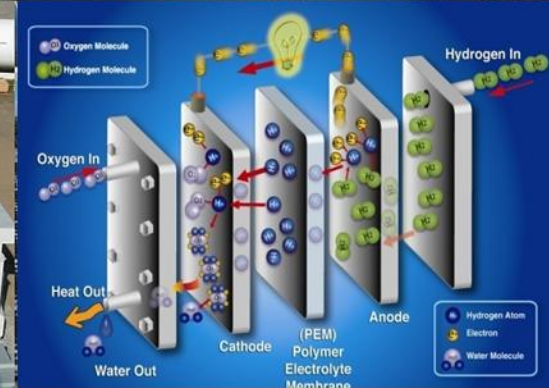


Fuel Cell Technologies Office Overview

U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy



IPHE H2igher Educational Round – Rome

December 1, 2014

Rome, Italy

Michael Mills

U.S. Department of Energy
Chief of Staff
Sustainable Transportation

All-of-the-Above Energy Strategy



*“We’ve got to invest in a serious, sustained, **all-of-the-above energy strategy** that develops every resource available for the 21st century.”*

- President Barack Obama

*“As part of an all-of-the-above energy approach, **fuel cell technologies** are paving the way to competitiveness in the global clean energy market and to new jobs and business creation across the country.”*

*- Secretary Moniz,
U.S. Department of Energy*



Secretary Moniz at DC Auto Show

Office of Energy Efficiency & Renewable Energy

Sustainable TRANSPORTATION

Renewable ELECTRICITY GENERATION

Energy Saving HOMES, BUILDINGS, & MANUFACTURING



Sustainable TRANSPORTATION

- Transportation Efficiency
- Diverse Fuel Sources
- Domestic & Renewable



Hydrogen and Fuel Cells



Vehicles



Bioenergy

National Energy Goals
&
Climate Action Plan

Net Oil Imports

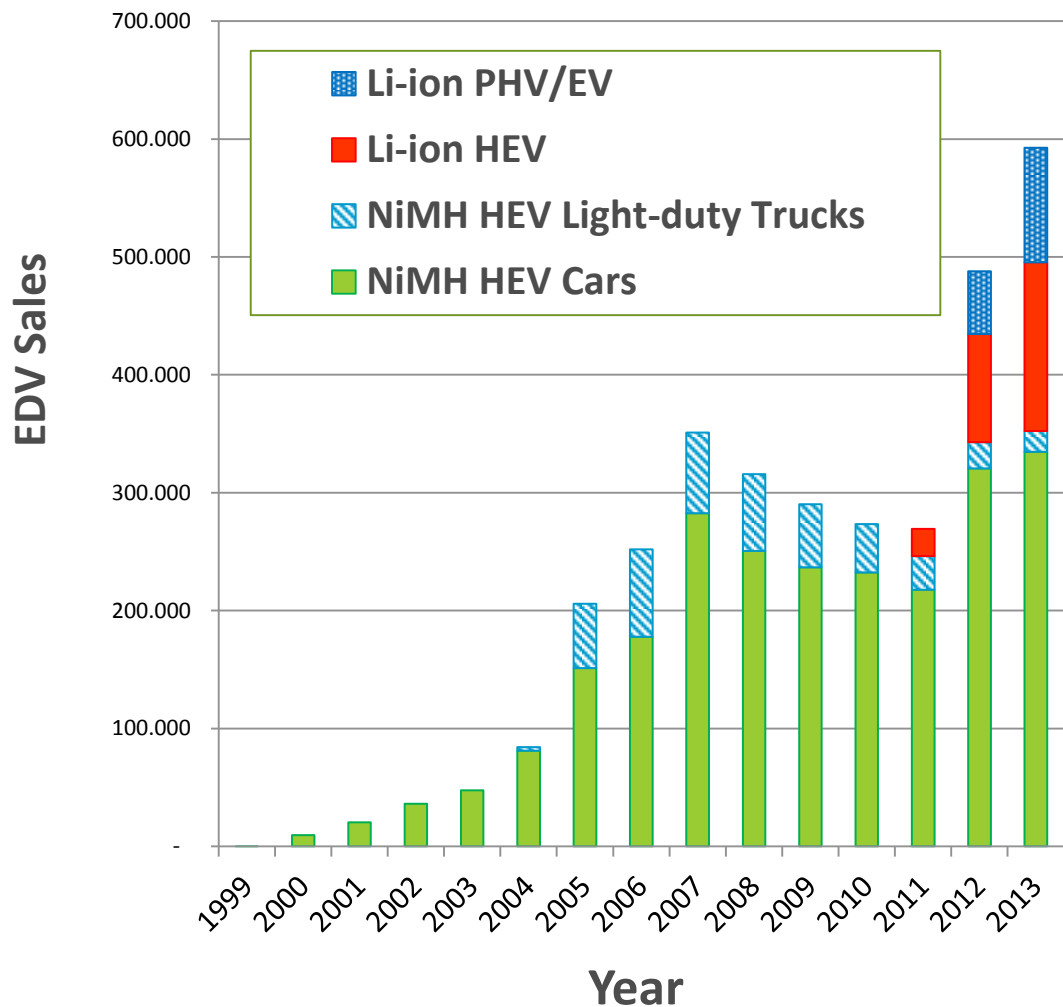
↓ **50%** by **2020**

GHG Emissions

↓ **17%** by **2020**
>80% by **2050**

Growth in Electric Drive Vehicle Sales

U.S. Electric Drive Vehicle Sales, by Technology (1999-2013)



2013 Sales Set Record

- **46** EDV models were available for sale
 - 575,000 Sales
- **~97,000** PEVs Sold. The top 6 models represent 95% of the sales :
 - Volt (23,094)
 - Leaf (22,610)
 - Model S (19,400)
 - Prius PHEV (12,088)
 - Cmax Energi (7,154)
 - Fusion Energi (6,089)
- **Over 3.1 million** EDVs on the road Jan.1, 2014

FCEVs Reduce Greenhouse Gas Emissions

>50%

from
Distributed
Natural Gas*

>80%

from
Renewables**
(Wind)

>90%

from
Renewables*
(Wind)

2012 Gasoline

Gasoline

Distributed NG

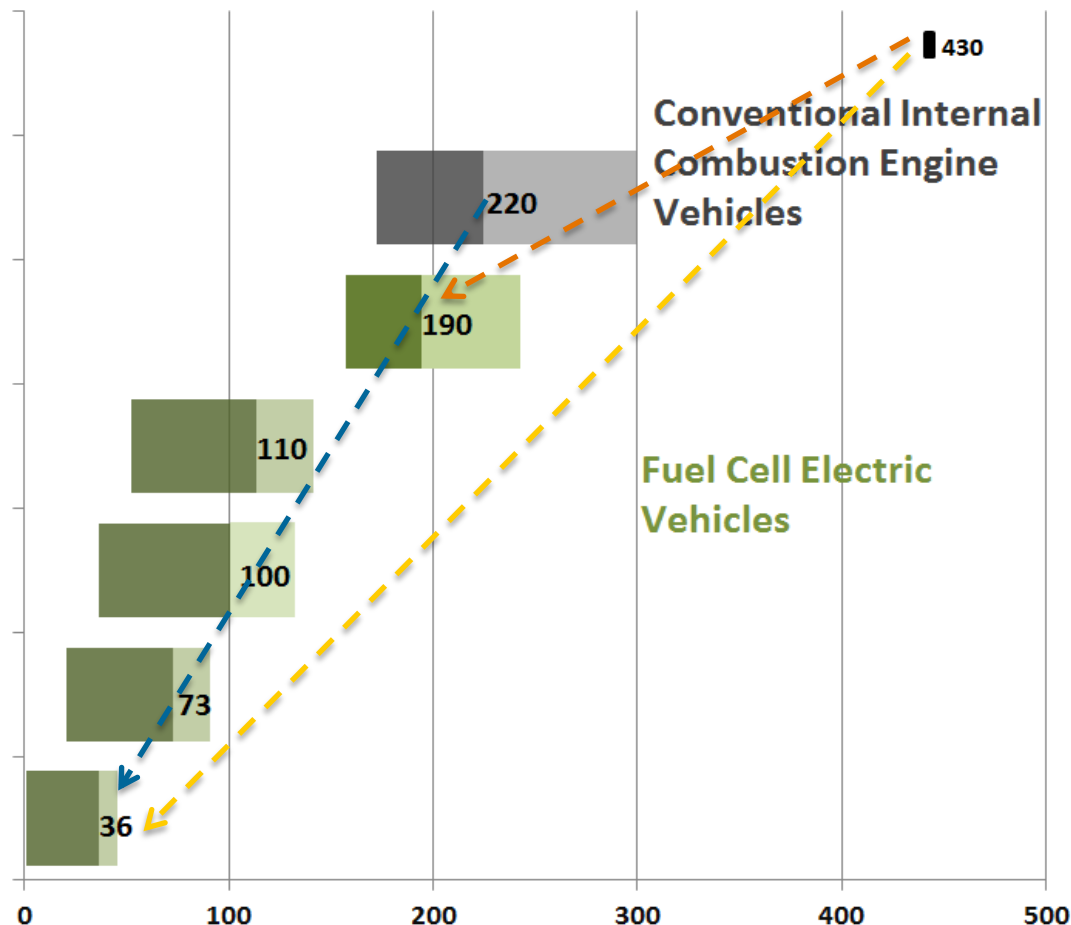
NG (Central) with
Sequestration

Coal Gasif. (Central)
w/ Sequestration

Biomass Gasif.
(Central)

Wind
Electricity

Well-to-wheels CO₂ emissions/mile

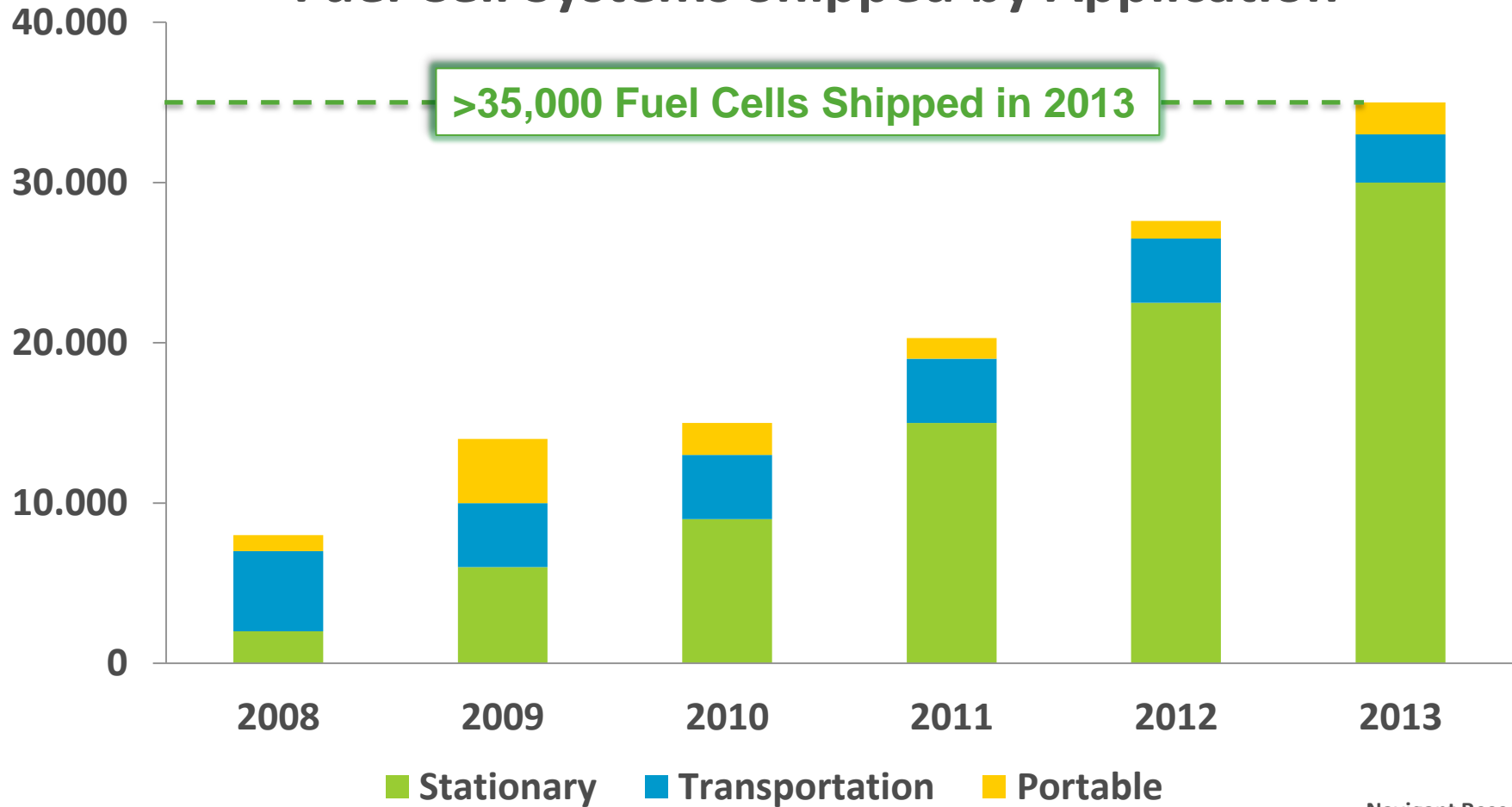


*Compared to 2012 gasoline vehicle

**Compared to 2035 gasoline vehicle

Substantial GHG reductions with H₂ produced from renewables

Fuel Cell Systems Shipped by Application



Navigant Research

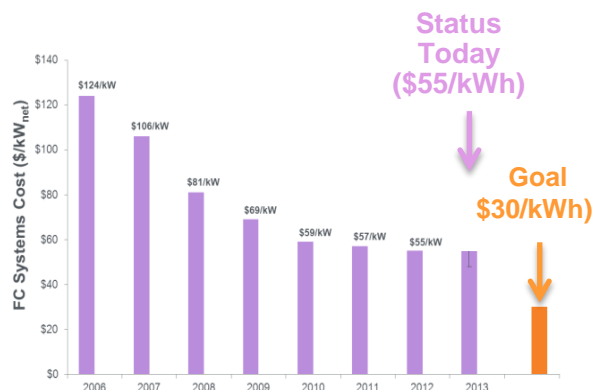
Consistent 30% annual growth since 2010

DOE Activities Span from R&D to Deployment

Research & Development

- **50% reduction since 2006**
- **80% electrolyzer cost reduction since 2002**

Fuel Cell System Cost*



*At 500,000-unit production

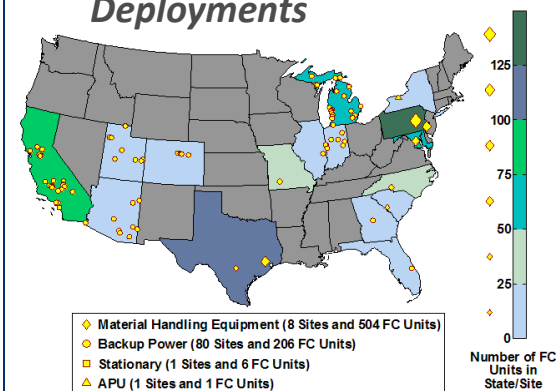
Demonstration

- **>180 FCEVs**
- **25 stations**
- **3.6 million miles traveled**
- **World's first tri-gen station**
(250 kW on biogas,
100 kg/d H₂ produced)



Deployment

- **Government Early Adoption**
(DoD, FAA, California, etc.)
- **Tax Credits: 1603, 48C**
- **~1,600 fuel cells deployed**
- **DOE Recovery Act & Market Transformation Deployments**



DOE's RDD&D activities are enabling commercialization of fuel cells

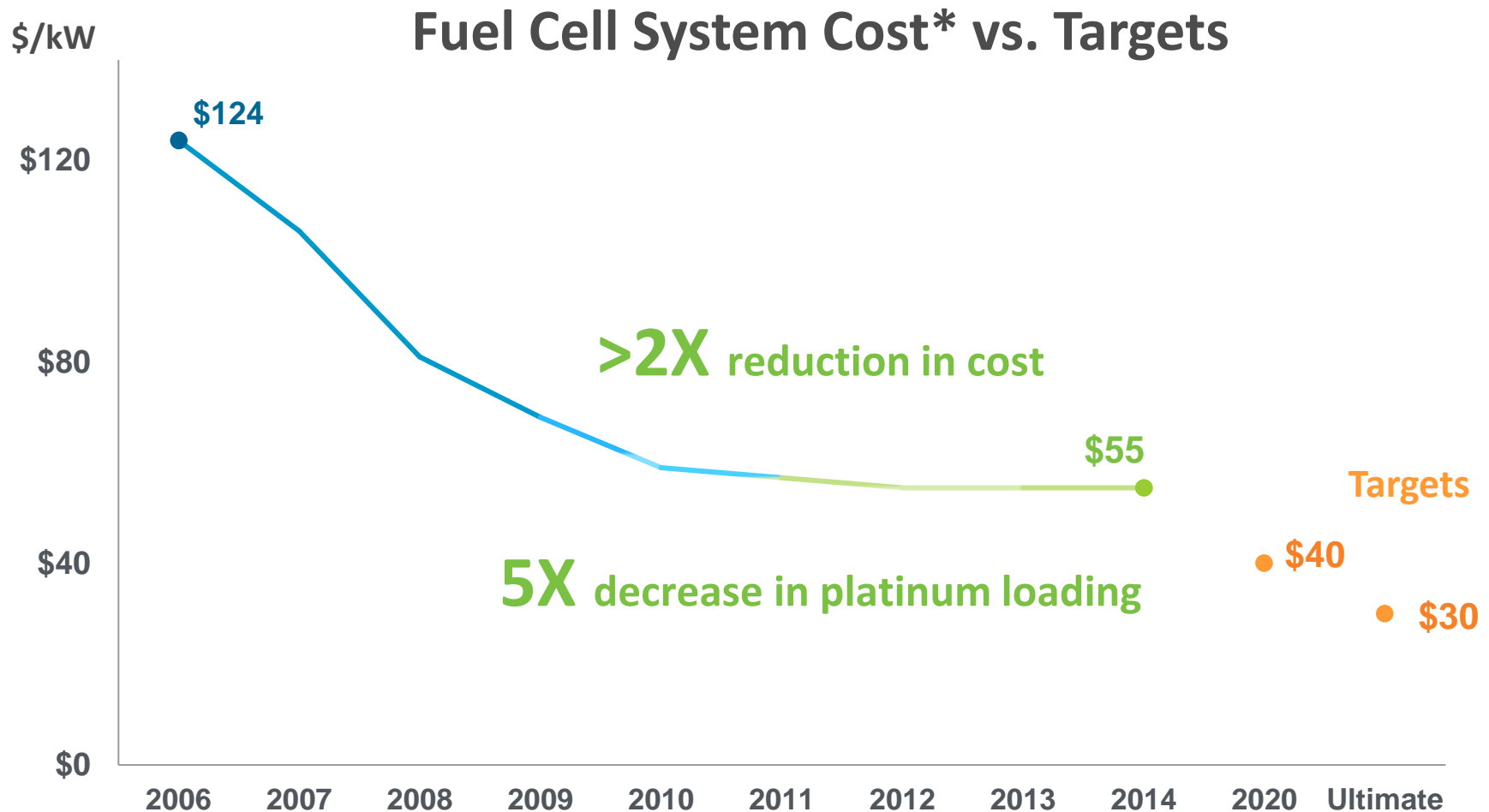
Hydrogen & Fuel Cell Budget

Key Activity	FY 2014 (\$ in thousands)	FY 2015 (\$ in thousands)
	Approp.	Request
Fuel Cell R&D	32,422	33,000
Hydrogen Fuel R&D	34,467	36,283
Manufacturing R&D	2,879	3,000
Systems Analysis	3,000	3,000
Technology Validation	6,000	6,000
Safety, Codes and Standards	6,909	7,000
Market Transformation	2,841	3,000
NREL Site-wide Facilities Support	1,000	1,700
SBIR/STTR	3,410	TBD
Total	\$92,928	\$92,983

Office	FY 2014
EERE	\$93M
Basic Science ²	\$20M to \$25M
Fossil Energy, SECA	\$25M
ARPA-E ³	\$33M

FY14 DOE Total: ~\$175M

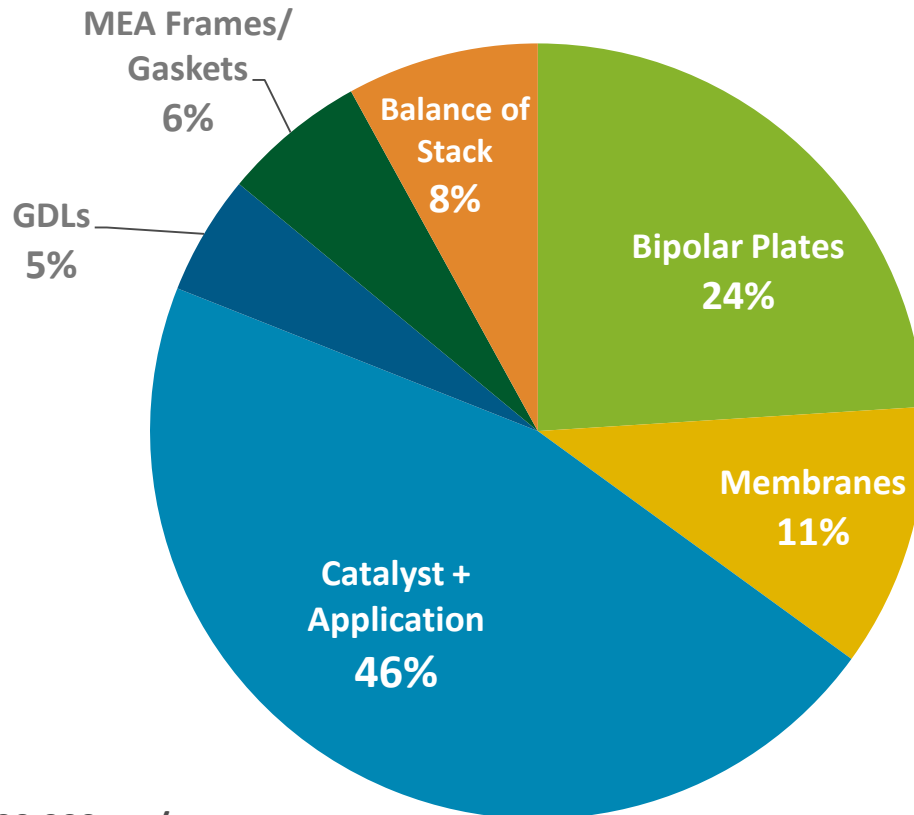
Consistent R&D funding request and appropriations in recent years



*At 500,000 sys/yr; ** \$280/kW † current technology at 20,000 sys/yr; †ORNL, top-down analysis based on OEM input

50% fuel cell cost reduction through DOE R&D since 2006

PEMFC Stack Cost Breakdown*



*500,000 sys/yr

- 2020 target for PEMFC cost is **\$40/kW**
- **Catalyst** is the largest cost

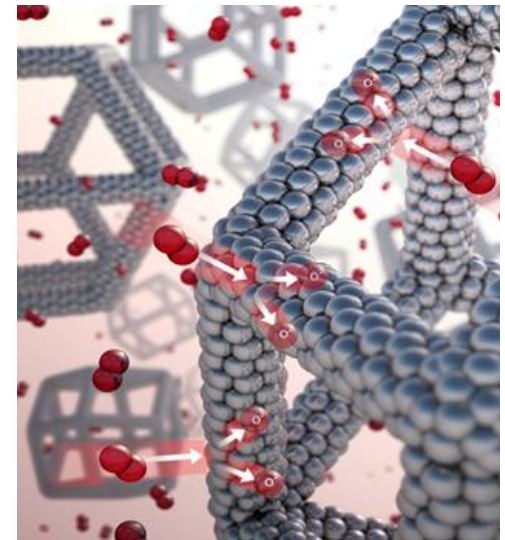
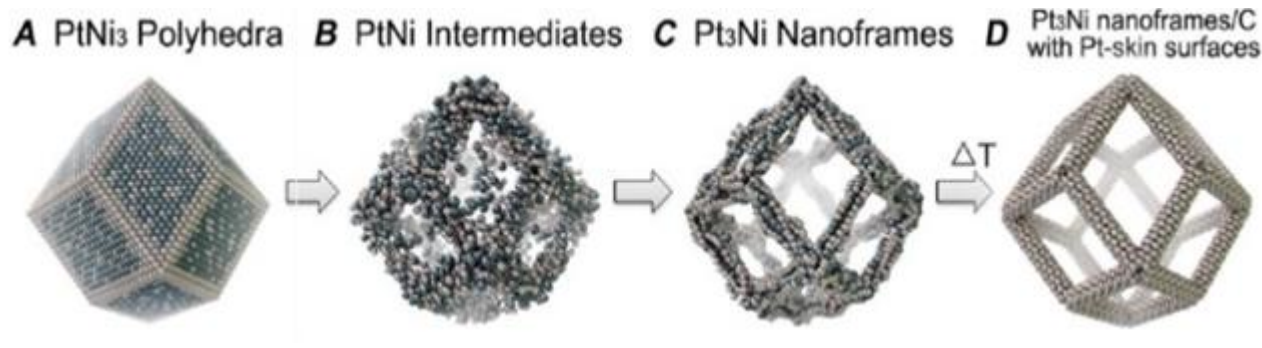
Catalyst remains key challenge and opportunity to lower cost

5X decrease in platinum loading

2X reduction system cost since 2006

30X increase in catalyst activity recently demonstrated in the lab

Collaboration between UC Berkeley and ANL



Potentially disruptive technologies are still possible!

Hydrogen Production Strategies

Current Technology

- Natural Gas (D/C)
- Electrolysis (D)

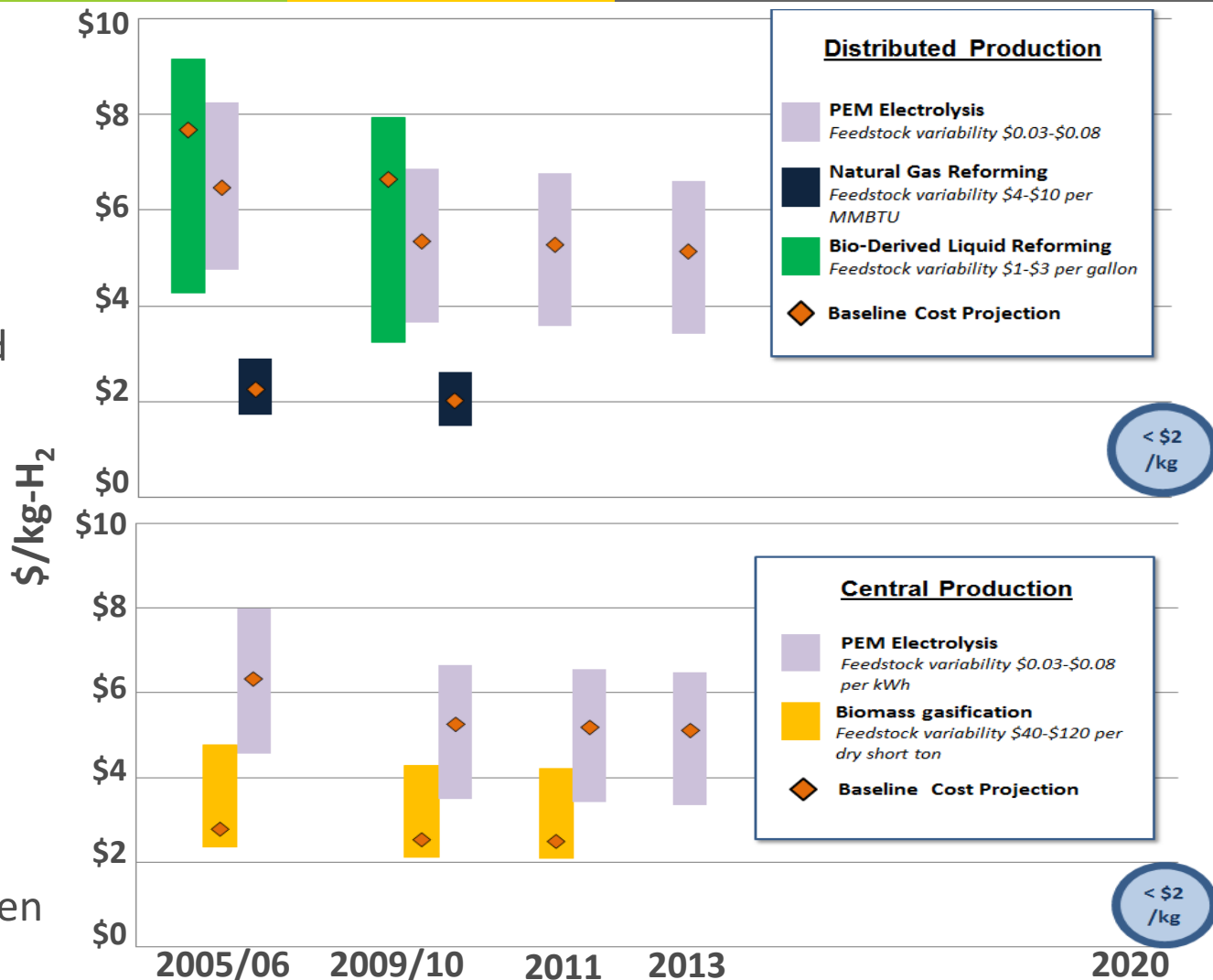
Near to Mid-Term:

- Electrolysis- Wind and Solar Powered (D/C)
- Bio-derived Liquids (D/C)
- Fermentation (D/C)

Long-Term (not shown):

Central Renewable H_2

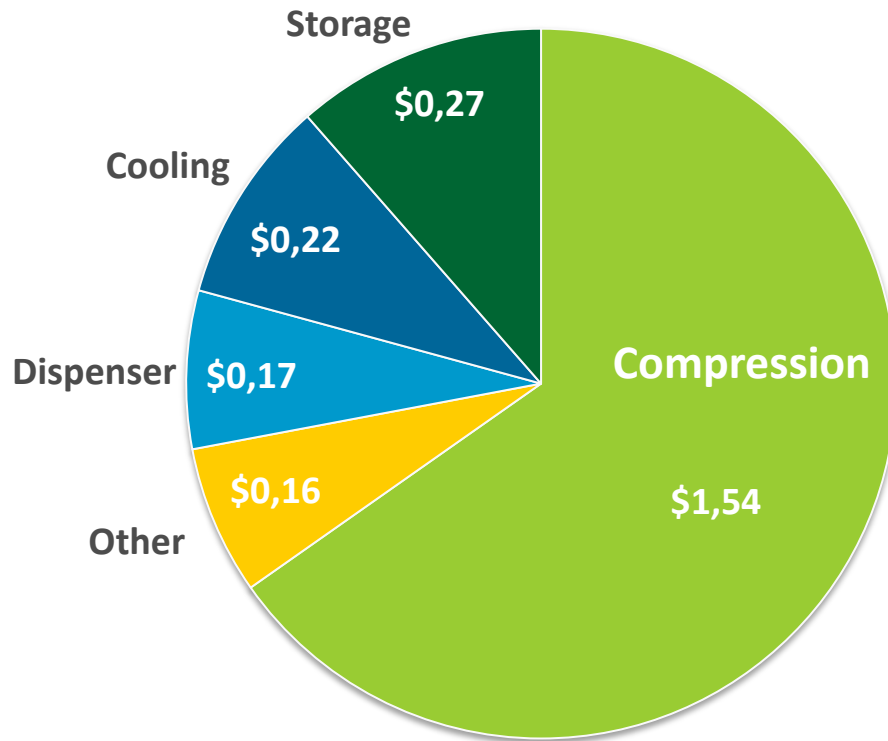
- Solar-based water splitting
- Photolytic Bio-hydrogen



D- Distributed C- Central

H_2 from NG can be competitive today - renewables is a longer-term focus

H₂ Compression, Storage and Dispensing (CSD) Cost Breakdown

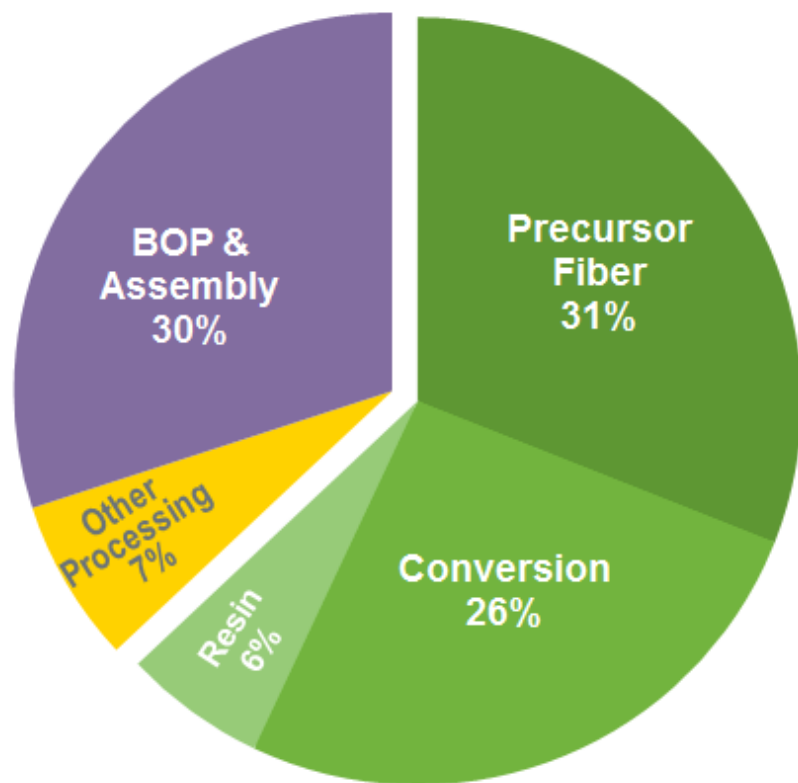


- 2020 goal for H₂ cost at the pump is **<\$4/gge**
- **Compression** and **storage** are **75%** of the cost of H₂ station dispensing costs.

*Based on the pipeline scenario

Compression is a key challenge for the cost of delivering and dispensing H₂

Cost breakdown for 700-bar H₂ Storage Tank*

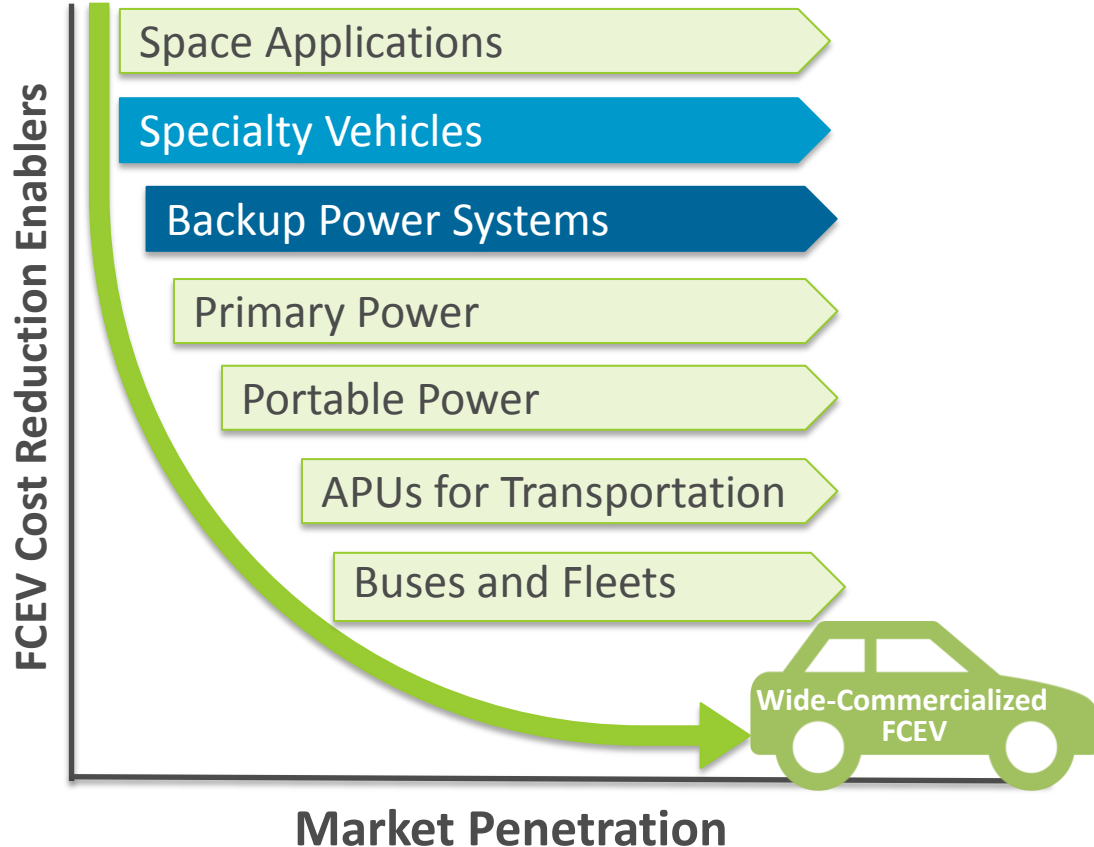


- 2020 goal for H₂ storage is **\$10/kWh**
- **Carbon fiber** precursor is the **largest** single cost contributor

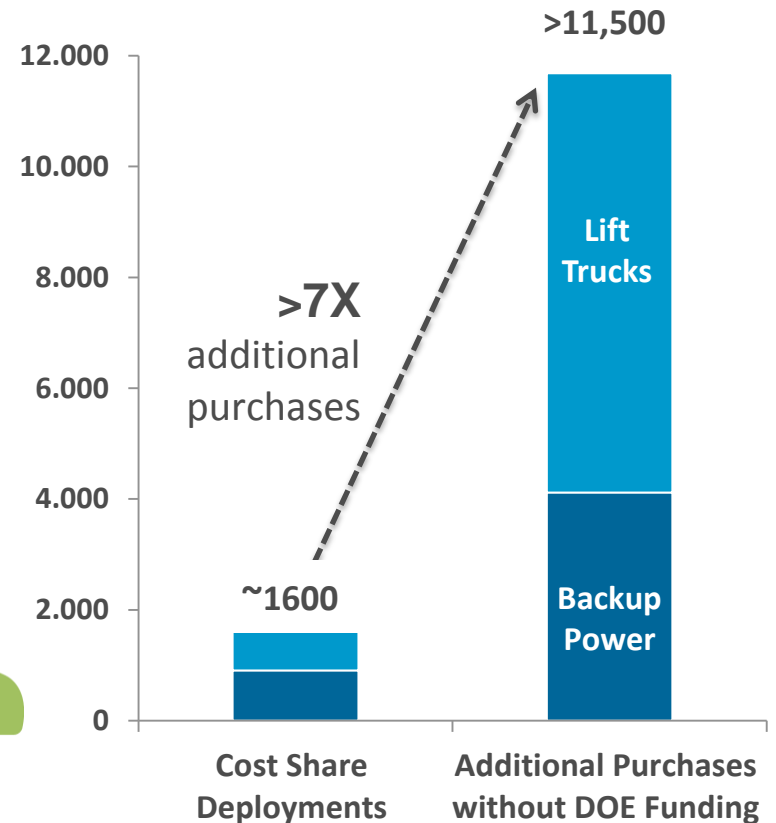
*Single tank holding 5.6kg H₂ total, cost in 2007\$, 500,000 systems/yr

Carbon fiber cost reductions are critical for 700-bar compressed H₂

FCEV Commercialization Strategy



DOE Cost-Shared Deployments and Additional Purchases



Catalyzing early markets enables broader commercialization of FCEVs

FCEVs are on U.S. Roads Now!

Just Announced Publicly- Toyota Mirai FCV
*1st commercially available FCEV
for sale in the US*



Toyota Mirai Fuel Cell Vehicle



**Deputy Secretary of Energy,
Daniel B. Poneman
test driving Hyundai Fuel Tucson**

OEMs bringing fuel cells to showrooms and driveways

H₂ USA Public-Private Partnership to address H₂ Infrastructure Challenges

H₂ USA



With 3X increase in partners and growing since 2013

Nationwide

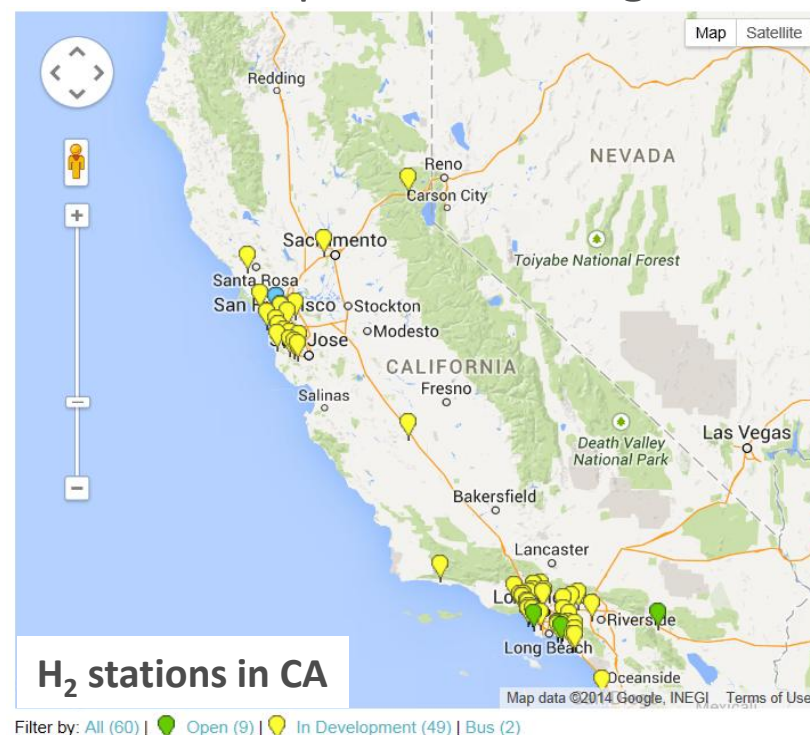
- **1500 mi.** of H₂ pipeline
- **>9M** metric tons produced/yr
- **~50 stations** (~10 public)

Other States

- **8-State MOU Members:** CA, CT, NY, MA, MD, OR, RI and VT
- **MA, NY, CT:** Preliminary plans for H₂ infrastructure and FCEVs deployment in metro centers in NE states.
- **Hawaii:** Public access refueling infrastructure on Oahu by 2020

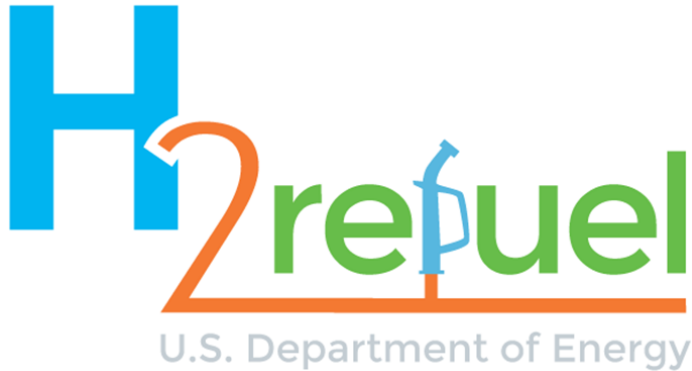
California

- **100 stations** - Goal
- **>~\$70M** awarded
- **~\$100M** planned through **2023**



NE states, California and Hawaii have H₂ infrastructure efforts underway

H-Prize Announcement



**\$1 million competition
for on-site home and
community-scale H₂
fueling systems.**

1st Year

**Teams form
and submit
designs**

2nd Year

**Selection of
finalists and
testing**

Late 2016

**Technical and
cost analysis to
select winner**

Award

\$1M

***Promoting H₂ fueling system development in the community
Visit <http://hydrogenprize.org/>***

What

- Contest to develop innovative hydrogen fueling station business and financing models



Who

- Undergraduate and graduate students worldwide

When

- Early Registration by Dec 5, 2014
- Jan 16, 2015- Deadline to register and to submit abstracts

Contest is now open at www.hydrogencontest.org

- Continue to promote and strengthen **R&D**
- Selectively **demonstrate** strategic, innovative technologies
- Conduct key **analyses** to guide RD&D
- Leverage **partnerships** to maximize impact of efforts

R&D, demonstrations, analysis and partnerships lead the path forward

Thank you

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