

Fuel Cell Technologies Program

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



DOE Hydrogen & Fuel Cell Overview

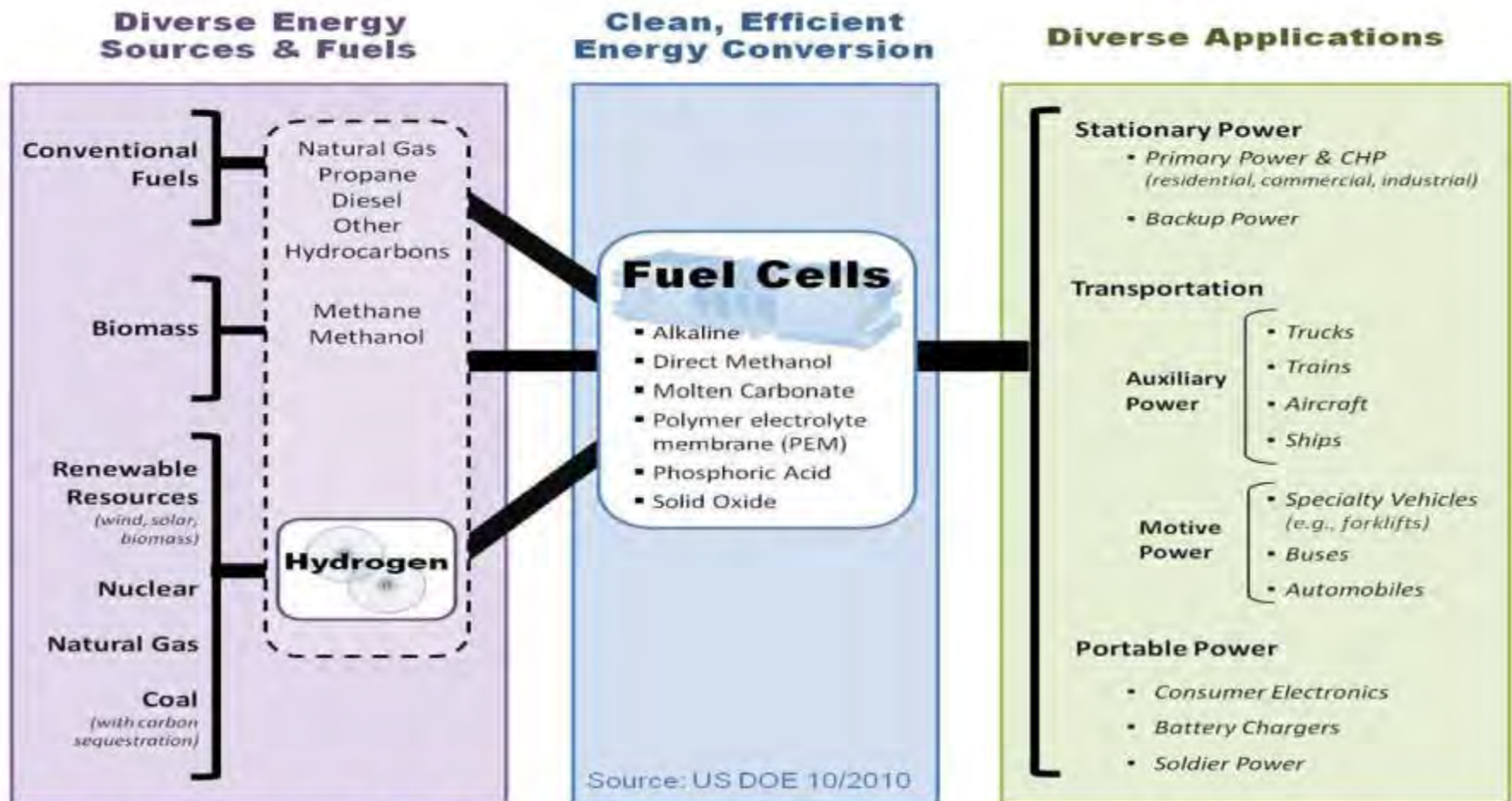
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Fuel Cells for Diverse Applications



Energy Storage for Renewable Electricity



Fuel Cells - *Where are we today?*

Fuel Cells for Stationary Power, Auxiliary Power, and Specialty Vehicles

The largest markets for fuel cells today are in stationary power, portable power, auxiliary power units, and forklifts.

~75,000 fuel cells have been shipped worldwide.

~24,000 fuel cells shipped in 2009 (> 40% increase over 2008).

Fuel cells can be a cost-competitive option for critical-load facilities, backup power, and forklifts.



Production & Delivery of Hydrogen

In the U.S., there are currently:

~9 million metric tons of H₂ produced annually

> 1200 miles of H₂ pipelines

Source: US DOE 09/2010



Fuel Cells for Transportation

In the U.S., there are currently:

> 200 fuel cell vehicles

~ 20 active fuel cell buses

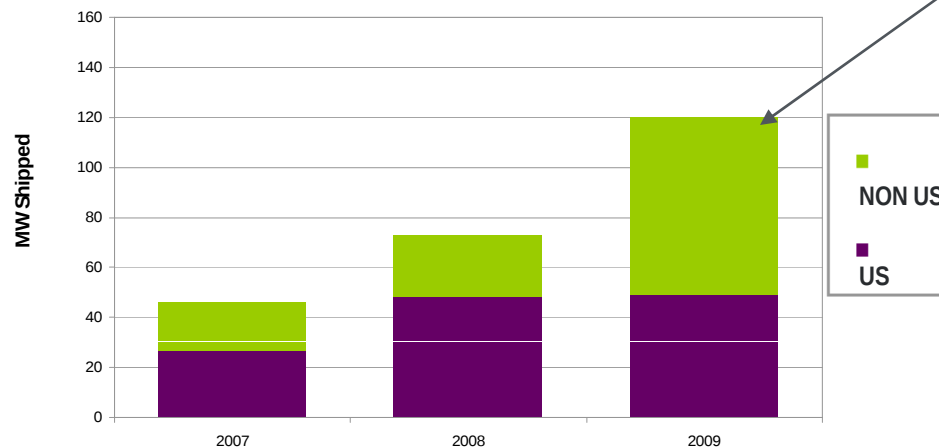
~ 60 fueling stations

Sept. 2009: Auto manufacturers from around the world signed a letter of understanding supporting fuel cell vehicles in anticipation of widespread commercialization, beginning in 2015.



Global competition is increasing

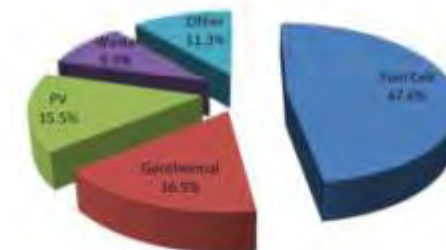
Global MWs Shipped, by US Companies and Non-US Companies



Significant increase in MW shipped by non-US companies in just 1 year
>40% market growth in just one year

Example: Seoul's Renewable energy generation plan includes ~**48% fuel cells**

Anticipated Renewable Energy Generation in Seoul, Korea by 2030



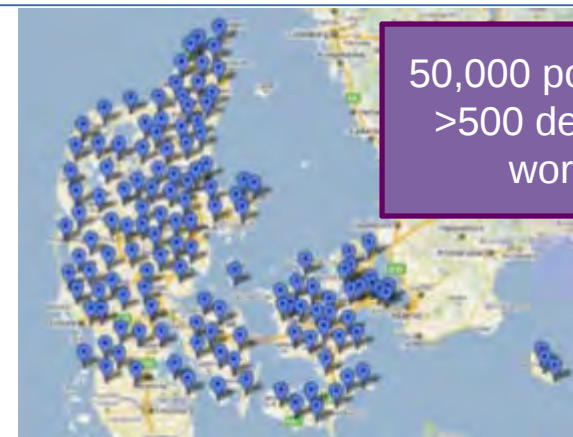
Source: Municipal Government of Seoul

Preliminary market analysis

International Landscape favors H₂ & Fuel Cells

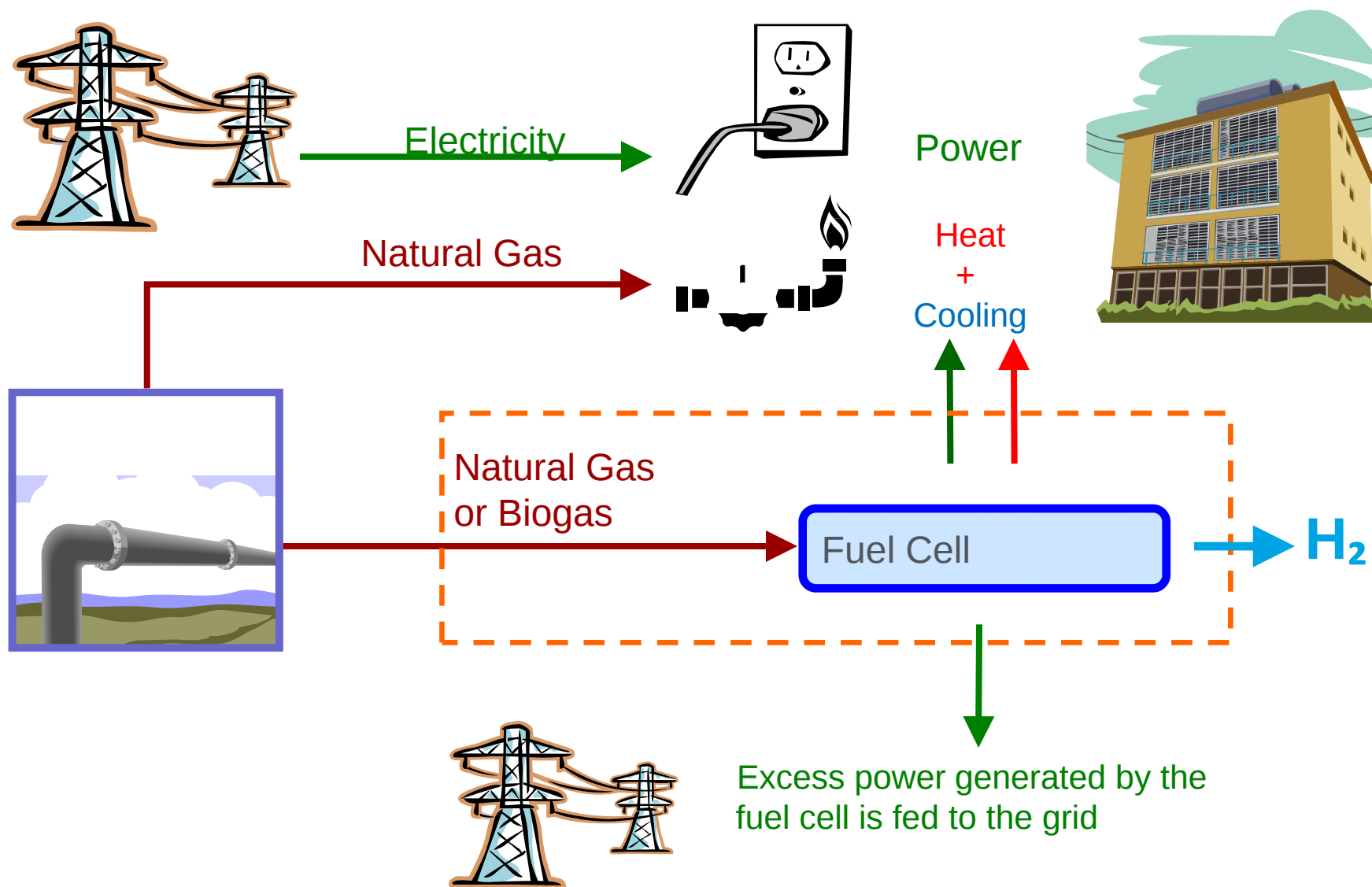
- Germany (>\$1.2B; 1,000 H₂ stations)
- European Commission (>\$1.2B, 2008-2013)
- Japan (2M vehicles, 1,000 H₂ stations by 2025)
- South Korea (plans to produce 20% of world shipments & create 560,000 jobs in Korea)
- China (thousands of small units; 70 FCVs, buses, 100 shuttles at World Expo, Olympics)
- Subsidies for jobs, manufacturing, deployments (e.g. South Africa)

Example: Denmark Backup Power Deployments



50,000 potential sites
>500 deployments worldwide

Overview of Combined Heat+Power

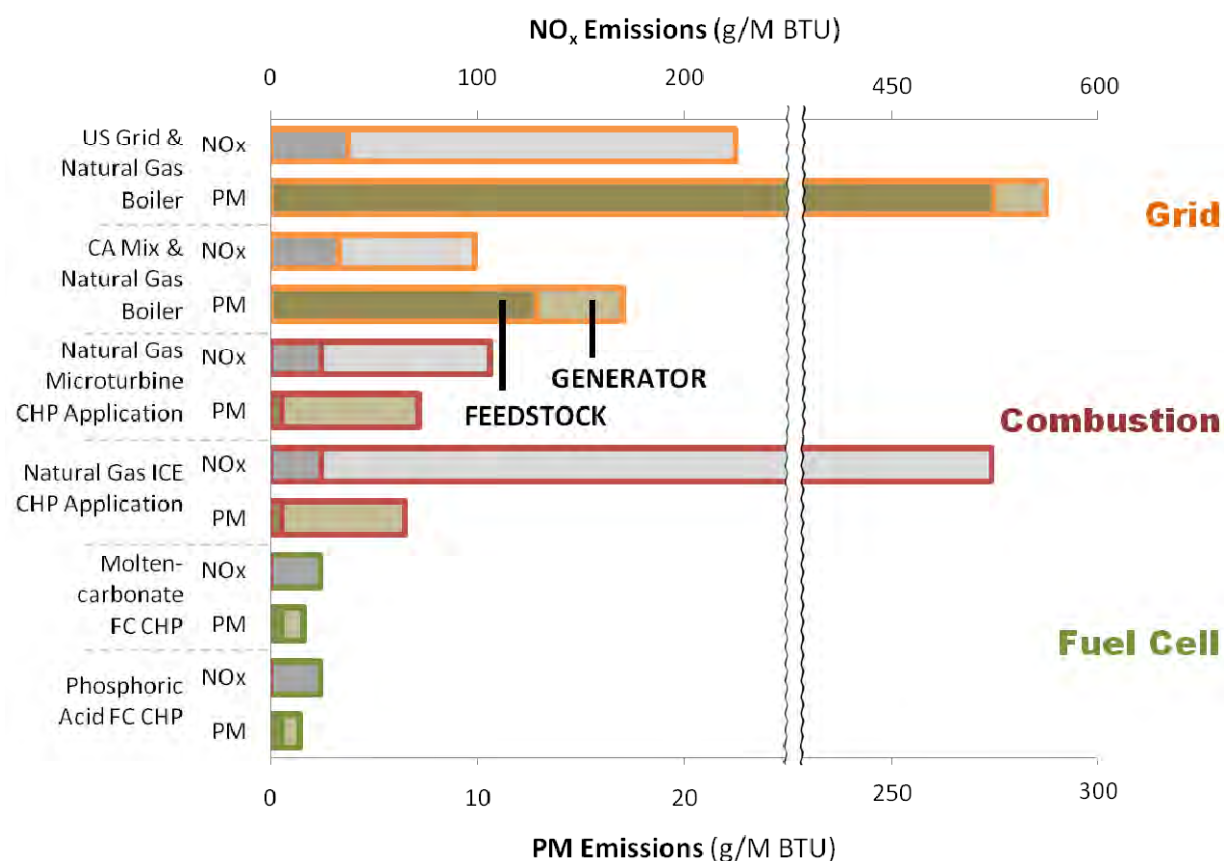


Biogas Benefits: Preliminary Analysis

Stationary fuel cells offer significant reductions in criteria pollutant emissions.

Criteria Pollutant Emissions (g/M BTU)

NO_x and PM Emissions from CHP and Competing Technologies

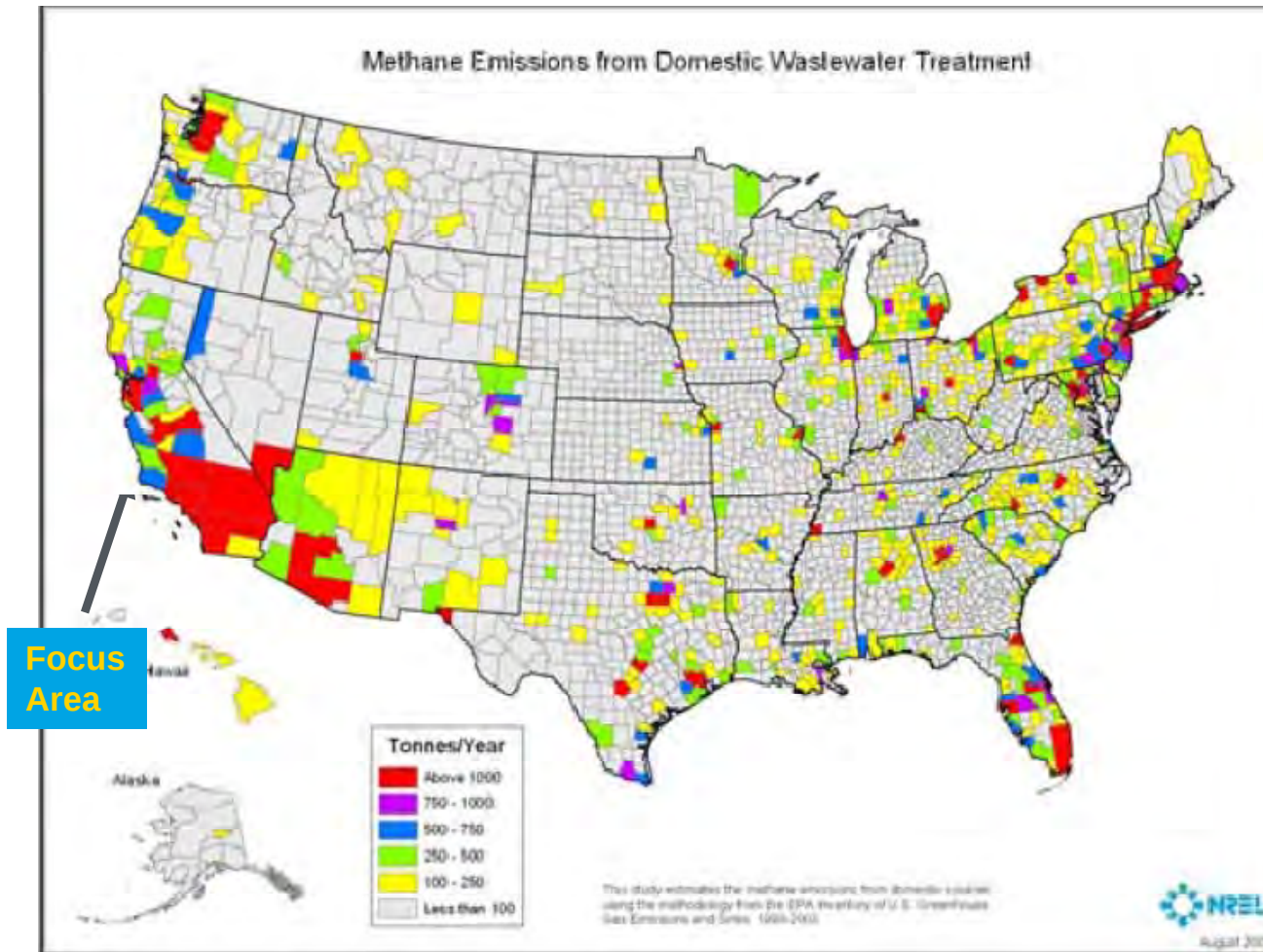


Criteria Pollutant Emissions from Generating Heat and Power. *Fuel cells emit about 75 – 90% less NO_x and about 75 – 80% less particulate matter (PM) than other CHP technologies, on a life-cycle basis. In addition, similar to other CHP technologies, fuel cells can provide more than 50% reduction in CO₂ emissions, when compared with the national grid.*

Source: US DOE 1/2011

Biogas Resource Example: Methane from Waste Water Treatment

Biogas from waste water treatment plants is ideally located near urban centers to supply hydrogen for fuel cell vehicles.

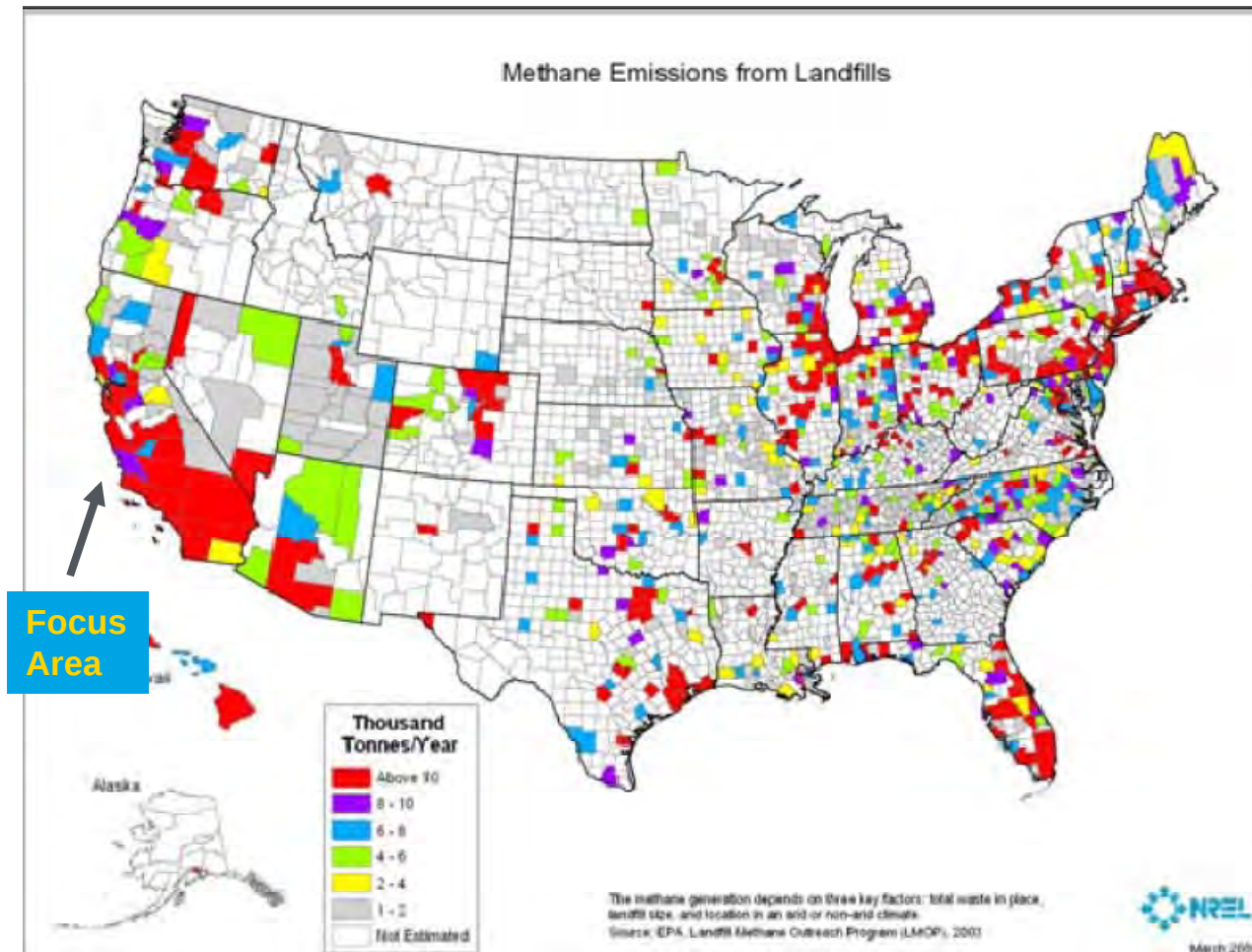


Source: NREL report *A Geographic Perspective on Current Biomass Resource Availability in the United States*, 2005

- 500,000 MT per year of methane available from waste water treatment plants in U.S.
- Majority of resource located near urban centers.
- If ~50% of the bio-methane was available, ~340,000 kg/day of renewable hydrogen could be produced from steam methane reforming
- Renewable hydrogen is enough to fuel ~340,000 fuel cell vehicles per day.

Biogas Resource Example: Methane from Landfills

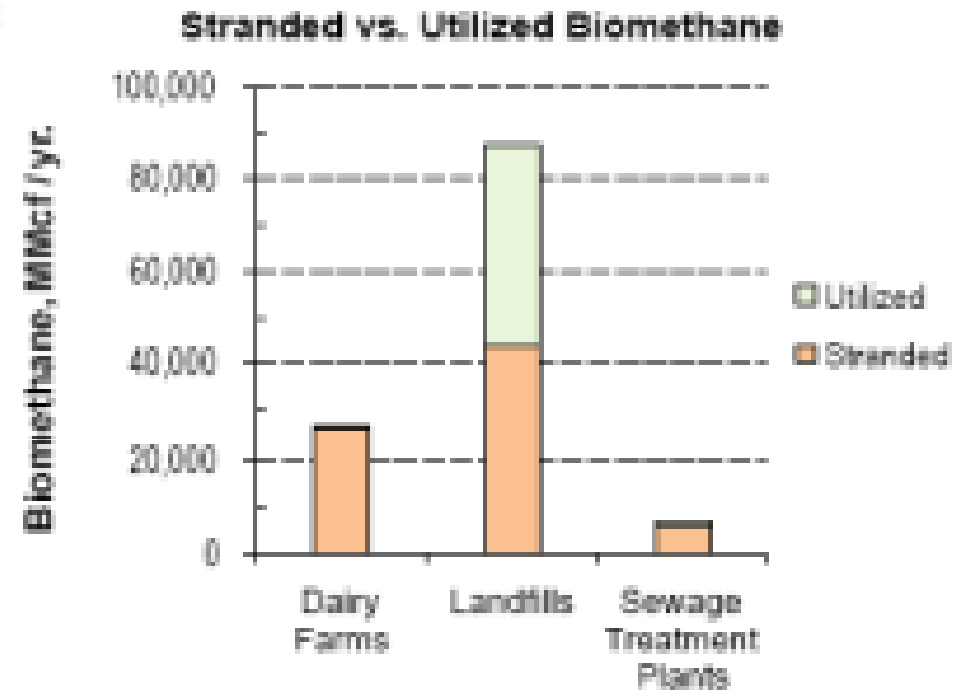
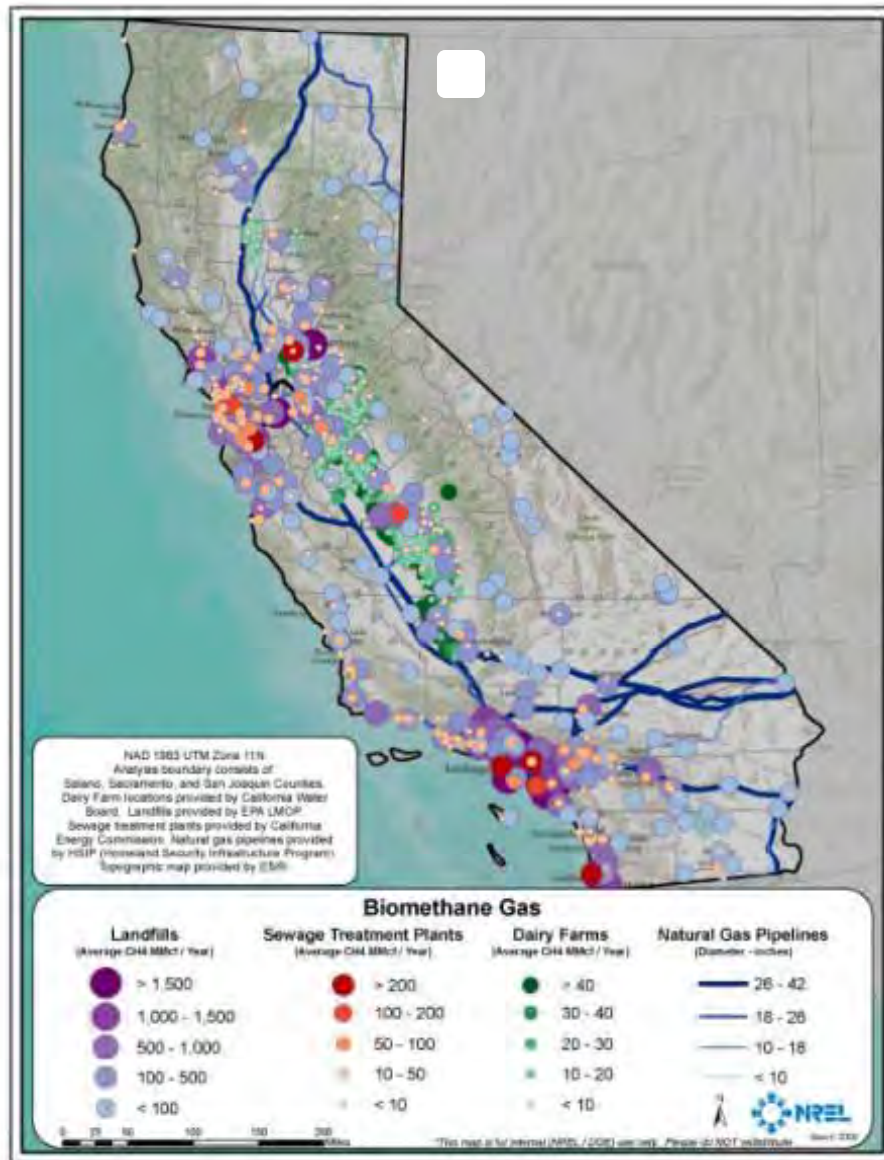
Biogas from landfills is located near large urban centers and could provide enough renewable resource to fuel ~8 million fuel cell vehicles per day.



- 12.4 million MT per year of methane available from landfills in U.S.
- Majority of resource located near urban centers.
- If 50% of the bio-methane was available, ~8 million kg/day of renewable hydrogen could be produced from steam methane reforming.
- Renewable hydrogen is enough to fuel ~8 million fuel cell vehicles per day.

Source: NREL report *A Geographic Perspective on Current Biomass Resource Availability in the United States*, 2005

California Example: Potential Sources of Biogas



Example:

Landfills offer ~1.6 M tons/yr of bio-methane.

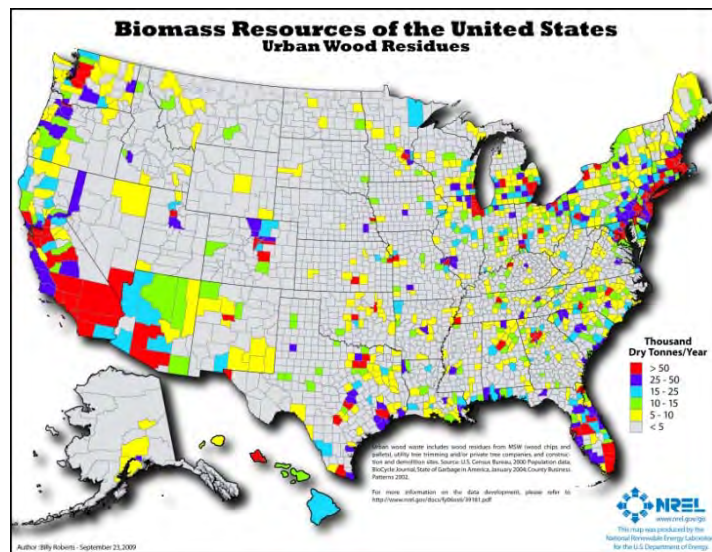
- Only ~50% of the landfill biomethane is used

Waste To Energy Example

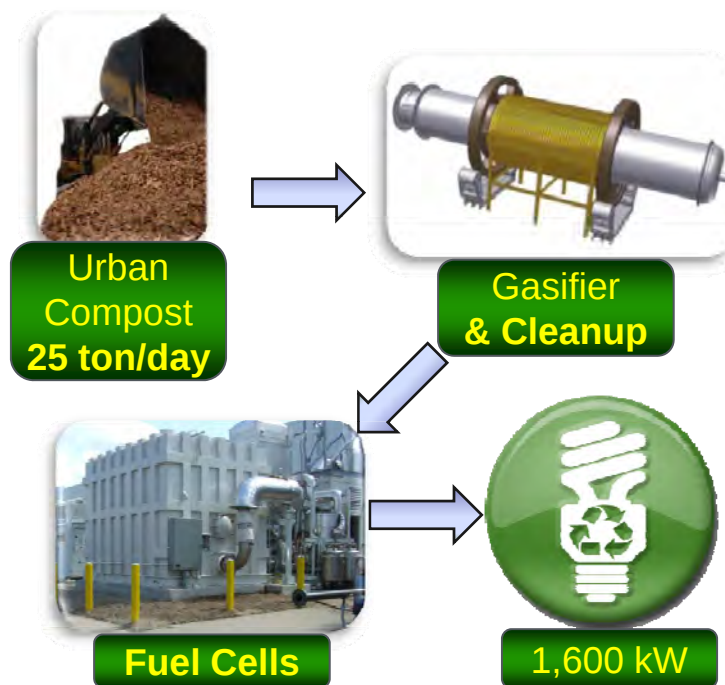
Los Alamitos Joint Forces Training Base (JFTB)



Los Alamitos JFTB



National Renewable Energy Laboratory
Innovation for Our Energy Future



Resource potential for Los Alamitos

- 300 tons/day
- 19,200 kW

Urban wood waste is an abundant feedstock around the US

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

RECENT PROGRESS

Vehicles & Infrastructure

- 152 fuel cell vehicles and 24 hydrogen fueling stations
- Over 2.8 million miles traveled
- Over 114 thousand total vehicle hours driven
- 2,500 hours (nearly 75K miles) durability
- Fuel cell efficiency 53-59%
- Vehicle Range: ~196 – 254 miles (independently also validated 430 mile range)

Buses

- DOE is evaluating real-world bus fleet data (DOT collaboration)
- H₂ fuel cell buses have a 41% to 132% better fuel economy compared to diesel & CNG buses

Forklifts

- Over 18,000 refuelings at Defense Logistics Agency site

Recovery Act

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



Landfills generate landfill gas (LFG) from active microorganisms interacting with the waste. Through available efficient reformation processes, this gas can easily be converted into hydrogen and used to provide energy or fuel, effectively turning trash into power.



BMW Manufacturing site.
Courtesy of Waste Management World

Source: US DOE 12/2010

Project Goals

- To show that LFG, cleaned up **and reformed**, can be used to power material handling equipment (MHE)

Next Steps

- Gas analysis & MHE performance data.
- Comparing LFG-produced hydrogen and delivered hydrogen.
- “Real world” evaluation and testing of equipment.

Landfill Gas to Hydrogen Benefits

- ✓ Reduced emissions
- ✓ Additional power supply
- ✓ Additional vehicle fuel source

Market Transformation activities seek to overcome barriers to commercialization

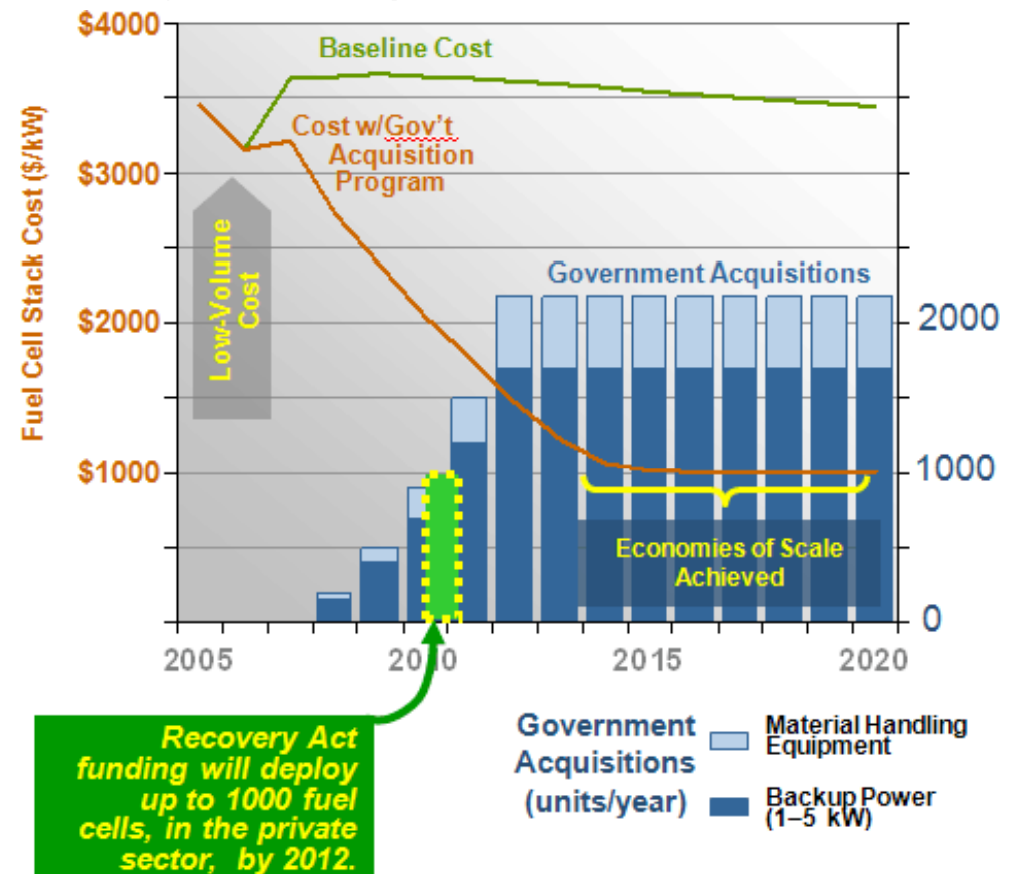
BARRIERS

Market/Industry	Lack of domestic supply base and high volume manufacturing. Estimated backlog > 100 MW
	Low-volume capital cost is >2-3x of targets
	Policies — e.g., many early adopters not eligible for \$3,000/kW tax credit
Delivery Infrastructure	Significant investment needed—~\$55B gov't funding required over 15 years for ~5.5M vehicles (\$~10B for stations)*
Codes and Standards	Complicated permitting process. 44,000 jurisdictions
	H ₂ -specific codes needed; only 60% of component standards specified in NFPA codes and standards are complete
	Need for domestic and international consistency
Education	In spite of >7,000 teachers trained and online tools averaging 300-500 visits/month, negative public perception and safety concerns remain.

*2008 National Academies Study, *Transitions to Alternative Transportation Technologies—A Focus on Hydrogen*

ADDRESSING BARRIERS Example:

A government acquisition program could have a significant impact on fuel cell stack costs



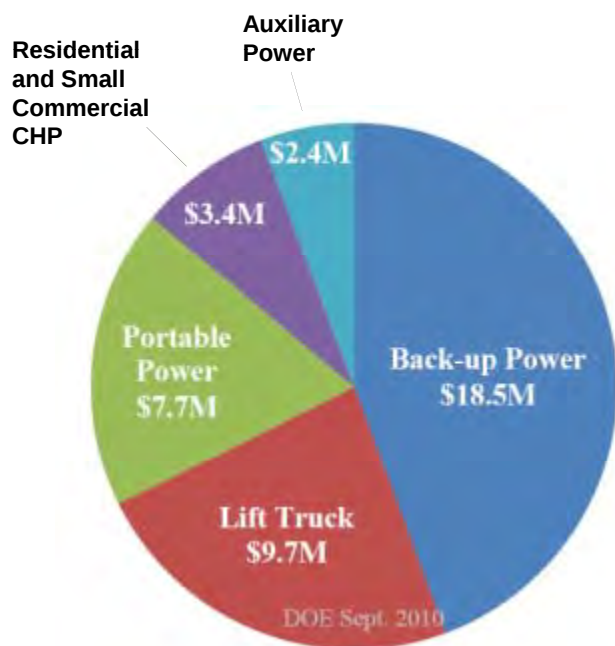
Source: David Greene, ORNL; K.G. Duleep, Energy and Environmental Analysis, Inc., *Bootstrapping a Sustainable North American PEM Fuel Cell Industry: Could a Federal Acquisition Program Make a Difference?*, 2008.

Recovery Act Funding for Fuel Cells

More than \$40 million from the 2009 American Recovery and Reinvestment Act to fund 12 projects to deploy up to 1,000 fuel cells

FROM the LABORATORY to DEPLOYMENT:

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



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

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
Univ. of N. 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

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Map of the United States showing the locations of Market Transformation and American Reinvestment and Recovery Act projects. The map displays various states and major cities. Blue pins represent Market Transformation projects, and red pins represent American Reinvestment and Recovery Act projects. The map shows a high concentration of projects in the Northeast, particularly in the New York City area, and in California. Other notable clusters are in the Midwest and South. A legend in the bottom right corner identifies the pin colors: blue for Market Transformation and red for American Reinvestment and Recovery Act.

15 | Fuel Cell Technologies Program Source: US DOE 10/2010

Department of Defense

Coordination

- Interagency Task Force
- Interagency Action Plan
- Interagency Working Group
- DOD/DOE MOU- LOU
 - Aviation APUs Workshop (completed)
 - Waste-to-Energy Workshop (1/13/11)
 - Shipboard APUs Workshop (TBD)
- Hawaii Hydrogen Initiative (H2I)
 - Commitment by industry, academia, and government to integrate hydrogen into Hawaii's sustainable energy plans

Deployments

- Over 30 DOD sites with fuel cells providing back up & primary power
- Deployment of H2ICE buses at Hickam, AFB Honolulu, HI
- Continue exploring new applications

DOD

- Defense Logistics Agency
 - 50 additional MHE units (on top of 40 current units) at Susquehanna, PA depot
- Office of Naval Research
 - Utility scale renewable hydrogen generation & H2ICE shuttle buses
- Army CERL
 - Backup power, waste-to-energy, and H2ICE shuttle buses

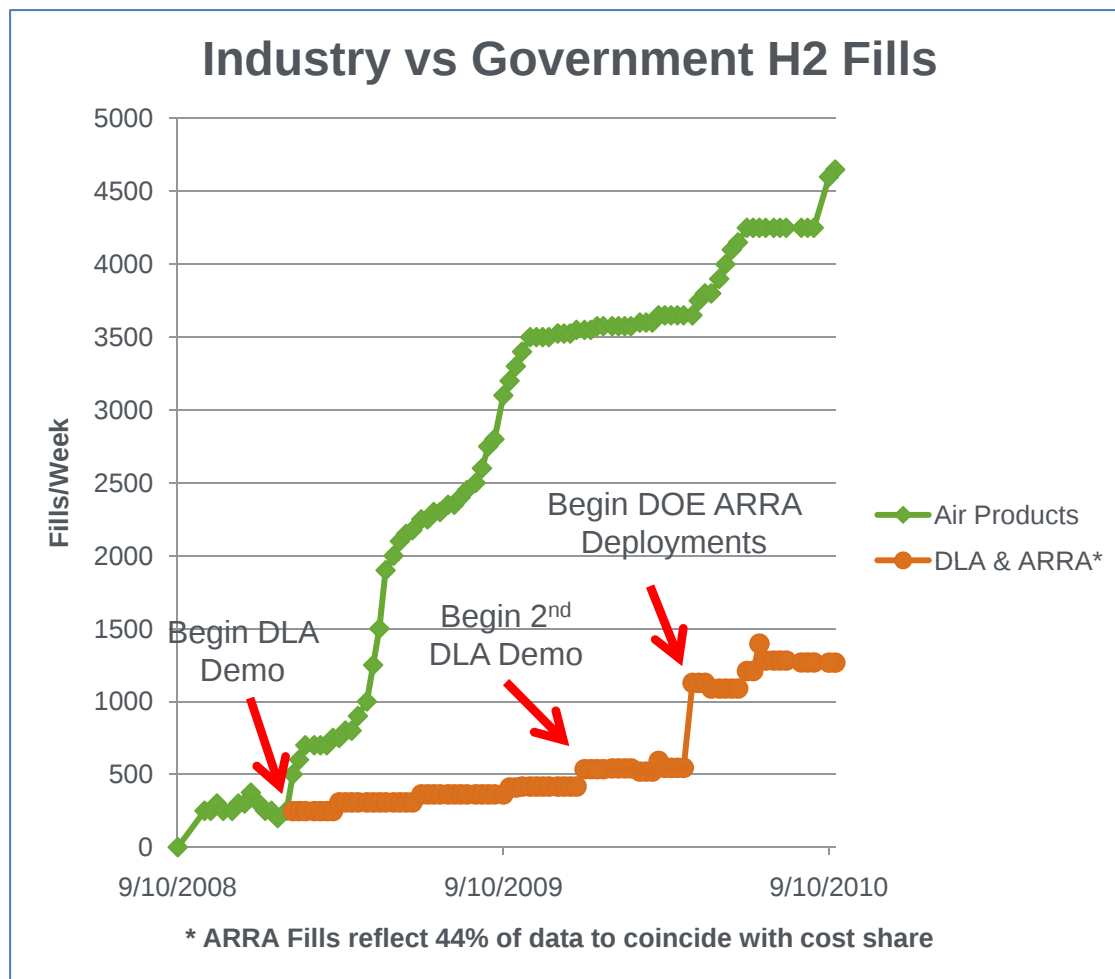
Other Agency Coordination

- Federal Aviation Administration
 - Ground support equipment & backup power
- National Park Service
 - Renewably generated backup power and H2ICE buses
- NASA
 - 5kW fuel cells for back up power
- USPS
- National Laboratories

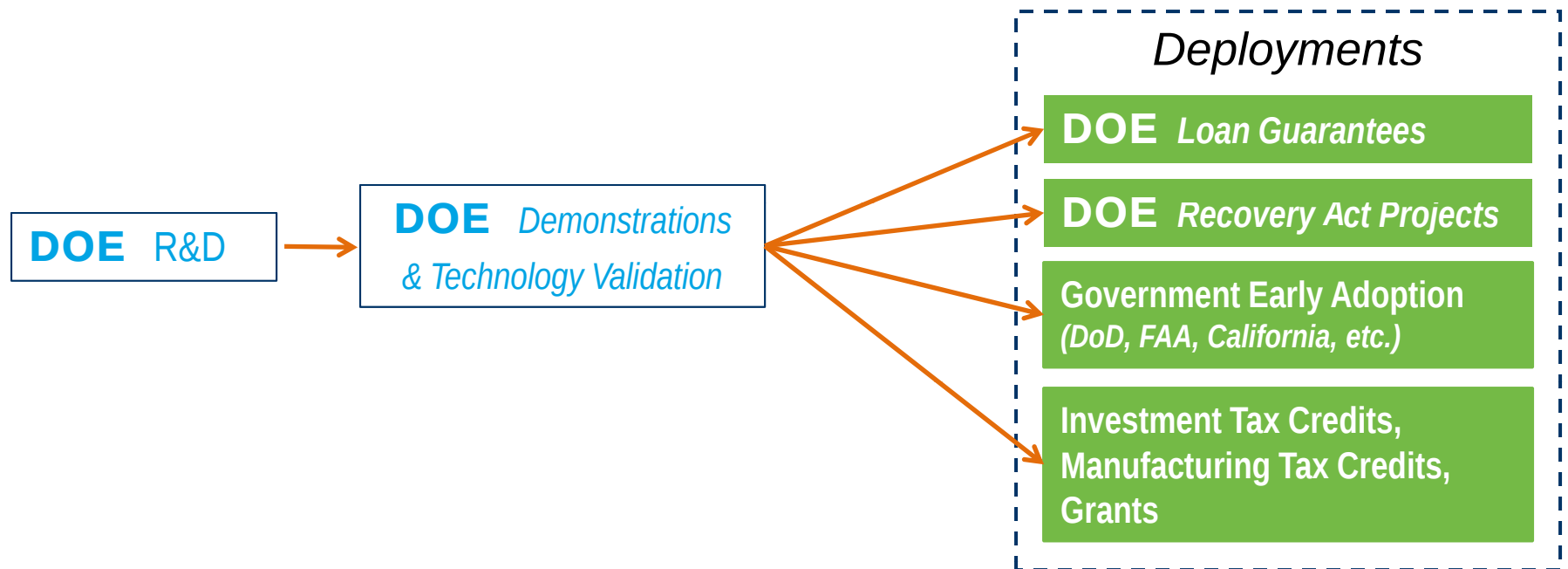
Source: US DOE 1/2011

Emerging Market Example

- Early Defense Logistics Agency (DLA) Procurement helped drive market development
 - From 250 fills/week to over 4500 fills/week
- Today's market is increasingly being driven by commercial demand
 - HEB, Whole Foods, Coca Cola, Sysco, Nestle, FedEx, BMW, etc
- DLA Demonstrations helped enable Codes and Standard approval of indoor Hydrogen dispensing



Example of RD&D to Deployments



Examples of Program

- Reduced high volume cost of transportation PEM Fuel Cells by 30% since 2008 and 80% since 2002
- Demonstrated double durability (>75,000 miles)

*What more can Government do to
accelerate commercialization?*



***On October 5, 2009
President Obama signed
Executive Order 13514 –
Federal Leadership in
Environmental, Energy, and
Economic Performance***

▪ Requires Agencies to:

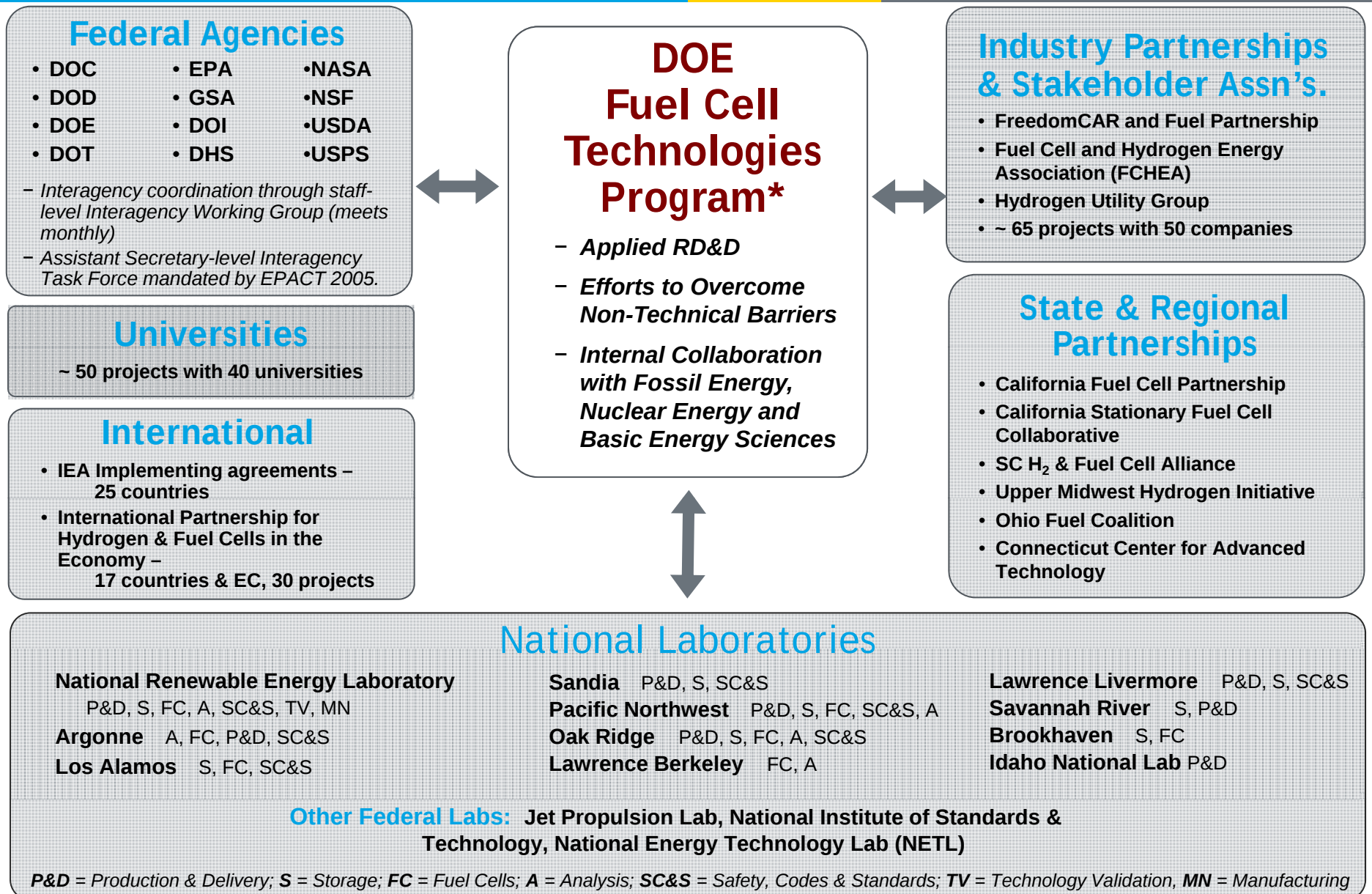
- Set GHG reduction Targets
- Develop Strategic Sustainability Plans and provide in concert with budget submissions
- Conduct bottom up Scope 1, 2 and 3 baselines
- Track performance

Examples:

- **Achieve** 30% reduction in vehicle fleet petroleum use by 2020
- **Requires** 15% of buildings meet the *Guiding Principles for High Performance and Sustainable Buildings* by 2015
- **Design** all new Federal buildings which begin the planning process by 2020 to achieve zero-net energy by 2030

**Potential opportunities for fuel cells
and other clean energy
technologies....**

Collaborations



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



Source: US DOE 2010

Thank you

For more information, please contact

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hydrogenandfuelcells.energy.gov