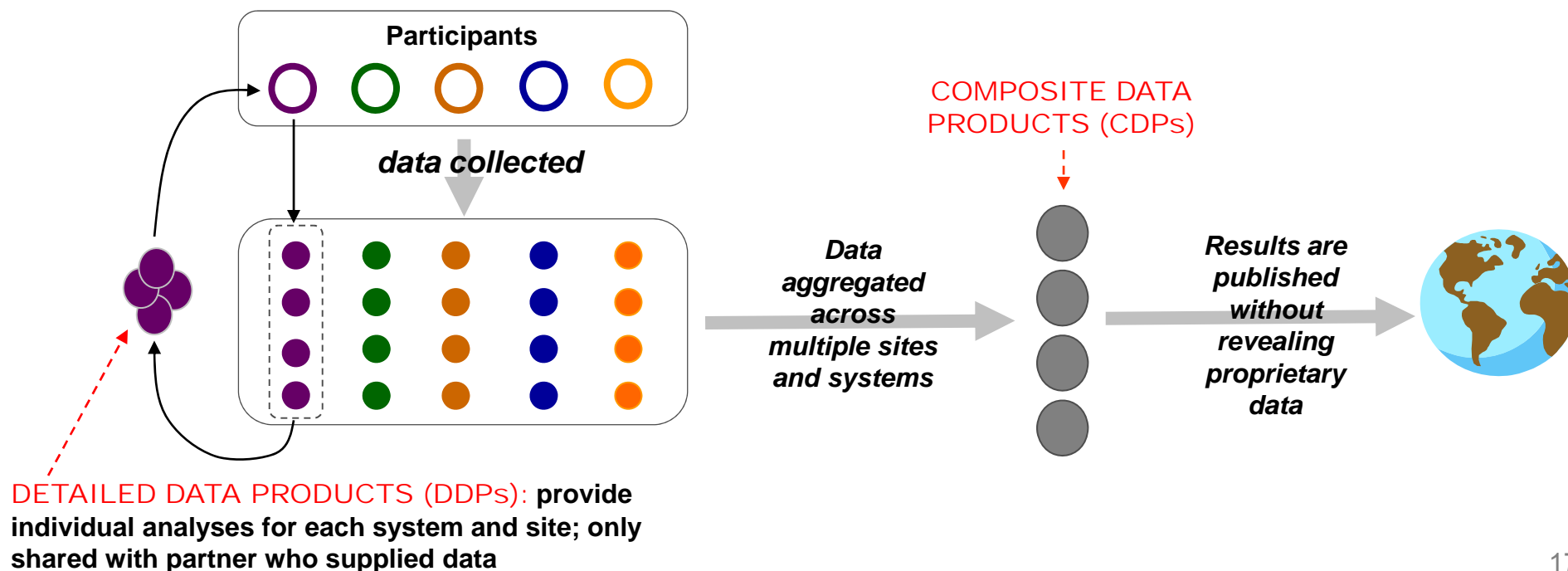
Data Collection, Analysis, and Feedback to Stakeholders

NREL is collecting and analyzing data from deployments supported by DOE's Market Transformation activities and Recovery Act funding.

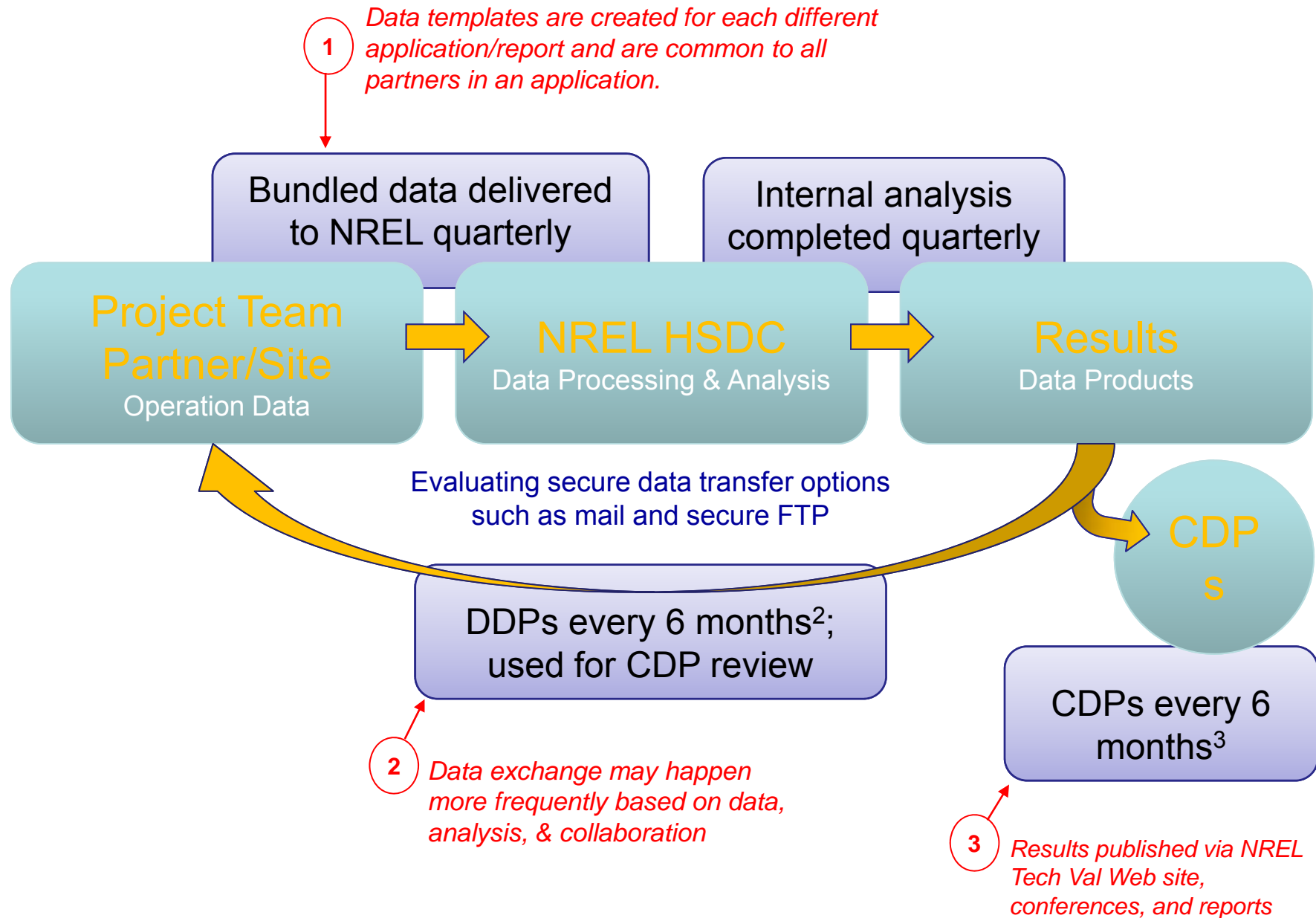
- *Conducting independent assessment of technologies*
- *Leveraging existing capabilities in data processing & analysis*

Key Goals

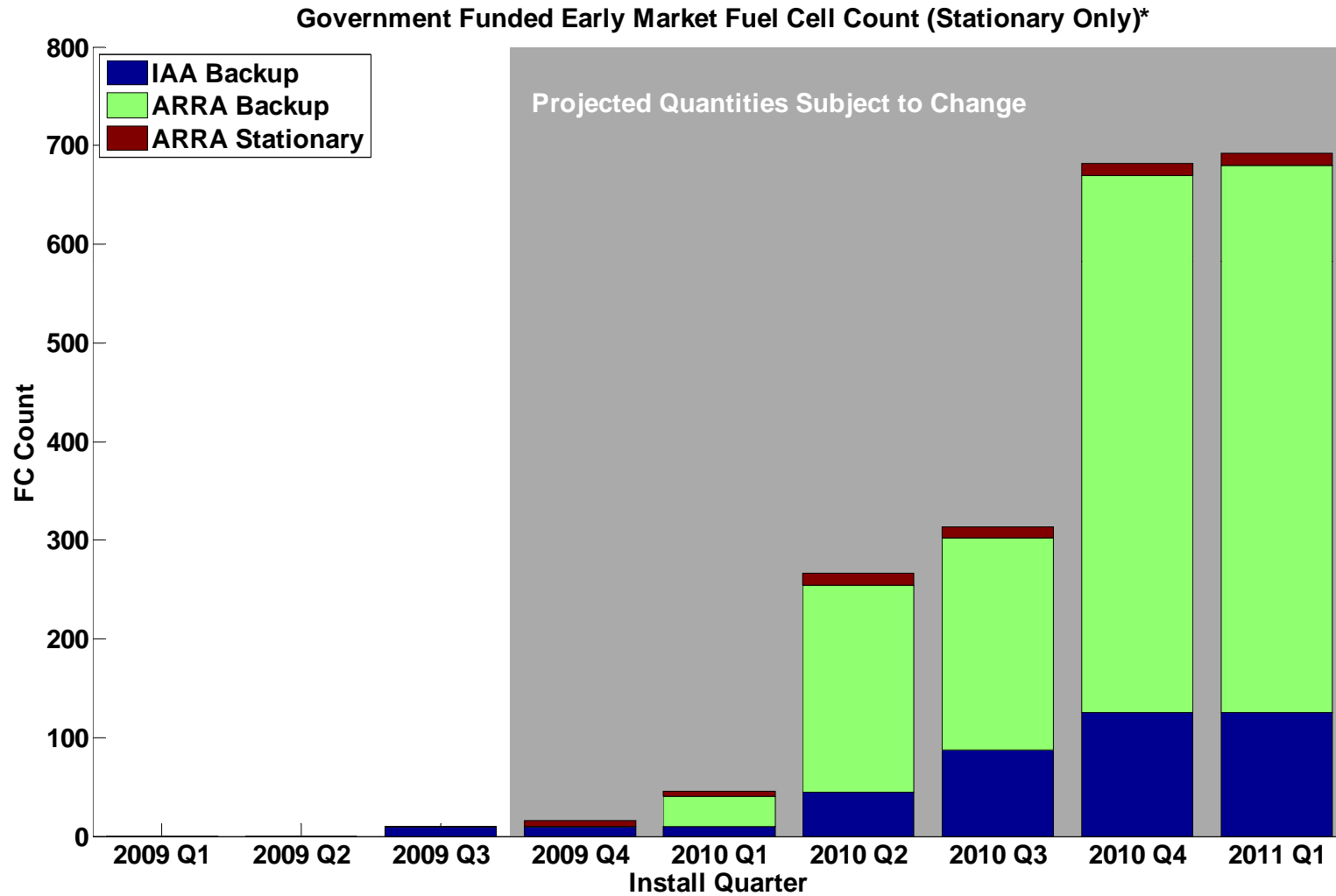
- **Feedback real-world data to R&D efforts**, and report to stakeholders on the status of the technology.
- **Support market growth of fuel cells** by reporting on areas relevant to the value proposition.
- **Establish a baseline** of real-world fuel cell operation and maintenance data
- **Identify technical & market barriers**



NREL's Data Analysis—Data Flow



Projected installations of Recovery Act (ARRA) projects and Market Transformation (Interagency Agreements—IAA) projects reflect rapid ramp-up.

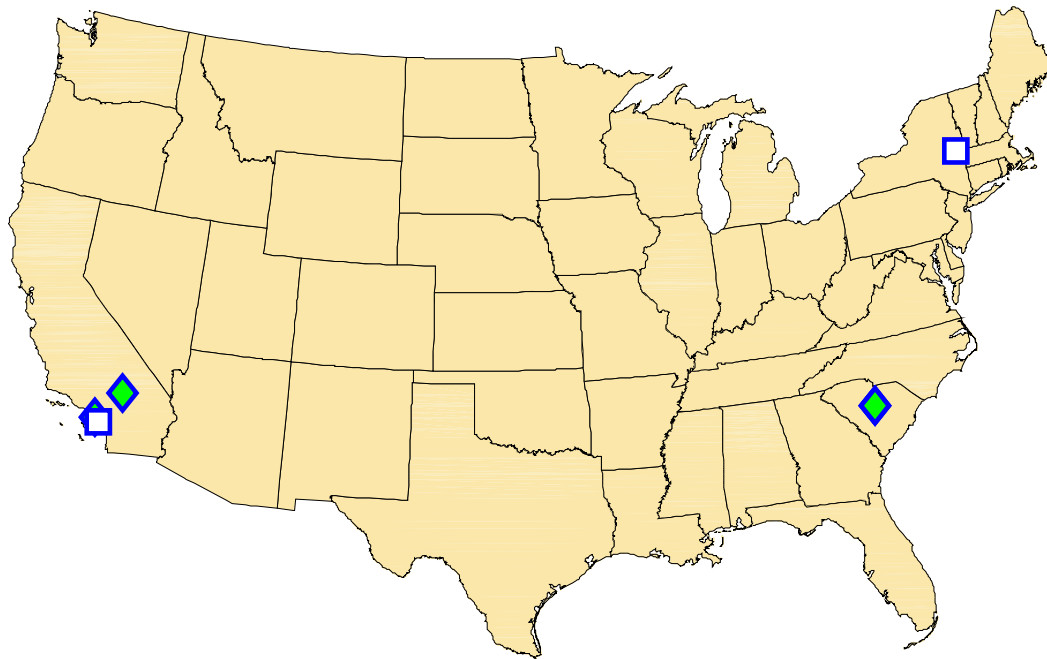


Created: Nov-12-09 1:47 PM

* FC forklifts and APUs are also being deployed and providing data for analysis.

Preliminary Data —Site Locations

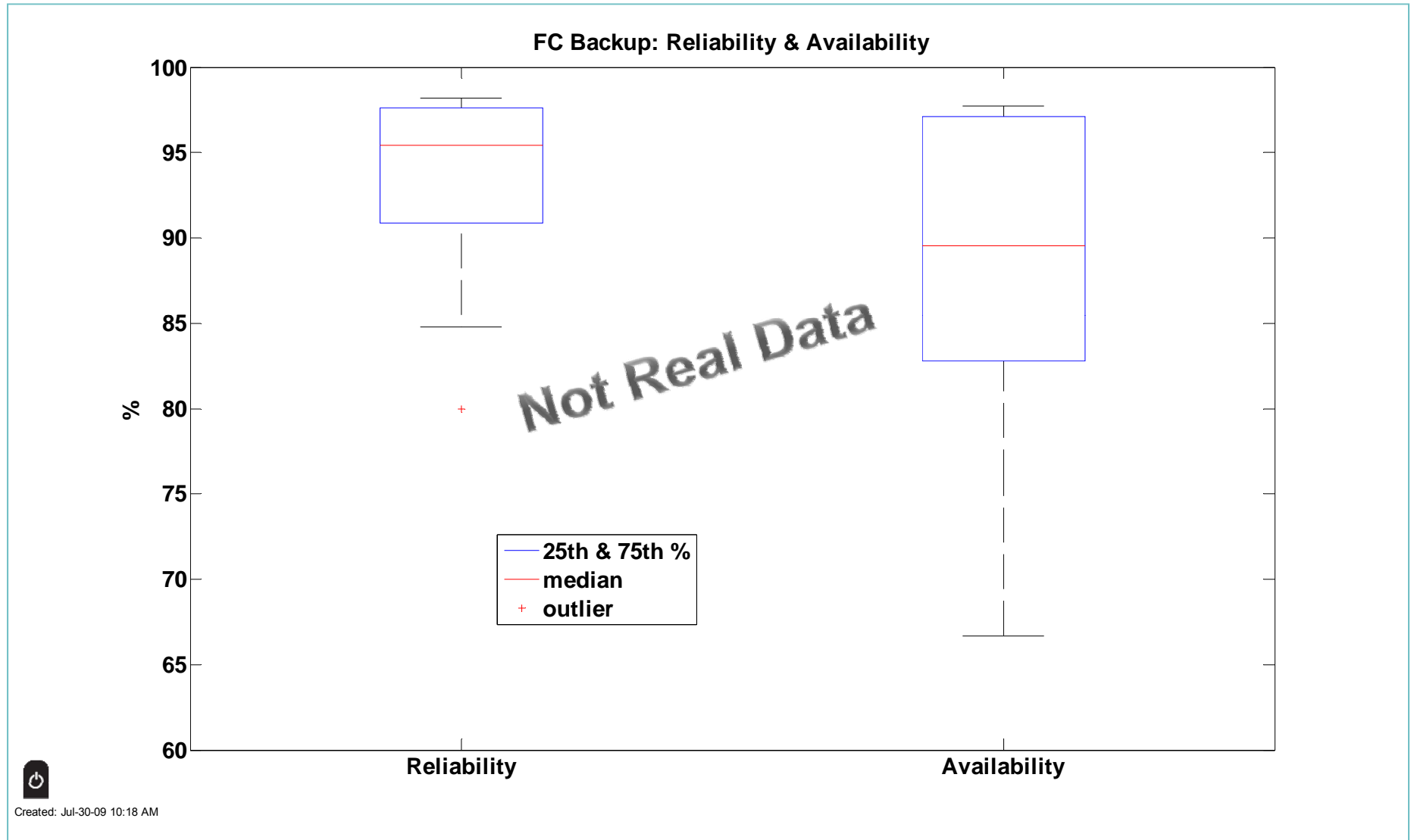
- ◇ ARRA Backup Site
- ◇ IAA Backup Site
- ARRA Stationary Site



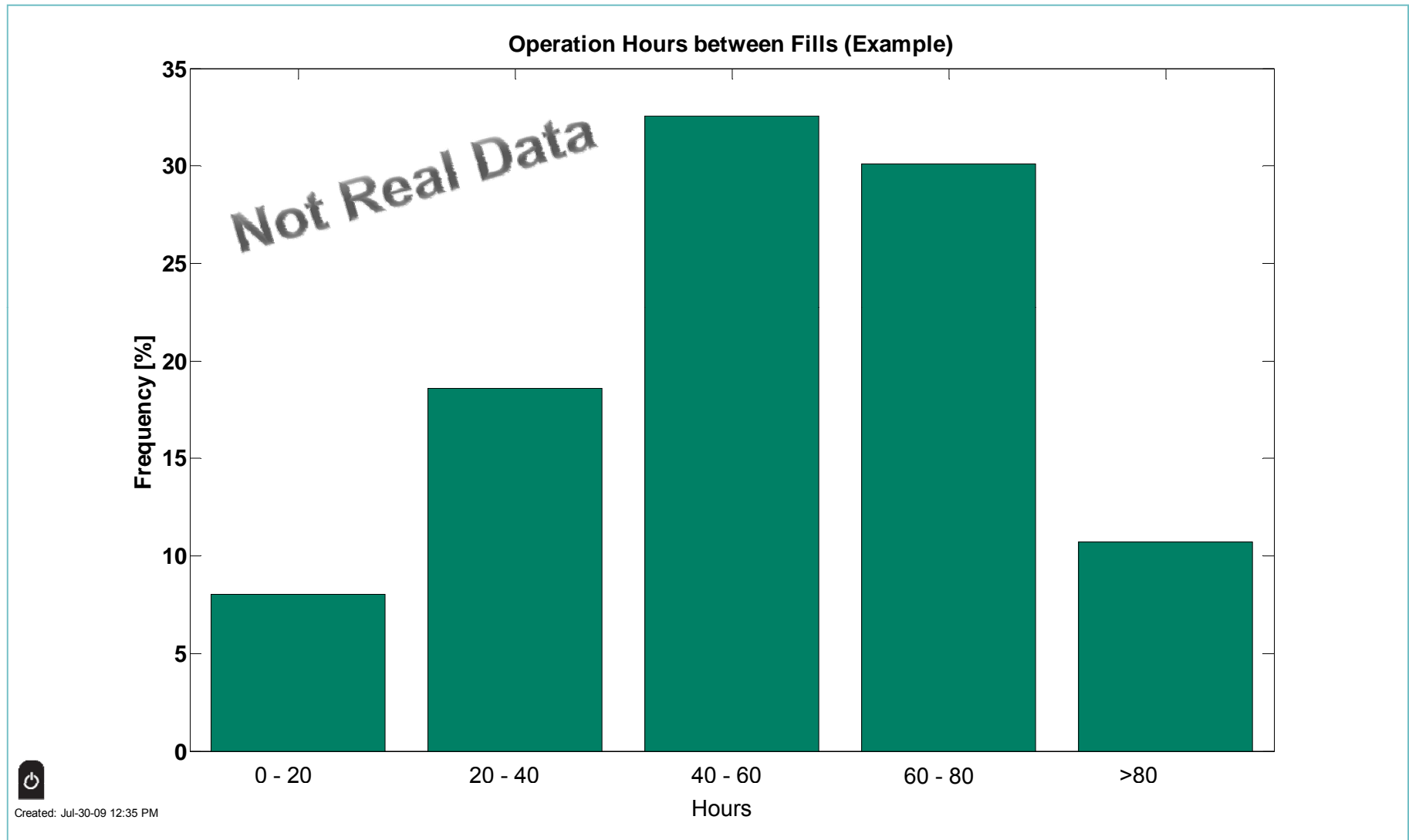
Many site locations to be determined.
Quantity and site locations are subject to change.



Sample Technical Data Product for Stationary FC Application — Reliability & Availability



Example of Technical Data Analysis for Backup Power — *Continuous Runtime*



The screenshot shows the NREL website interface. At the top, the NREL logo and name are displayed, along with the tagline "Innovation for Our Energy Future". A navigation bar includes links for "ABOUT NREL", "SCIENCE & TECHNOLOGY", "TECHNOLOGY TRANSFER", "APPLYING TECHNOLOGIES", and "LEARNING ABOUT RENEWABLES". The main heading is "Hydrogen & Fuel Cells Research". A left sidebar contains a menu with categories like "Hydrogen & Fuel Cells Research Home", "Capabilities", "Projects", "Technology Validation", "Safety", "Codes & Standards", "Analysis", "Education", "Manufacturing", "Research Staff", "Facilities", "Working with Us", "Energy Analysis", "Publications", "Awards & Honors", and "News". The "Technology Validation" section is highlighted, showing a definition of technology validation, a description of the validation process, and a list of three major projects: "Hydrogen Fuel Cell Vehicle and Infrastructure Learning Demonstration", "Hydrogen Fuel Cell Bus Evaluations", and "Early Fuel Cell Market Demonstrations". Each project has a brief description and a link to access more information. There are also images of a hydrogen fuel cell car, a hydrogen fuel cell bus, and a hydrogen fuel cell forklift at a refueling station.

www.nrel.gov/hydrogen/proj_tech_validation.html

Jennifer Kurtz
jennifer.kurtz@nrel.gov
303-275-4061

News

New Targets for CHP & APUs

- RFI was issued in May — to seek input on refining performance, cost, and durability targets for CHP and APUs. Input was received from 18 respondents (industry & labs).
- Targets are defined by consumer expectations, not by the limits/constraints of fuel cell technologies.
- Revised targets announced November 17 (*just yesterday*). Final targets will be published in the updated *Multi-Year Program Plan* (to be released in FY10).

NEW CHP TARGETS

	2008 Status	2012	2015	2020
Electrical efficiency at rated power ^[1]	34%	40%	42.5%	45%
CHP energy efficiency ^[2]	80%	85%	87.5%	90%
Factory Cost ^[3]	\$750/kW	\$650/kW	\$550/kW	\$450/kW
Transient response (10 - 90% rated power)	5 min	4 min	3 min	2 min
Start-up time from 20°C ambient temperature	60 min	45 min	30 min	20 min
Degradation with cycling ^[4]	< 2%/ 1000 h	0.7%/ 1000 h	0.5%/ 1000 h	0.3%/ 1000 h
Operating lifetime ^[5]		30,000 h	40,000 h	60,000 h
System availability	97%	97.5%	98%	99%

NEW APU TARGETS

	2008 Status	2012	2015	2020
Electrical efficiency at rated power ^[1]	25%	30%	35%	40%
Power density	17 W/L	30 W/L	35 W/L	40 W/L
Specific power	20 W/kg	35 W/kg	40 W/kg	45 W/kg
Factory Cost ^[2]	\$750/kW	\$700/kW	\$600/kW	\$500/kW
Transient response (10-90% rated power)		4 min	3 min	2 min
Start-up time from 20°C ambient temperature	50 min	30 min	10 min	5 min
Degradation with cycling ^[3]	2.6%/ 1000 h	2%/ 1000 h	1.3%/ 1000 h	1%/ 1000 h
Operating lifetime ^[4]	~3000 h	10,000 h	15,000 h	20,000 h
System availability	97%	97.5%	98%	99%

[1] Regulated AC net/LHV of fuel.

[2] Only heat available at 80 °C or higher is included in CHP energy efficiency calculation.

[3] Cost includes materials and labor costs to produce stack, plus any balance of plant necessary for stack operation. Cost defined at 50,000 unit/year production (250 MW in 5-kW modules).

[4] Based on operating cycle to be released in 2010.

[5] Time until >20% net power degradation.

[1] Regulated DC net/LHV of fuel.

[2] Cost includes materials and labor costs to produce stack, plus any balance of plant necessary for stack operation. Cost defined at 50,000 unit/year production (250 MW in 5-kW modules).

[3] Based on operating cycle to be released in 2010.

[4] Time until >20% net power degradation

New Opportunity for Deployments/Demonstrations

Broad Agency Agreement announced by the U.S. Army's Construction Engineering Research Laboratory (CERL): "Federal-wide Backup Power PEM Fuel Cell Demonstration" (BAA # W9132T10BAA01)

- Installations funded by DOE, TARDEC, and the federal host sites
- Announced November 12, 2009; installations will be for backup power in federal facilities:
 - ~36 buildings at 13 sites across the country
 - 1 to 20 kW of power per system
 - ~400 kW of backup power will be installed
 - Systems will operate for 5 years; data collected for 24 months
- *Seeks as much variety as possible in the systems to be demonstrated*
- Pre-proposals due December 30.

Sites for BAA Installations

- Argonne National Laboratory, IL
- Cheyenne Mountain Air Force Station, CO
- Aberdeen Proving Ground, MD
- Fort Bragg, NC
- Fort Hood, TX
- Fort Irwin, CA
- Ohio National Guard
- Picatinny Arsenal, NJ
- NASA Ames Research Center, CA
- Marine Corps Air Ground Combat Center 29 Palms, CA
- U.S. Military Academy at West Point, NY
- Fort Richardson, AK
- National Park Service Fort Sumter, SC

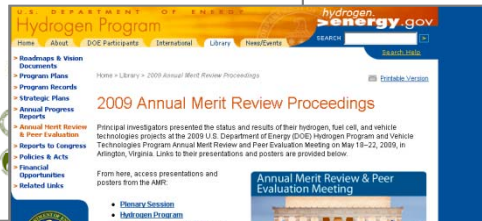
Hydrogen Posture Plan

An Integrated Research, Development and Demonstration Plan

Fuel Cell Program Plan

Outlines a coordinated plan for fuel cell activities in the Department of Energy

- **Replacement for current Posture Plan**
- **To be released in early 2010**



Annual Merit Review Proceedings

Includes downloadable versions of all presentations at the Annual Merit Review

- **Latest edition released June 2009**

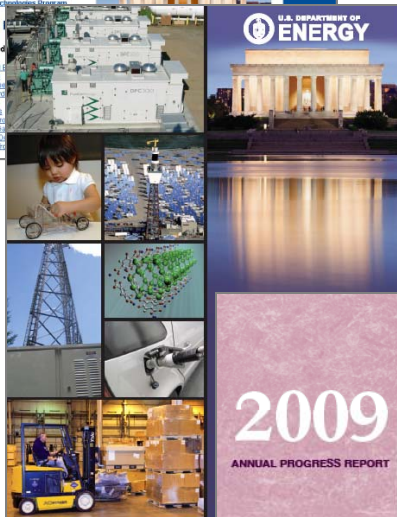
www.hydrogen.energy.gov/annual_review09_proceedings.html

Annual Merit Review & Peer Evaluation Report

Summarizes the comments of the Peer Review Panel at the Annual Merit Review and Peer Evaluation Meeting

- **Latest edition released October 2009**

www.hydrogen.energy.gov/annual_review08_report.html



2009 ANNUAL PROGRESS REPORT DOE Hydrogen Program



Annual Progress Report

Summarizes activities and accomplishments within the Program over the preceding year, with reports on individual projects

- **Latest edition published November 2009**

www.hydrogen.energy.gov/annual_progress.html

Next Annual Review: June 7 – 11, 2010

Washington, D.C.

<http://annualmeritreview.energy.gov/>

Thank you

Joseph Stanford (jstanford@sentech.org & joseph.stanford@ee.doe.gov)

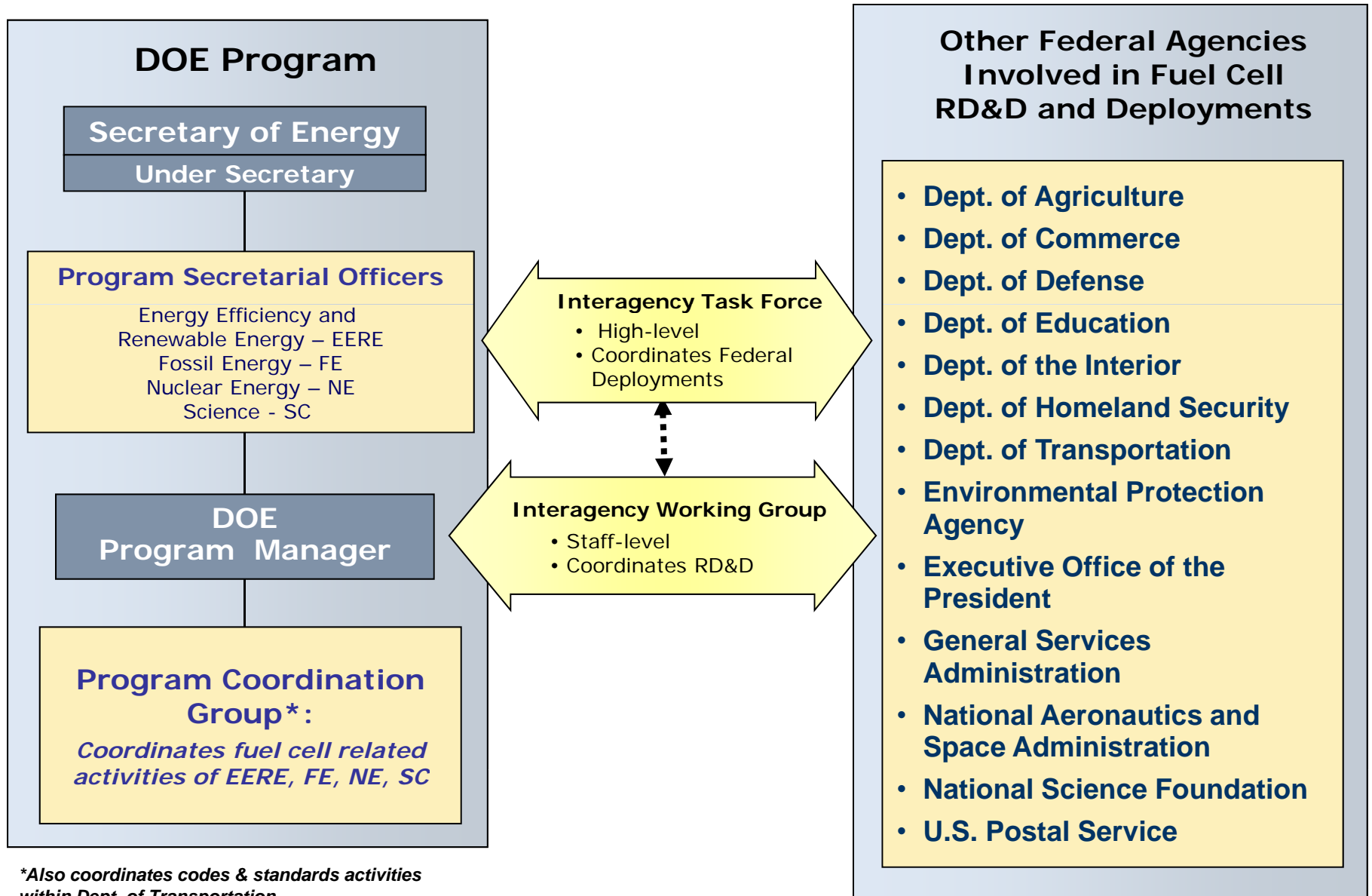
Dimitrios Papageorgopoulos (dimitrios.papageorgopoulos@ee.doe.gov)

Nancy Garland (nancy.garland@ee.doe.gov)

www.hydrogenandfuelcells.energy.gov

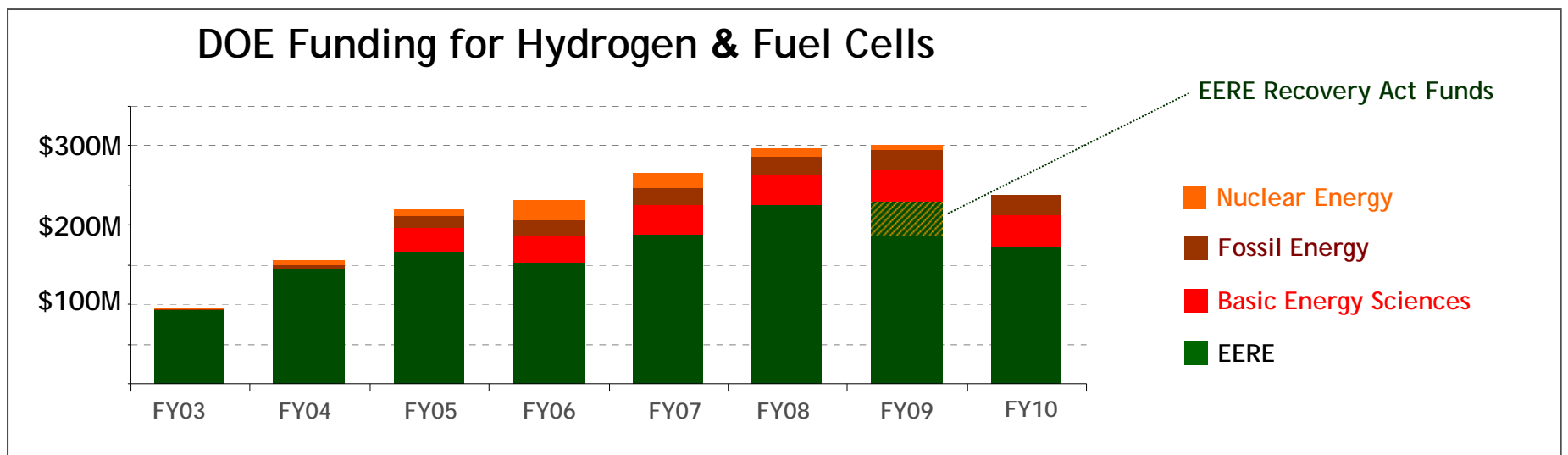
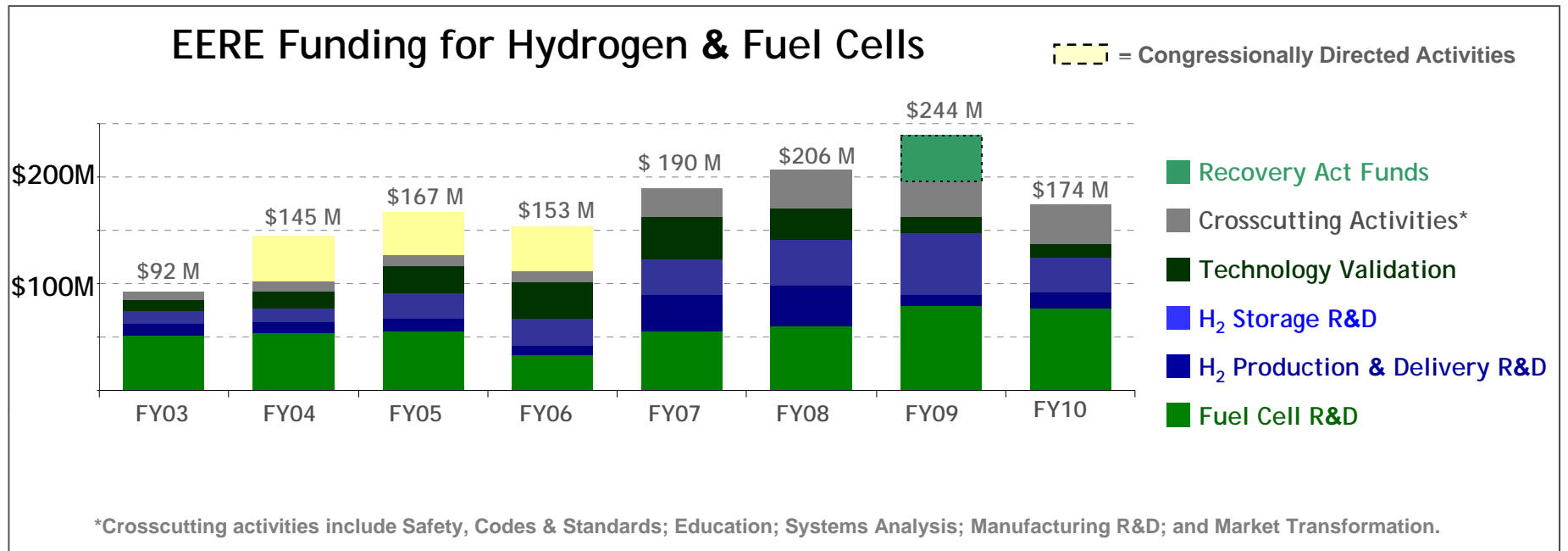
Additional Information

Federal Interagency Coordination



*Also coordinates codes & standards activities within Dept. of Transportation

Funding History for Fuel Cells



EERE Hydrogen and Fuel Cells Budget *(in thousands)*

<i>Key Activity</i>	FY 2007	FY 2008	FY 2009	FY 2010
Hydrogen Production & Delivery R&D	33,702	38,607	10,000	15,000
Hydrogen Storage R&D	33,728	42,371	59,200	32,000
Fuel Cell Stack Component R&D	37,100	42,344	62,700	62,700
Technology Validation	39,413	29,612	14,789*	13,097
Transportation Systems R&D	7,324	7,718	6,600	3,201
Distributed Energy Systems R&D	7,257	7,461	10,000	11,410
Fuel Processor R&D	3,952	2,896	3,000	171
Safety, Codes & Standards	13,492	15,442	12,500*	8,839
Education	1,978	3,865	4,200*	2,000
Systems Analysis	9,637	11,099	7,713	5,556
Manufacturing R&D	1,928	4,826	5,000	5,000
Market Transformation	0	0	4,747	15,026
Total	\$189,511**	\$206,241**	\$200,449	\$174,000

* Under Vehicle Technologies Budget in FY 2009

** FY07 and FY08 numbers exclude SBIR/STTR funding

Hydrogen & Fuel Cells Budgets: *FY07 – FY10*

	Funding (\$ in thousands)						
	FY 2004 Approp.	FY 2005 Approp.	FY 2006 Approp.	FY 2007 Approp.	FY 2008 Approp.	FY 2009 Approp.	FY 2010 Approp.
EERE Hydrogen	144,881	166,772	153,451	189,511	206,241	200,449	174,000
Fossil Energy (FE)	4,879	16,518	21,036	21,513	24,088	20,000 ¹	~25,000 ^{1,2}
Nuclear Energy (NE)	6,201	8,682	24,057	18,855	9,668	7,500	0
Science (SC)	0	29,183	32,500	36,388	36,484	38,284	~38,284 ³
DOE TOTAL	155,961	221,155	231,044	266,267	276,481	266,233	~237,284

¹ Does not include funding for program direction.

² Includes coal to hydrogen and other fuels. Fossil Energy also plans \$50M for SECA in FY10.

³ Exact funding for hydrogen- and fuel cell-related projects to be determined. The Office of Science also plans ~\$14M for hydrogen production research in the Office of Biological and Environmental Research in FY10.

New Recovery Act Projects

Deploying Fuel Cells for Specialty Vehicles



FedEx Freight East (Harrison, AR)

\$1.3 million

35 fuel cells in class-1 lift trucks

GENCO (Pittsburgh, PA)

\$6.1 million

156 fuel cells in six fleets of class-1 and class-3 lift trucks

Nuvera Fuel Cells (Billerica, MA)

\$1.1 million

Supplement a fuel cell forklift fleet with 10 fuel cell power packs and a hydrogen fueling system

Sysco of Houston (West Houston, TX)

\$1.2 million

90 fuel cells in class-3 pallet trucks

TOTAL: ~\$10 million

Advantages of Fuel Cells for Specialty Vehicles:

- Allow for rapid refueling — much faster than changing-out or recharging batteries (*refueling takes about one minute, while battery changes can take 20 – 45 minutes, and recharging can take anywhere from 2 to 16 hours*)
- Provide constant power without voltage drop
- Eliminate space requirements of batteries & chargers
- Can provide **substantial cost-savings** over battery-powered forklifts (more than 50% reduction in lifecycle costs for a 3-kW pallet truck)

Deploying Fuel Cells for Back-up Power



Plug Power
(Latham, NY)

\$2.7 million

- *Up to 275 kW at government sites*

ReliOn Inc.
(Spokane, WA)

\$8.6 million

- *25 sites in utility communications network*
- *180 installations for telecommunications network*

Sprint
(Reston, VA)

\$7.3 million

- *1- to 10-kW fuel cells for state/local first responders*

Jadoo Power
(Folsom, CA)

\$1.8 million

- *Evaluation of environmental and cost benefits of using 1-kW fuel cell, as opposed to gas/diesel generators and batteries*

TOTAL: **\$20.4 million**

Advantages of Fuel Cells for Backup Power:

- **Provide longer continuous run-time, greater durability than batteries** (*Battery systems usually run 4 – 8 hrs, and have to be replaced every 3 – 5 years, while fuel cell runtime is limited only by storage capacity, and they could last 15 years or more, depending on amount of actual use.*)
- **Require less maintenance than batteries or generators** (*estimated routine maintenance of two hours per year for fuel cells and eight hours per year for batteries and generators*)
- **Can be remotely monitored**
- **Can provide substantial cost-savings over battery-generator systems** (*nearly 25% reduction in lifecycle costs for a 5-kW, 52-hour backup-power system*)

New Recovery Act Projects

Demonstrating PEM Fuel Cells for Residential and Small Commercial CHP

ADVANTAGES of FUEL CELLS for CHP...

- **Up to 85% overall efficiency**
- **25 – 35% reduction in emissions from household energy use**
- **Zero emissions**
- **Low noise and vibration**
- **Low O&M requirements, less down-time**
 - *100x more reliable than the average power supply for data centers—three seconds of down time per year versus an average of five minutes*
- **Less variation in efficiency across variable loads**

Plug Power, Inc.
(Latham, NY)

**\$3.4
million**

**5-kW
stationary
CHP systems**



*Plug Power's
GenSys Blue, for
residential and small
commercial
applications*

New Recovery Act Projects

Deploying Fuel Cells for Portable Power

**MTI MicroFuel
Cells**
(Albany, NY)

\$2.4 million

- *1-W consumer electronics power pack*

PolyFuel, Inc.
(Mountain View, CA)

\$2.5 million

- *Portable power system for mobile computing*

TOTAL: **\$4.9 million**

Deploying Fuel Cells for Auxiliary Power

Delphi Automotive
(Troy, MI)

\$2.4 million

- *3- to 5-kW SOFC APUs for heavy-duty class-8 trucks*