Advancements and Opportunities for Fuel Cells

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

Fuel Cell Seminar and Energy Exposition

November 10, 2014

Los Angeles, CA

Reuben Sarkar

U.S. Department of Energy
Deputy Assistant Secretary
Sustainable Transportation

Plenary at Glance

- **National Energy Priorities**
- **Program Level Priorities and Progress**
- **The Role of National Labs**
- **How can we get to where we need to be?**

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

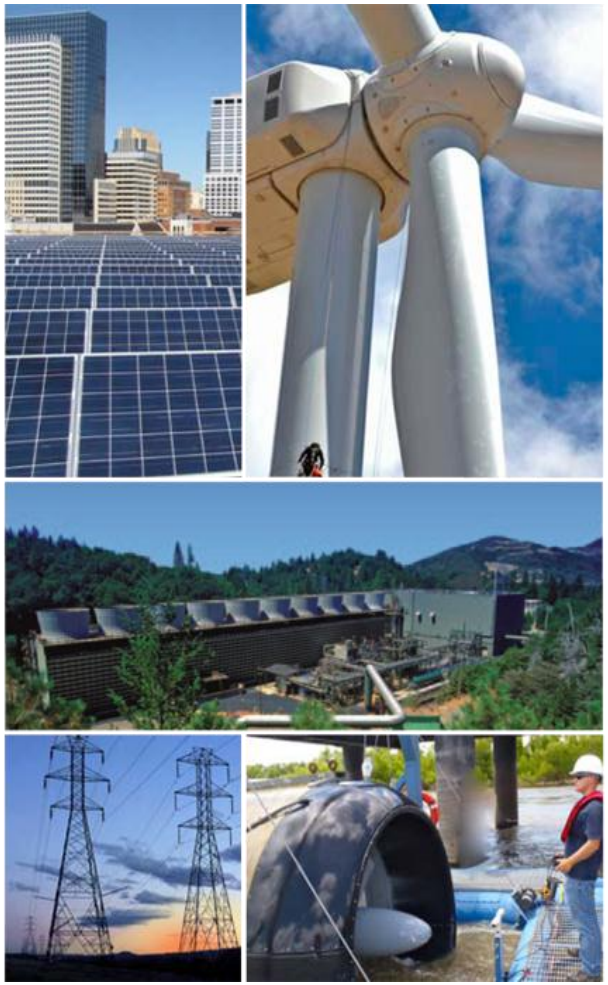
Secretary Moniz at DC Auto Show

Office of Energy Efficiency & Renewable Energy

Sustainable
TRANSPORTATION

Renewable
ELECTRICITY GENERATION

Energy Saving
HOMES, BUILDINGS, & MANUFACTURING



Sustainable Transportation Sector

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

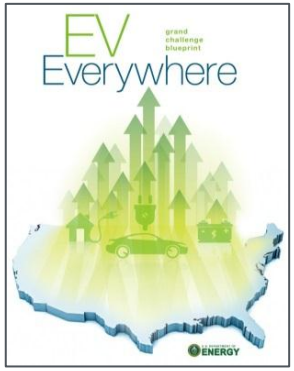
↓ **>80%** by 2050

Transportation Sector Priorities

Core Focus

- Vehicle Electrification
- Materials Lightweighting
- Advanced Combustion
- Drop-in Biofuels
- Community Partner Projects
- Fuel Cell Technology
- Hydrogen Infrastructure
- Crosscuts (multi-office)

Programs & Initiatives



Workplace Charging Challenge
U.S. DEPARTMENT OF ENERGY

Clean Cities
U. S. Department of Energy

H_2 USA

H_2FIRST

Portfolio of technology R&D and market transformation activities

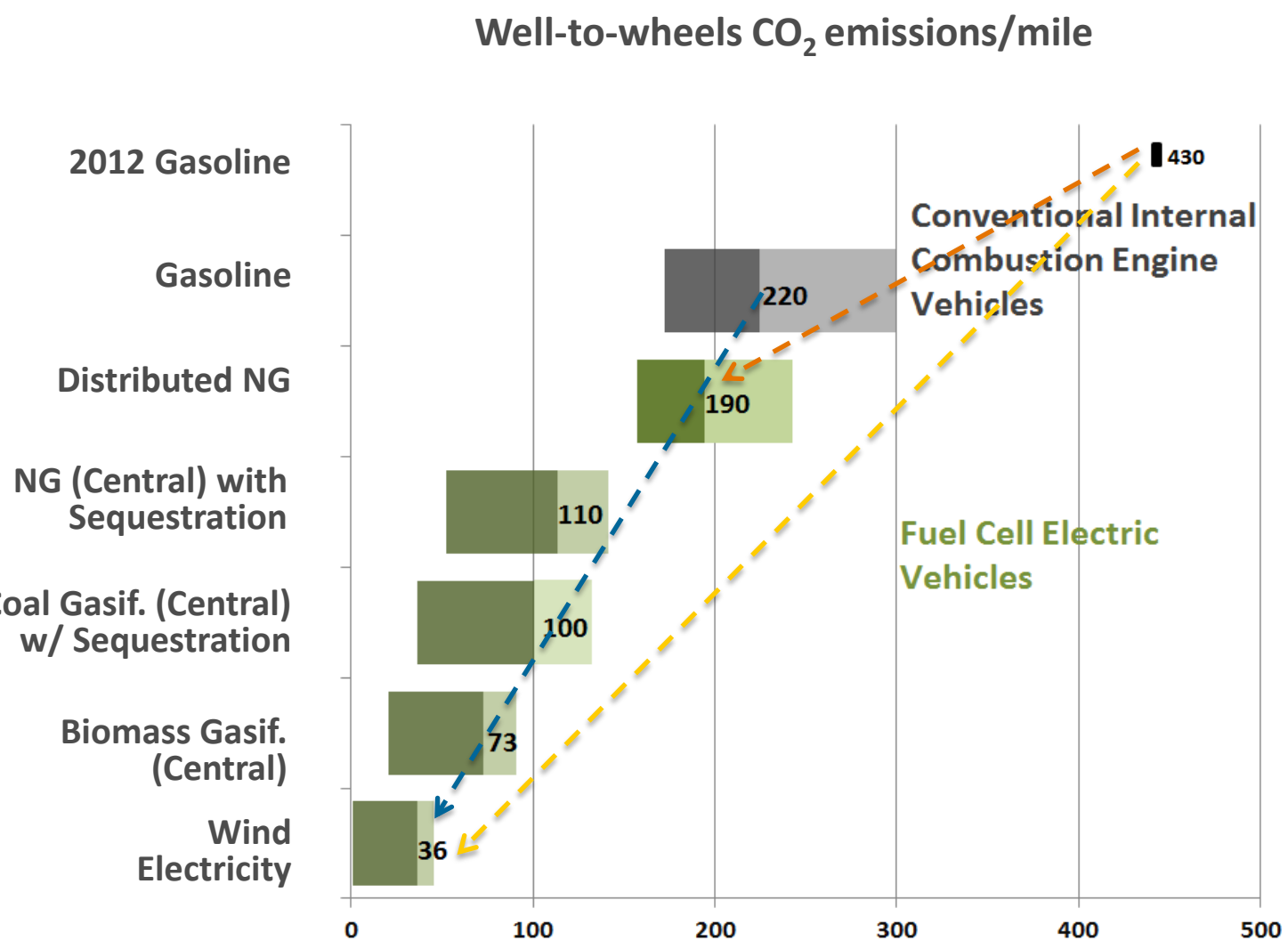
FCEVs Reduce Greenhouse Gas Emissions

>50% from Distributed Natural Gas*

>80% from Renewables** (Wind)

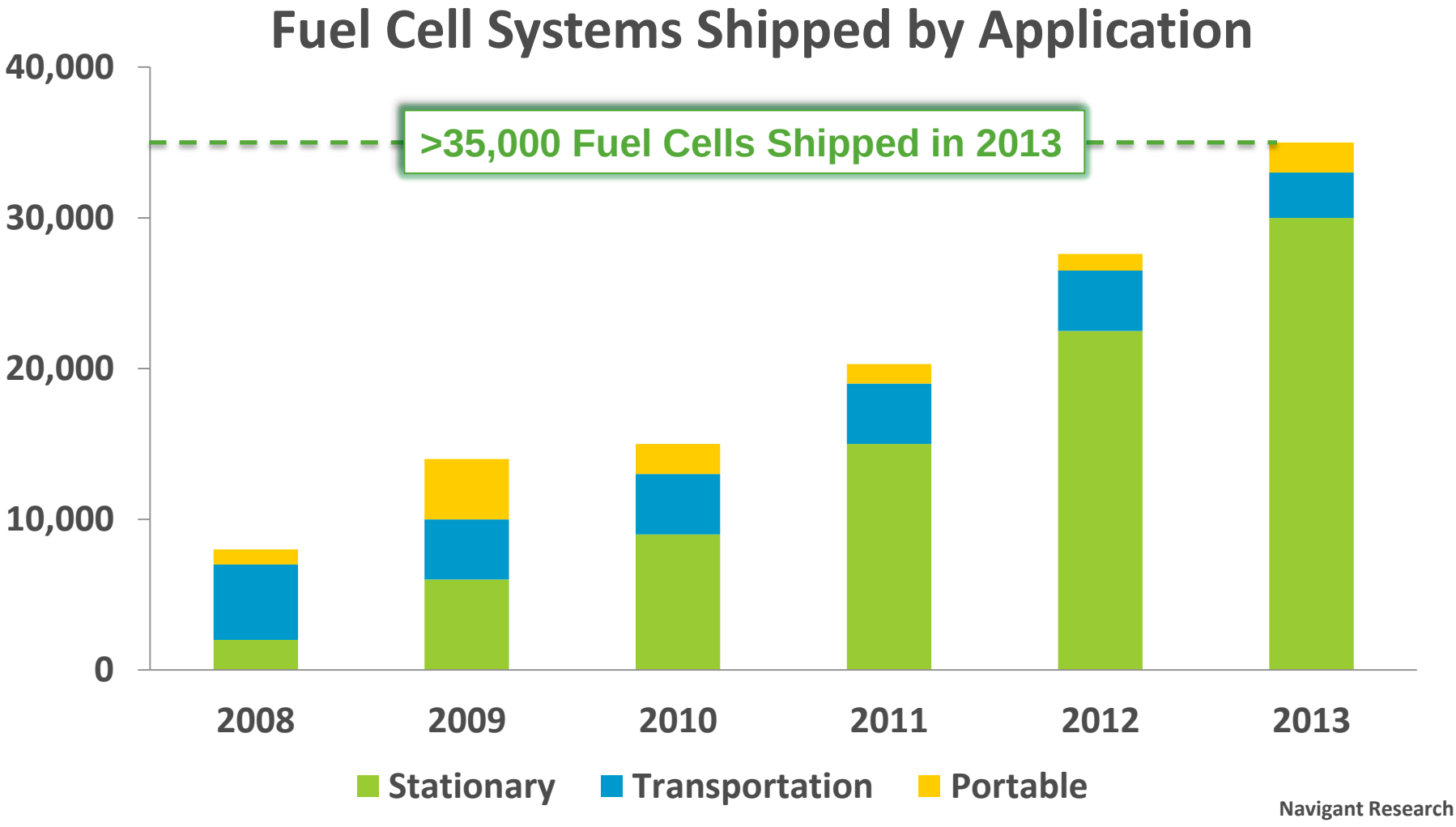
>90% from Renewables* (Wind)

*Compared to 2012 gasoline vehicle
**Compared to 2035 gasoline vehicle



Substantial GHG reductions with H_2 produced from renewables

Market Growth in Fuel Cell Sales



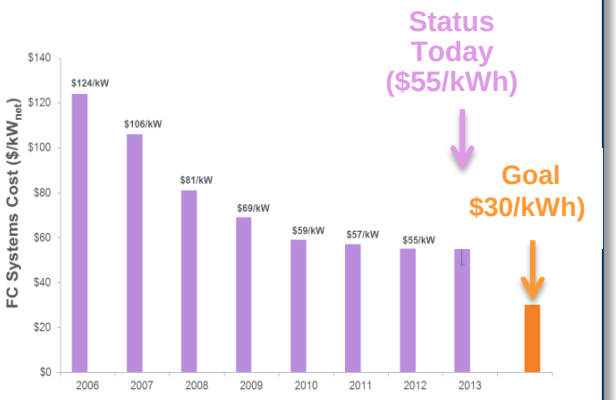
Consistent 30% annual growth since 2010

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*

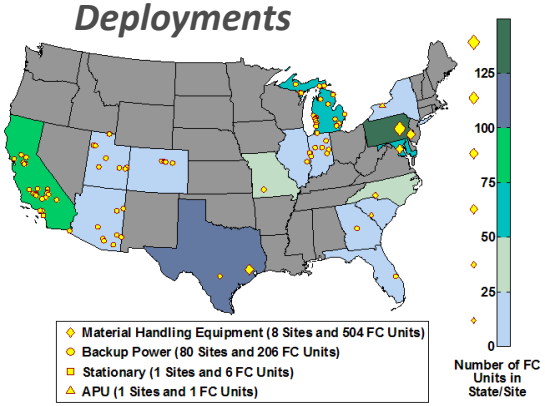
Demonstration

- *>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

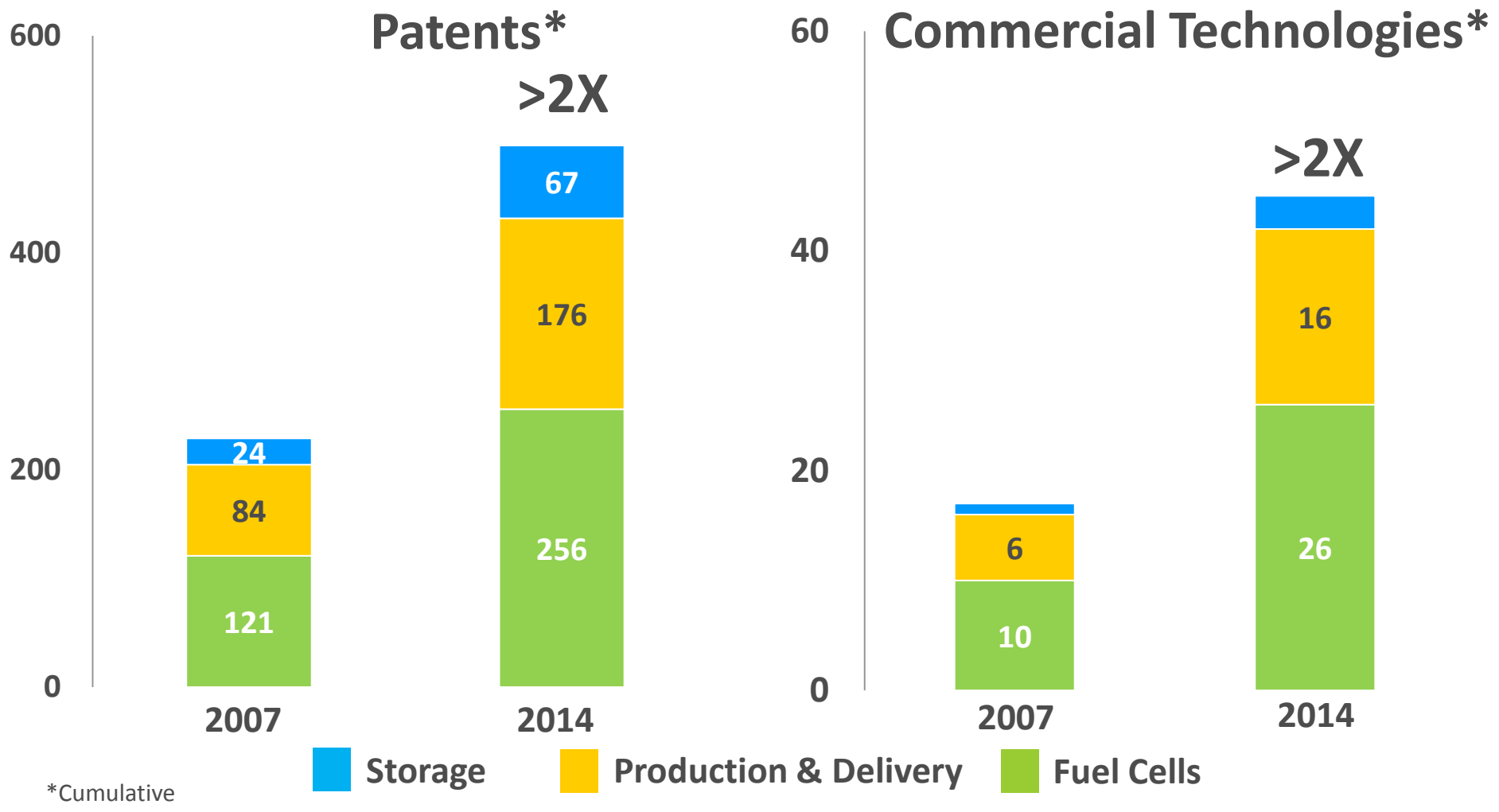
Key Activity	FY 2014 ($ in thousands)		FY 2015 ($ in thousands)
	Request	Approp.	Request
Fuel Cell R&D	37,500	32,422	33,000
Hydrogen Fuel R&D	38,500	34,467	36,283
Manufacturing R&D	4,000	2,879	3,000
Systems Analysis	3,000	3,000	3,000
Technology Validation	6,000	6,000	6,000
Safety, Codes and Standards	7,000	6,909	7,000
Market Transformation	3,000	2,841	3,000
NREL Site-wide Facilities Support	1,000	1,000	1,700
SBIR/STTR	-------	3,410	TBD
Total	$100,000	$92,928	$92,983

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

FY14 DOE Total: ~$175M

Consistent R&D funding request and appropriations in recent years

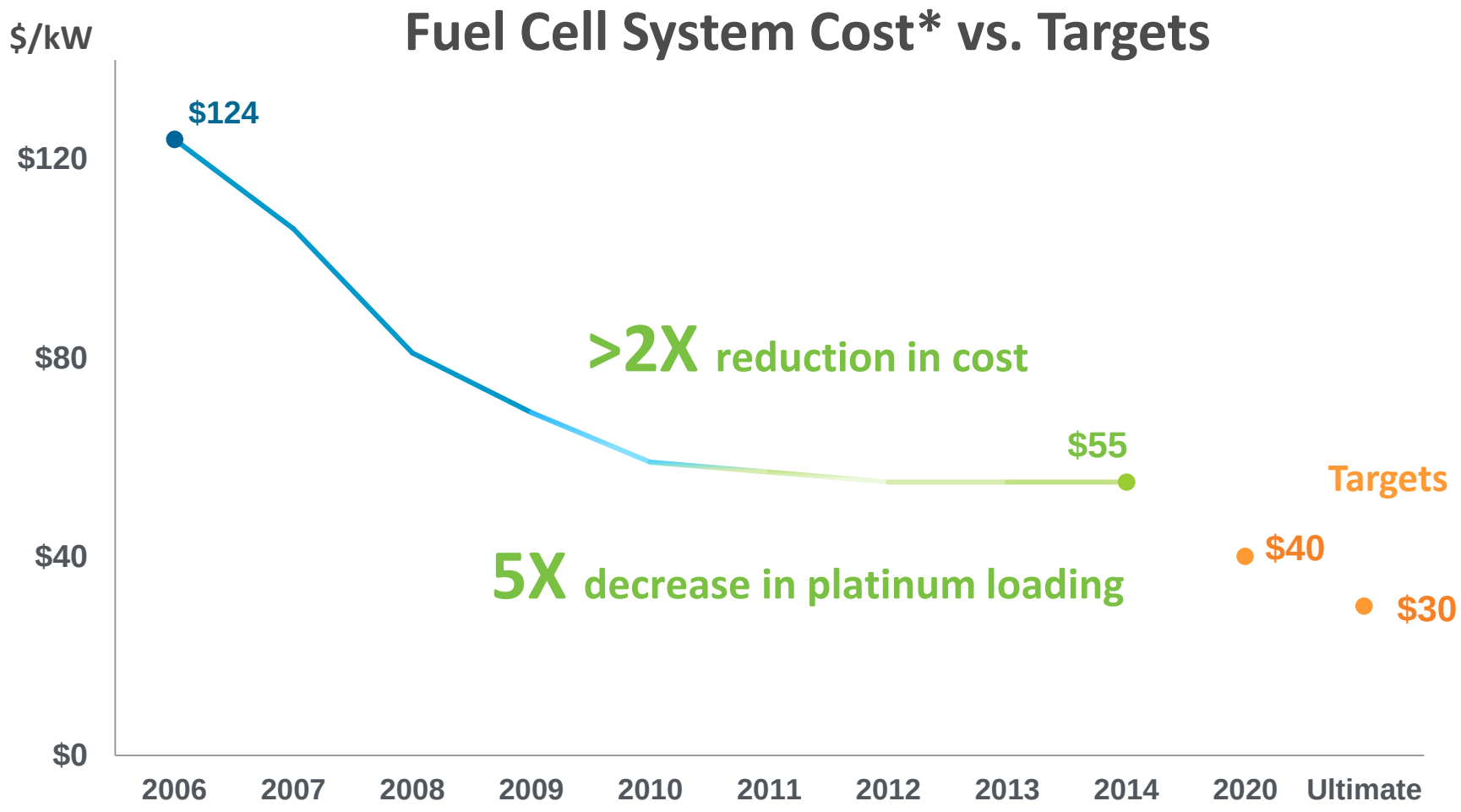
Technology Innovation and Commercialization



*Cumulative

EERE funding has led to ~500 patents and 45 commercial technologies

Fuel Cell Cost Reductions

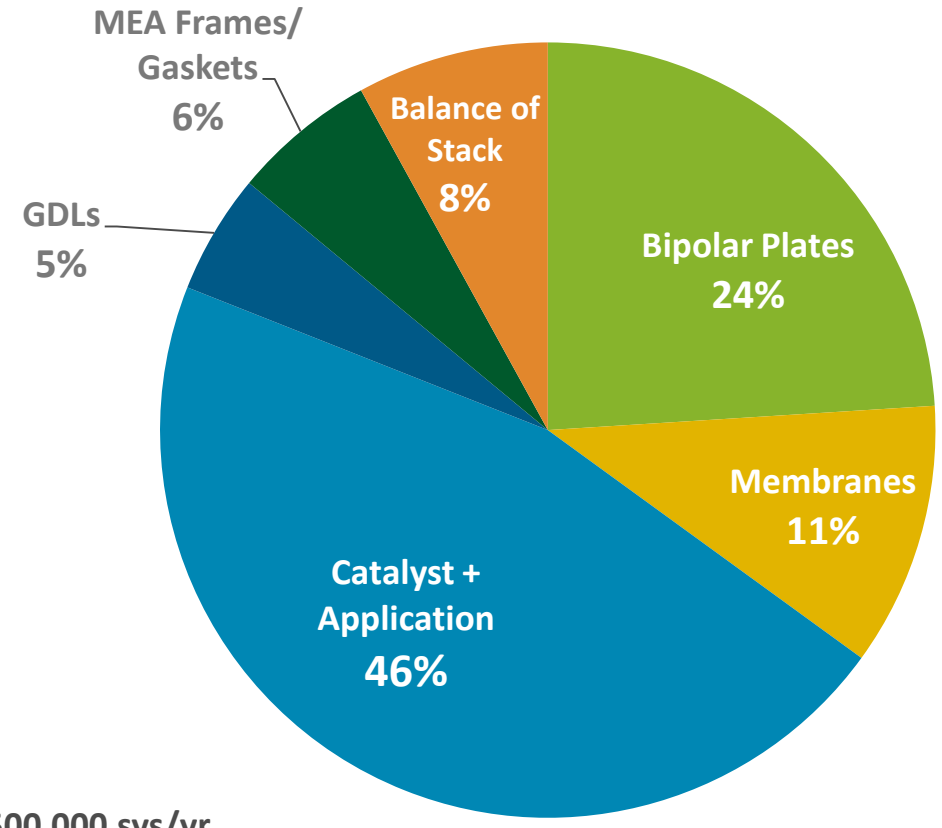


*At 500,000 sys/yr; ** $280/kW † current technology at 20,000 sys/yr; †ORNL, top-down analysis based on OEM input

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

Fuel Cell Critical Costs

PEMFC Stack Cost Breakdown*



*500,000 sys/yr

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

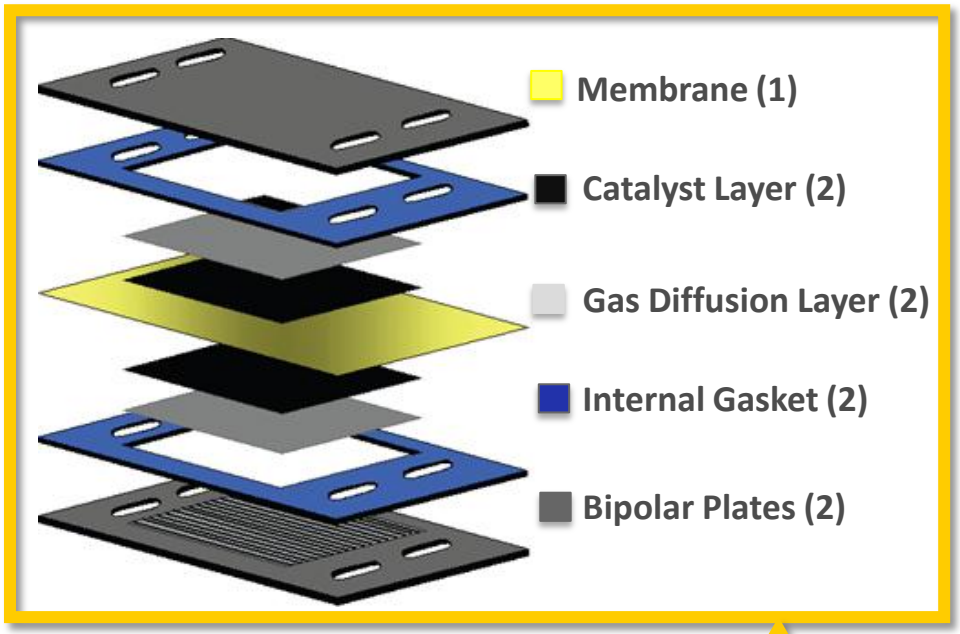
Catalyst remains key challenge and opportunity to lower cost

DOE-Led Innovation in Fuel Cells

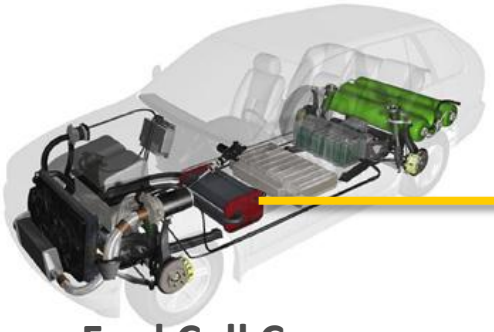
Examples of DOE-Led Fuel Cell Technology Breakthroughs

- **Ionomer-Impregnated Catalyzed Gas Diffusion Electrodes-** *US Pat 4,876,115 (1989)*
  "**ELAT**" – Electrode, Los Alamos Type
- **Catalyst-Coated Membranes-**
  US Pats 5,211,984 and 5,234,777 (1993)
- **Microporous Film on Gas Diffusion Layers-** *US Pat 5,641,586 (1997)*
- **Thermoset Composite Bipolar Plates-**
  US Pat 6,248,467 (2001)

Los Alamos NATIONAL LABORATORY EST. 1943



MEA in Fuel Cell Unit



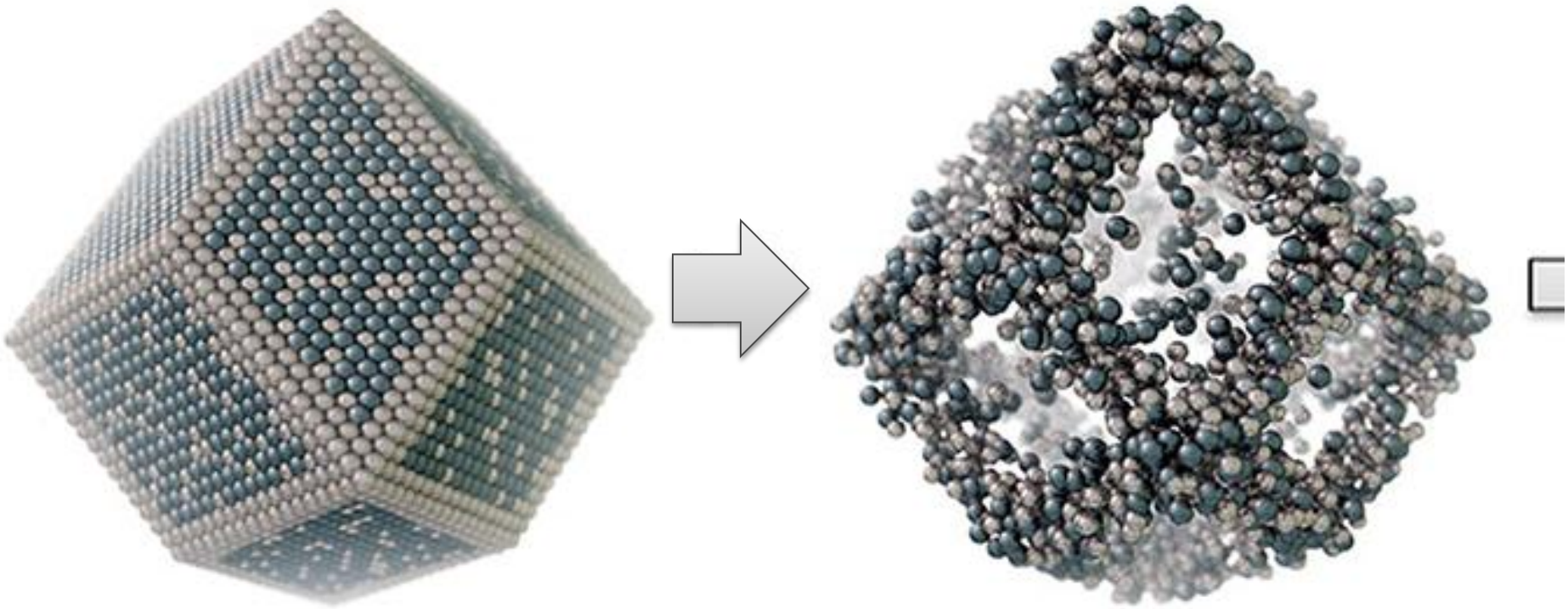
Fuel Cell Car

Fuel Cell Stack

Innovation from LANL can be found in most fuel cells today

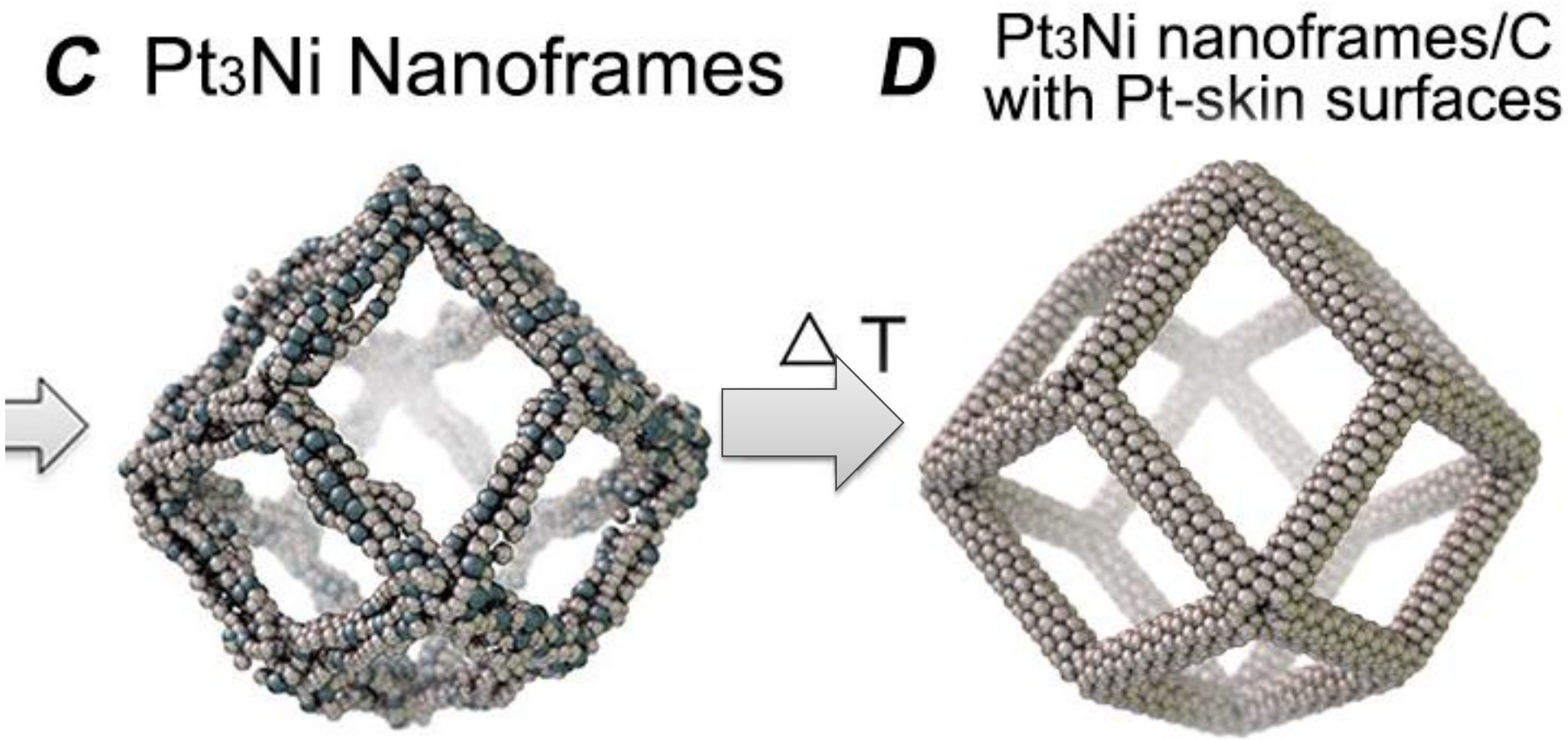
Synthesis & Evaluation of Nanoframes

A $PtNi_3$ Polyhedra **B** PtNi Intermediates



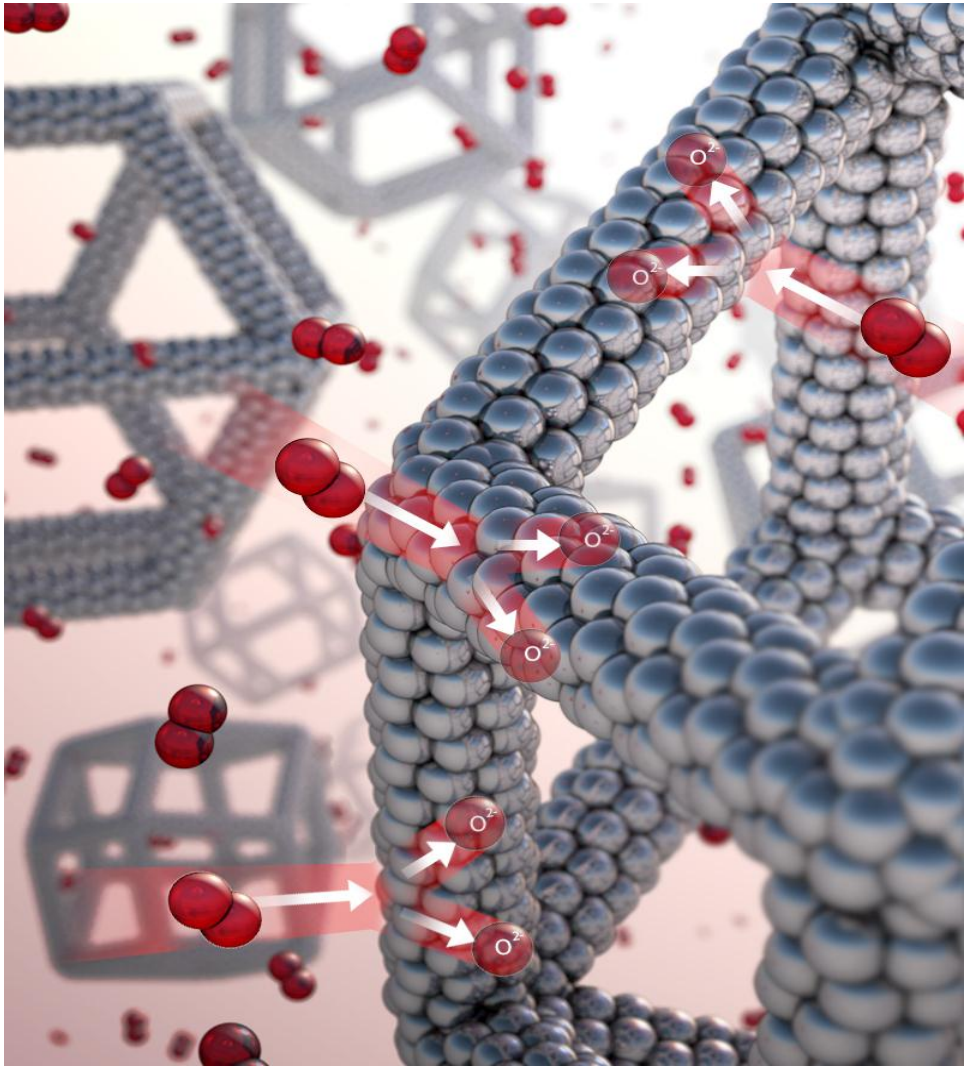
ANL and UC Berkeley scientists develop a high-mass activity nanoframe

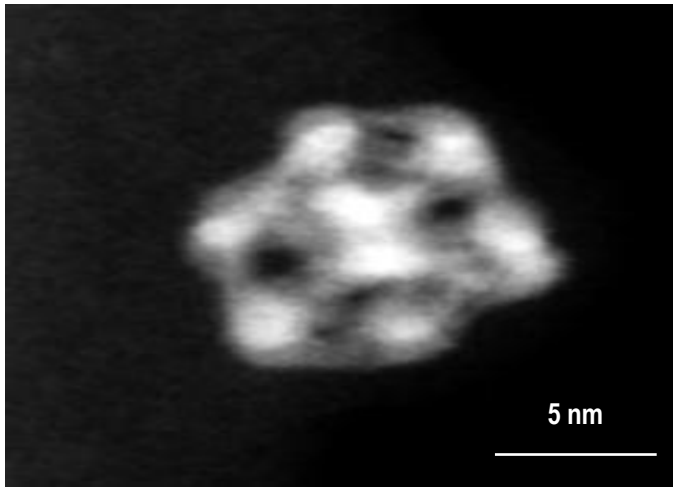
Synthesis & Evaluation of Nanoframes

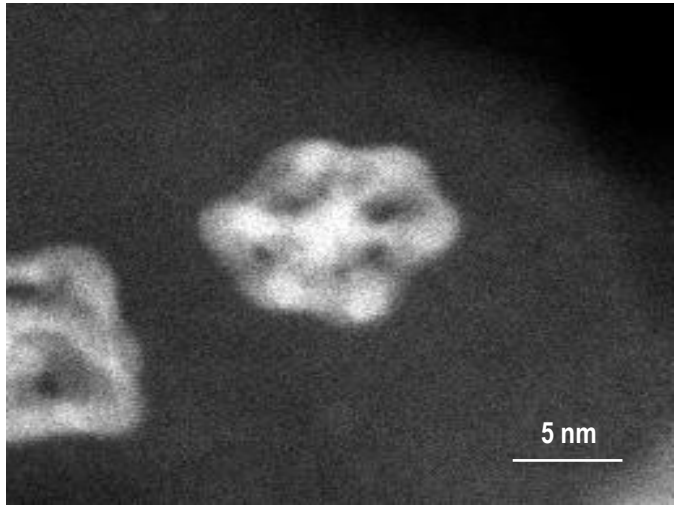


Dispersible cathode catalyst with extended thin film catalyst properties

Synthesis & Evaluation of Nanoframes



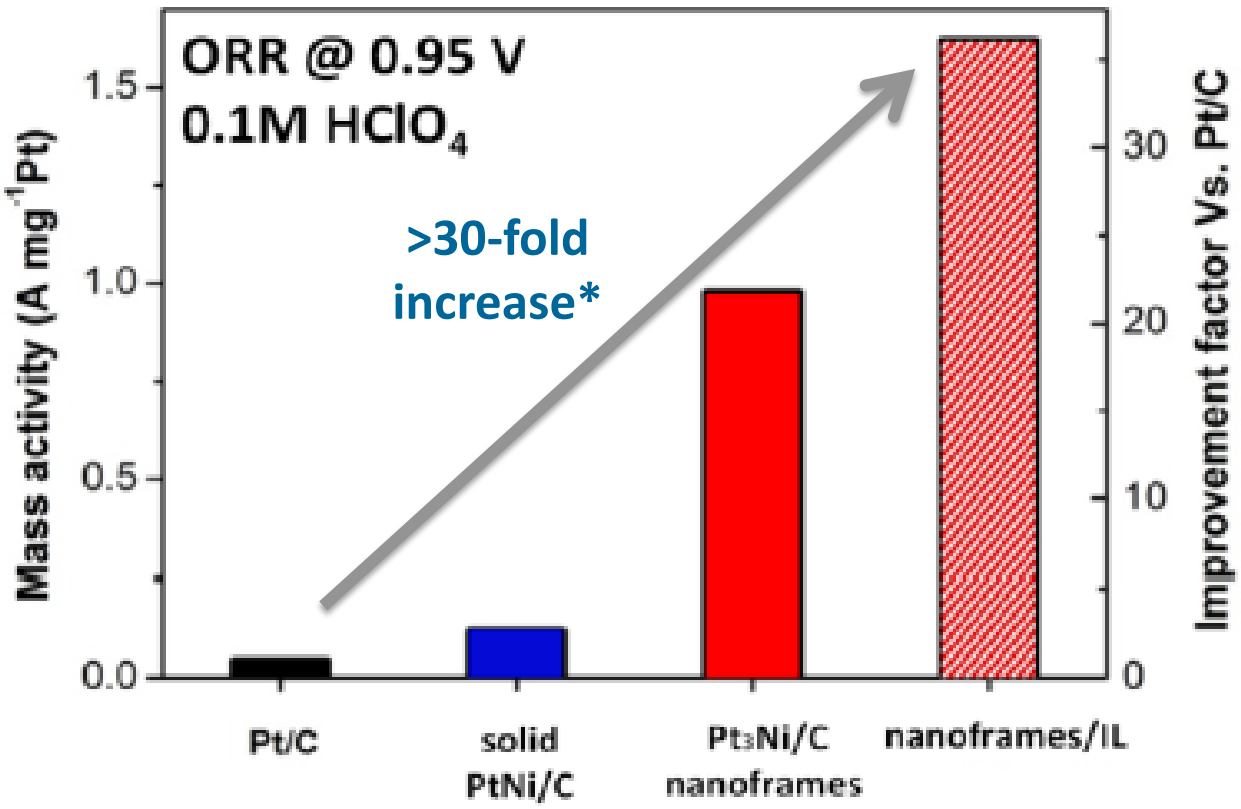




TEM- Karen Morre, ORNL

Microscopy demonstrates nanoframe hollow structure

Synthesis & Evaluation of Nanoframes



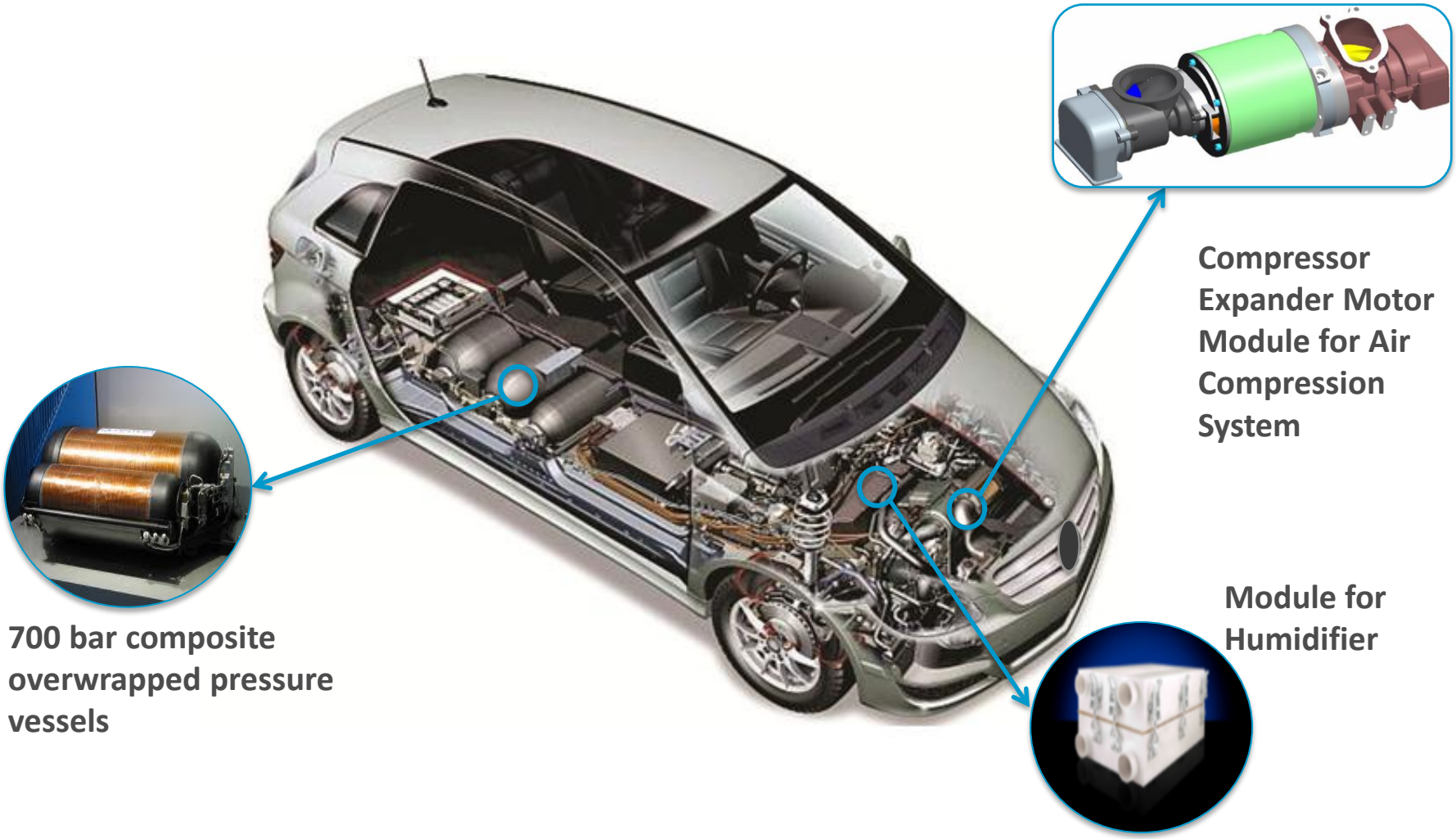
*Catalyst only in RDE tests

Future plans: Demonstrate MEAs

Reference:
"Highly Crystalline Multimetallic Nanoframes with Three-Dimensional Electrocatalytic Surfaces"
Vojislav Stamenkovic (ANL) & Peidong Yang (LBNL/UCB)
Science, 343 (2014) 1339

Catalyst mass activity >30X higher than conventional Pt/C

FCEV Technology Advancements



DOE funded R&D has advanced the state of technology for FCEV systems

Tech-to-Market (T2M) Strategy

T2M Strategy

Activities

Increase Industry Contact	• Business-to-Business Product Theater (Eleven Labs) • Manufacturing Road Show
Listen to the Voice of the Customer	• Key Staff Exchange with Industry
Develop Technology Transfer Skills	• Business Plan Development Training • Lab Corps

→ **Increase Market Understanding**

→ **Improve Private Sector Relationships**

Improving technology transfer and targeted impact from lab to market

T2M Activities at the Fuel Cell Seminar and Exposition

- **Tools**
  - Workshop sessions
  - Business-to-business product theaters
- **Key Questions**
  - How do I work with the National Labs?
  - Why should I work with the National Labs?
- **Objective**
  - Collaboration and understanding between national labs and industry

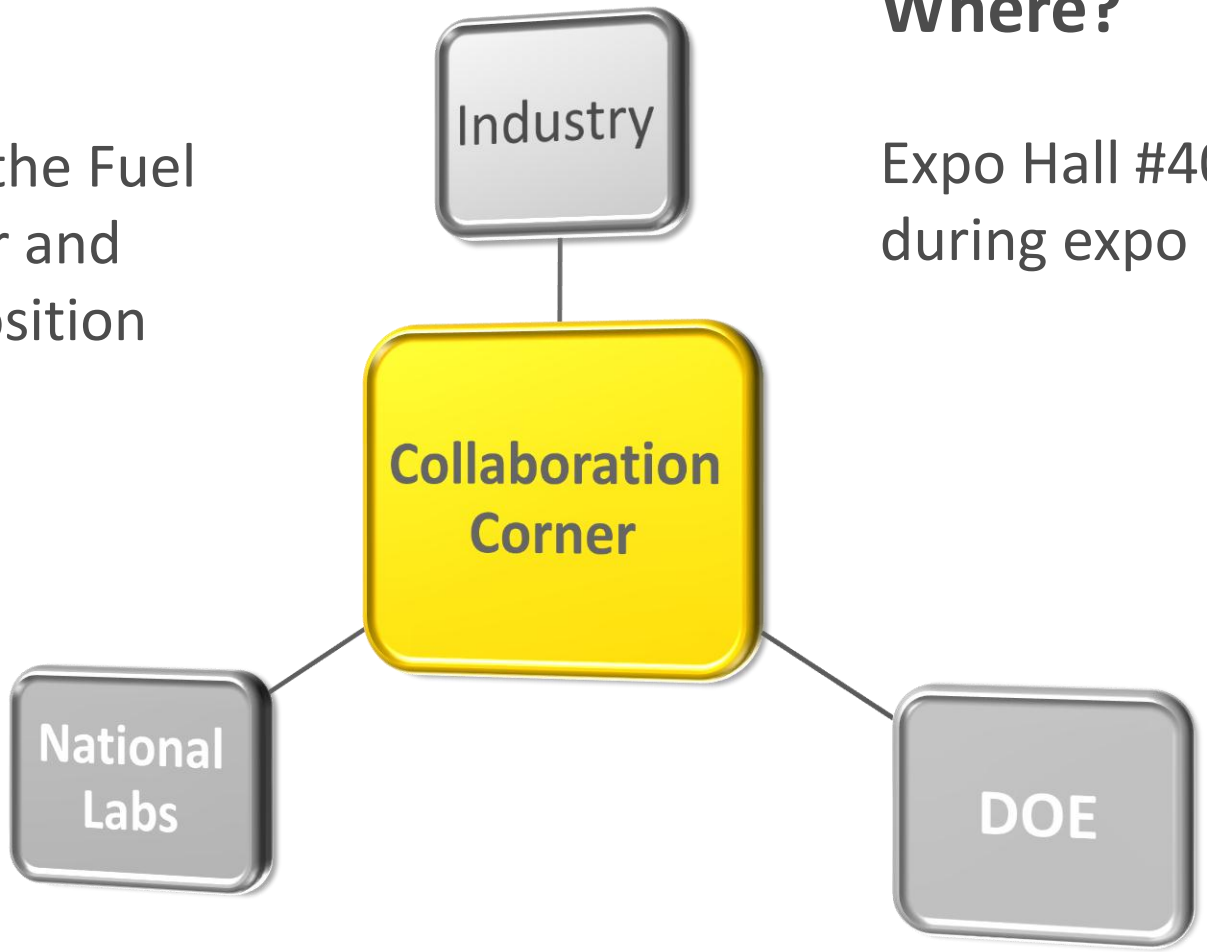
FCTO's ad on T2M Showcase Activities for the FCS

Visit DOE-sponsored T2M events during this conference

DOE National Lab Collaboration Corner

When?

All week at the Fuel Cell Seminar and Energy Exposition



Where?

Expo Hall #404 during expo hours

Networking opportunity for Industry, DOE, National Labs

SBIR Announcements

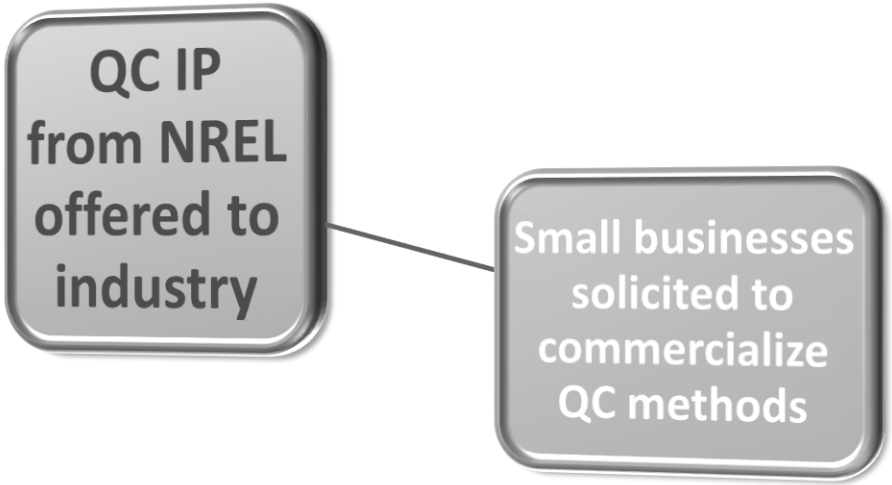
When?

LOI due December 15

What?

$150K Phase 1
$1M Phase 2

1) TTO on NREL's quality control IP
2) Design & analysis for niche medium/heavy duty fleet FCEVs: Bucket trucks

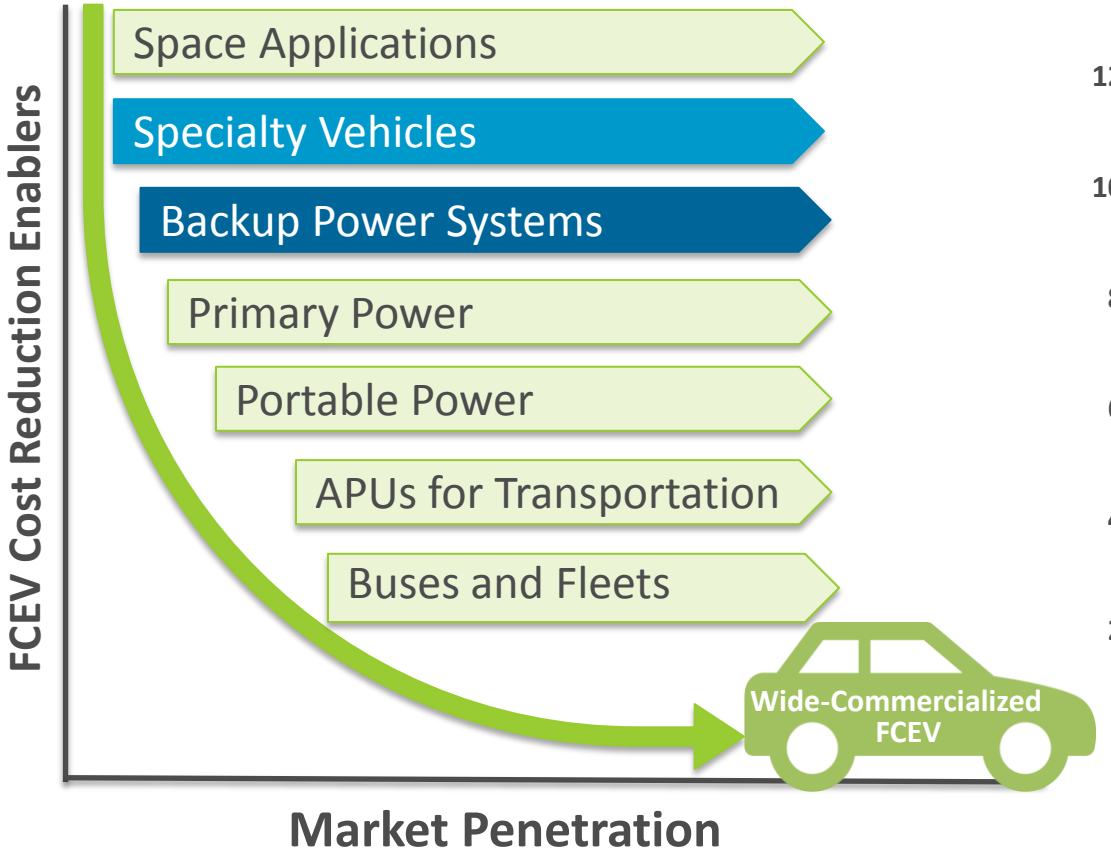


Class 5 plug-in hybrid electric bucket truck

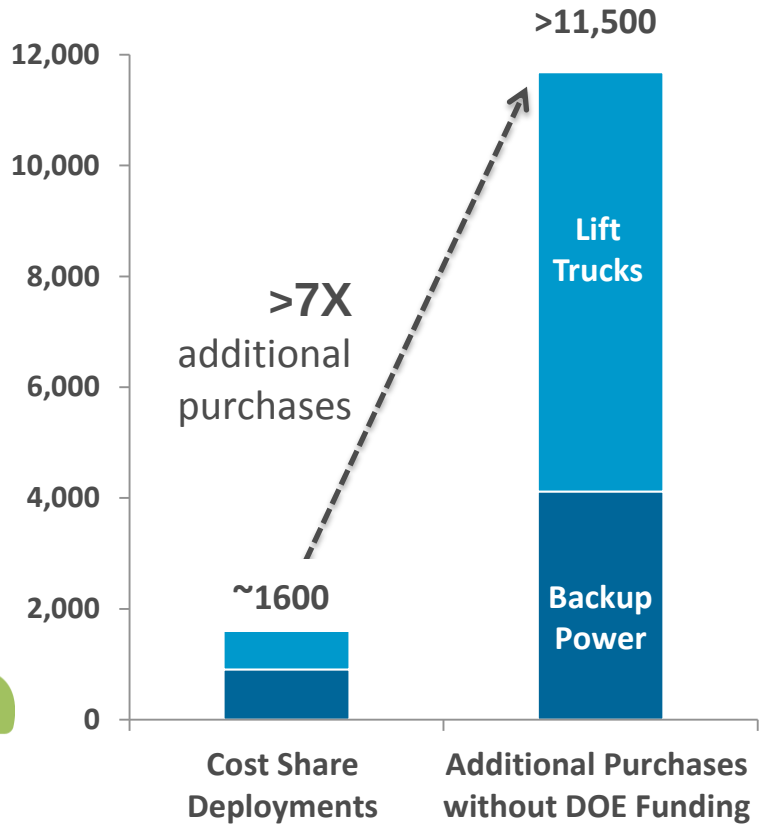
SBIR announcements cover T2M and market transformation

DOE Impact on Early Market Applications

FCEV Commercialization Strategy



DOE Cost-Shared Deployments and Additional Purchases



Catalyzing early markets enables broader commercialization of FCEVs

From Mars…


Think H_2 and Fuel Cells are just for rockets and spaceships …
Think again

… To Cars

FCEVs are Here!

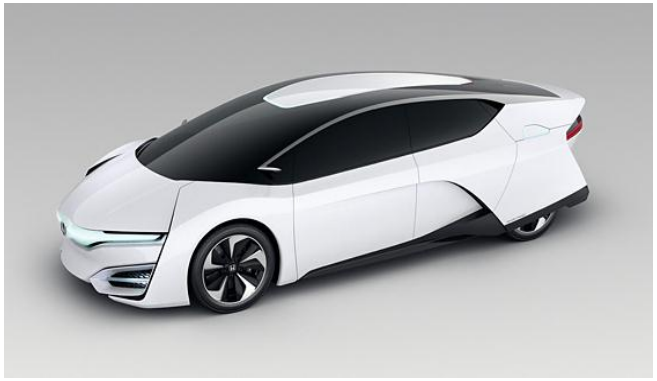
Available for Public Purchase Soon….

Toyota Fuel Cell Electric Vehicle

Now Leasing…

Hyundai Tucson Fuel Cell SUV

In Auto Shows…



Honda Fuel Cell Electric Vehicle

OEMs bringing fuel cells to showrooms and driveways

H_2USA Public-Private Partnership to address H_2 Infrastructure Challenges

With 3X increase in partners and growing since 2013

Hydrogen Fueling Infrastructure Research Station Technology

$1.4M DOE Funding
Leveraging Expertise of National Labs

NREL NATIONAL RENEWABLE ENERGY LABORATORY & Sandia National Laboratories

In Support of H_2USA and tasked to deliver

- **Reference Station Design**
- **Fuel Contaminant Detection**
- **HyStEP Device**
  - H_2 Station Equipment Performance Device
  - H_2First Inaugural Task
  - HyStEP will help reduce time required to place H2 stations in service

DOE's H_2FIRST project supports H2USA goals to address infrastructure

H-Prize Announcement

H2refuel
U.S. Department of Energy

$1 million competition for on-site home and community-scale H_2 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 H_2 fueling system development in the community
Visit http://hydrogenprize.org/

Outreach and Communication Efforts

- **Publications - ~80/yr.**
  - Monthly Newsletter
  - Success Stories
  - News Alerts
  - Blogs
- **Investor Days**
  - NYC and CA
- **House Senate Caucus Events**
- **Annual Merit Review & Peer Evaluation**
  - June 2014- 1,800 attendees
- **Ride-n-Drives**

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

Increasing public awareness and understanding about fuel cells and H_2

The Path Going Forward

- 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

Reuben Sarkar
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Sustainable Transportation

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