Fuel Cells and Hydrogen: US Perspectives

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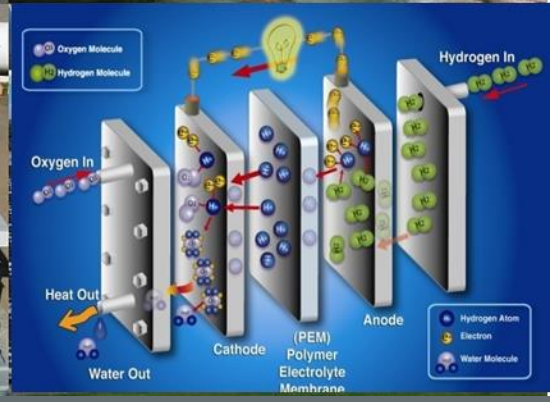


Fuel Cells and Hydrogen Stakeholder Forum

November 19, 2015

Brussels, Belgium

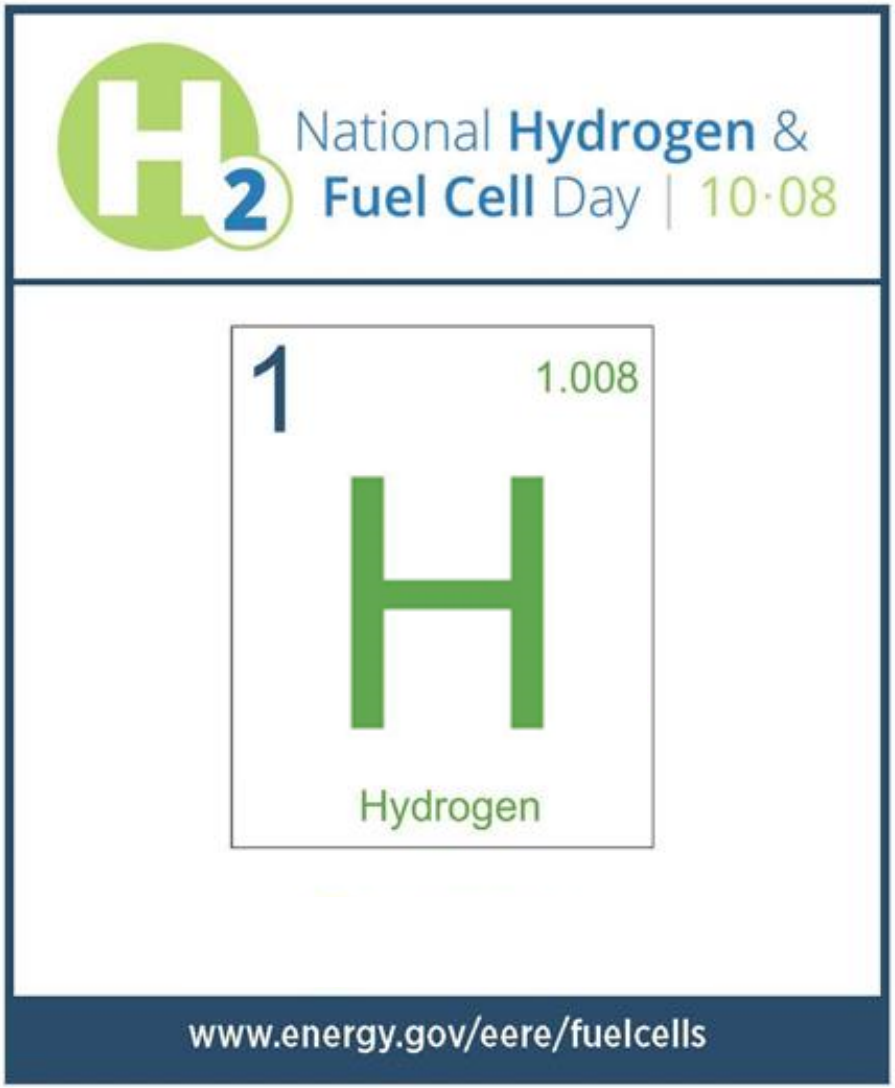
Reuben Sarkar

Deputy Assistant Secretary- Sustainable Transportation

Energy Efficiency and Renewable Energy Office

U.S. Department of Energy

Why Hydrogen?



The Only Technology with Potential to be:

Fast Filled
Long Range
Zero Emission*
Zero Criteria Pollutants*
Renewable Fuel
Domestic Sources
Diverse Uses
Fewer Vehicle Trade-offs

*From renewable sources

10-08 … an auspicious day for the 1st ever Hydrogen and Fuel Cells Day

Office of Energy Efficiency & Renewable Energy

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Sustainable
TRANSPORTATION

Renewable
ELECTRICITY GENERATION

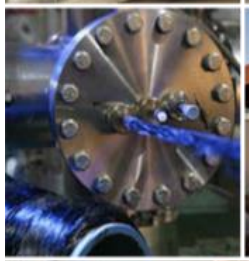
Energy Saving
HOMES, BUILDINGS, & MANUFACTURING



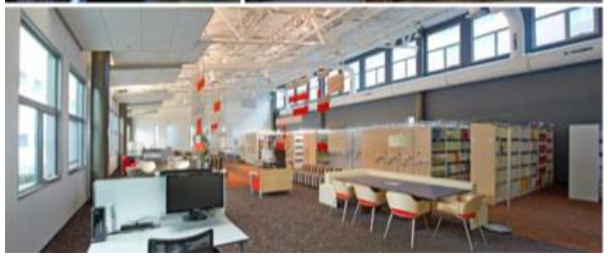










Major Administration Energy Goals

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Reduce GHG emissions by 17% by 2020, 26-28% by 2025 and 83% by 2050 from 2005 baseline Climate Action Plan

Reduce net oil imports by half by 2020 from a 2008 baseline Blueprint Secure

By 2035, generate 80% of electricity from a diverse set of clean energy resources Blueprint Secure Energy Future

Reduce CO2 emissions by 3 billion metric tons cumulatively by 2030 through efficiency standards set between 2009 and 2016 CAP Progress Report

Double energy productivity by 2030 Department of Energy

"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

Fuel Cell Cost Reductions

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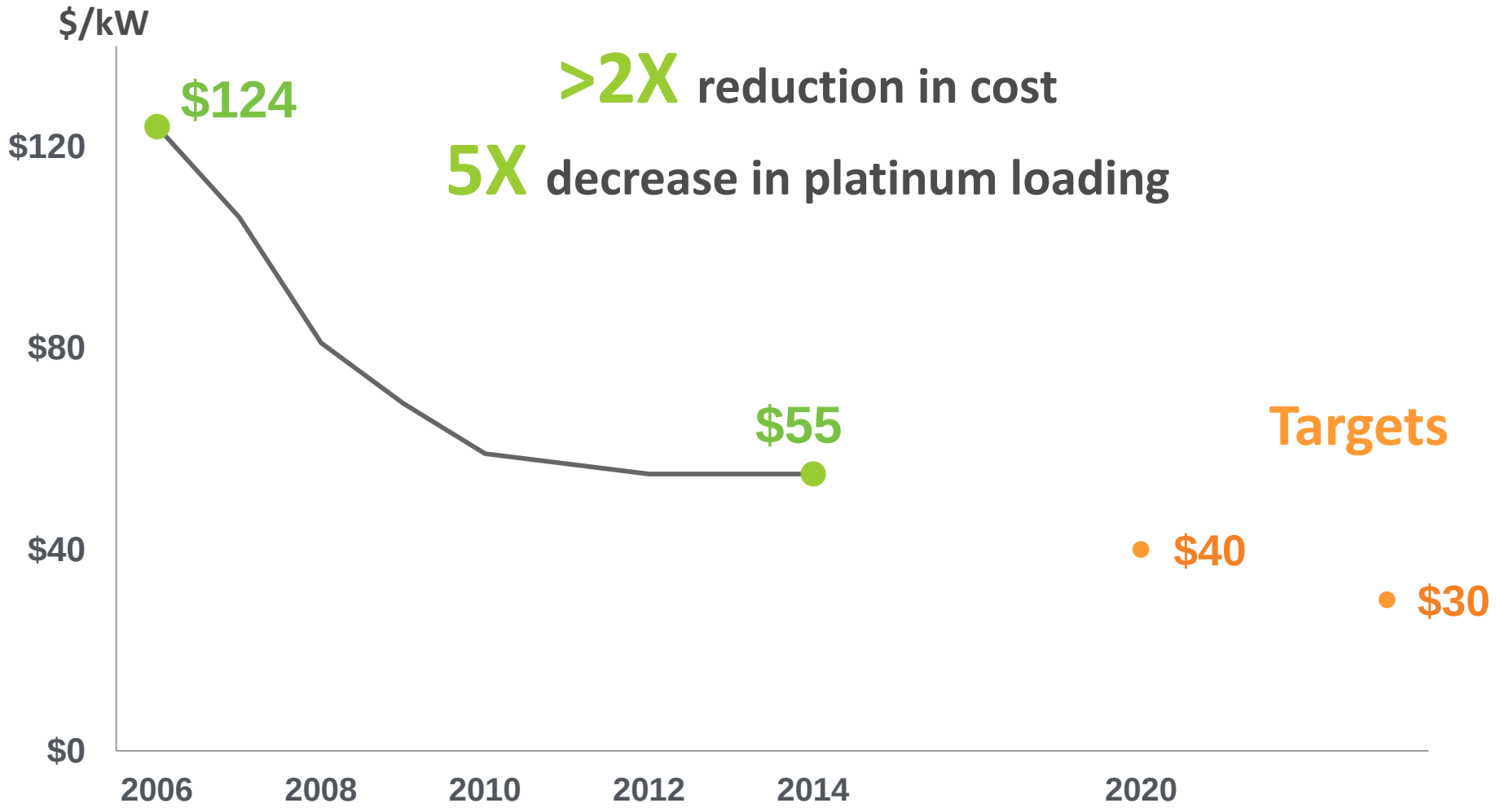

*At 500,000 sys/yr.; ** $280/kW † current technology at 20,000 sys/yr.; †ORNL, top-down analysis based on OEM input

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

Hydrogen and Fuel Cell R&D Strategy

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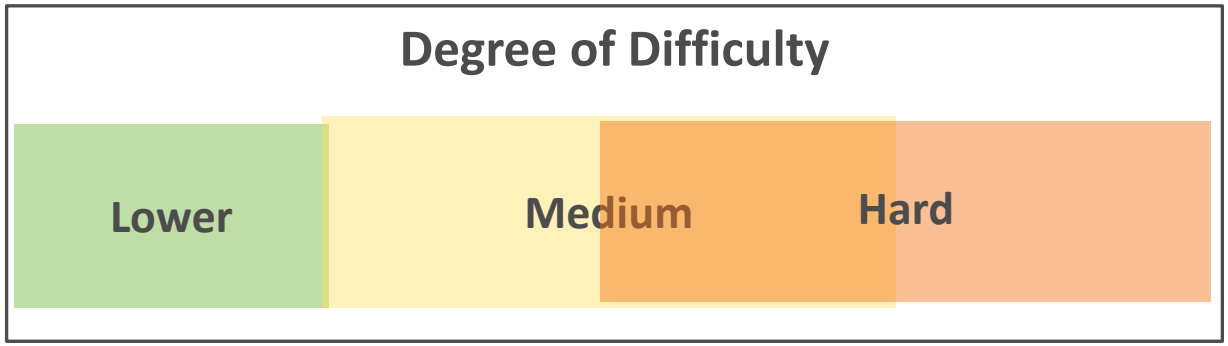
Barriers	Near to Mid-term	Long-Term
Fuel Cell Cost and Durability	Low PGM catalysts MEA durability performance	PGM-Free Catalysts & MEAs
Hydrogen Storage	700 bar tanks Cryo-compressed	Materials Based Low Pressure Storage
Hydrogen Production and Delivery	H_2 from NG/ Electrolysis Delivered & compressed	H_2 from Renewables (PEC, biological, etc.) Pipelines, low P option



2020 Cost & Performance Targets

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Fuel Cell Cost	$40/kW	$1,000/kW* $1,500/kW**
Durability	5,000 hrs.	80,000 hrs.
H_2 Storage (On-Board)		$10/kWh 1.8 kWh/L, 1.3 kWh/kg
H_2 Cost at Pump		<$4/gge

*For Natural Gas
**For Biogas

Meeting targets will enhance competitiveness in marketplace

FCEVs Reduce Greenhouse Gas Emissions

Well-to-Wheels CO_2 Emissions (in grams per km)

- 2012 Gasoline ICE (270 g-CO_2/km) **Baseline**
- 2035 FCEV Distributed Natural Gas (120 g-CO2/km) **>50%**
- 2035 FCEV with Renewables (23 g-CO_2/km) **>90%**
- 2035 Gasoline ICE (140 g-CO_2/km) **~50%**
- 2035 FCEV with Renewables (23 g-CO_2/km) **>80%** vs. 2035 ICE

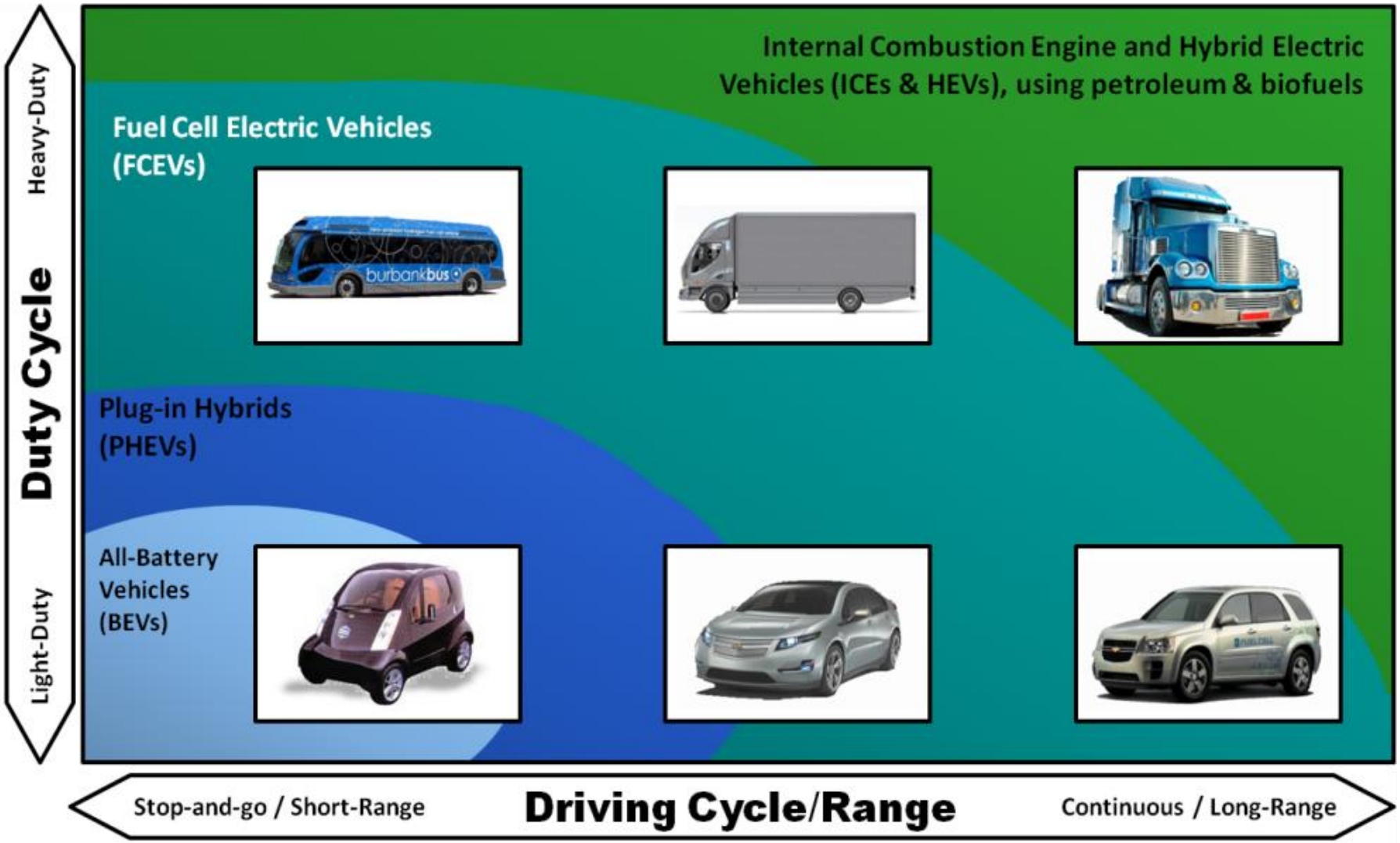
Substantial GHG reductions with H_2 from renewables

Leading the Pack

- Low cost H_2 from renewable sources is an enabler
- ICEs and other technologies continue to improve
- GHG is the difference between running with or ahead of the pack

FCEVs can lead the pack on GHG with renewable H_2

Delivering on Consumer Value



FCEVs provide a product/market fit in transportation portfolios

FCEVs are on U.S. Roads Now!

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Toyota Mirai available for commercial sale in the U.S.

Toyota Mirai Fuel Cell Vehicle

Now Leasing…

In Auto Shows…

OEMs bringing fuel cells vehicles to showrooms and driveways

H_2USA: Public-Private Partnership

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H_2 USA

Partners

~ 45 Partners in 2015

Mission

To address hurdles to **establishing hydrogen fueling infrastructure**, enabling the **large scale adoption of fuel cell electric vehicles**

Structure

4 Working Groups coordinated by the **Operations** Steering Committee

H_2FIRST Coordination panel

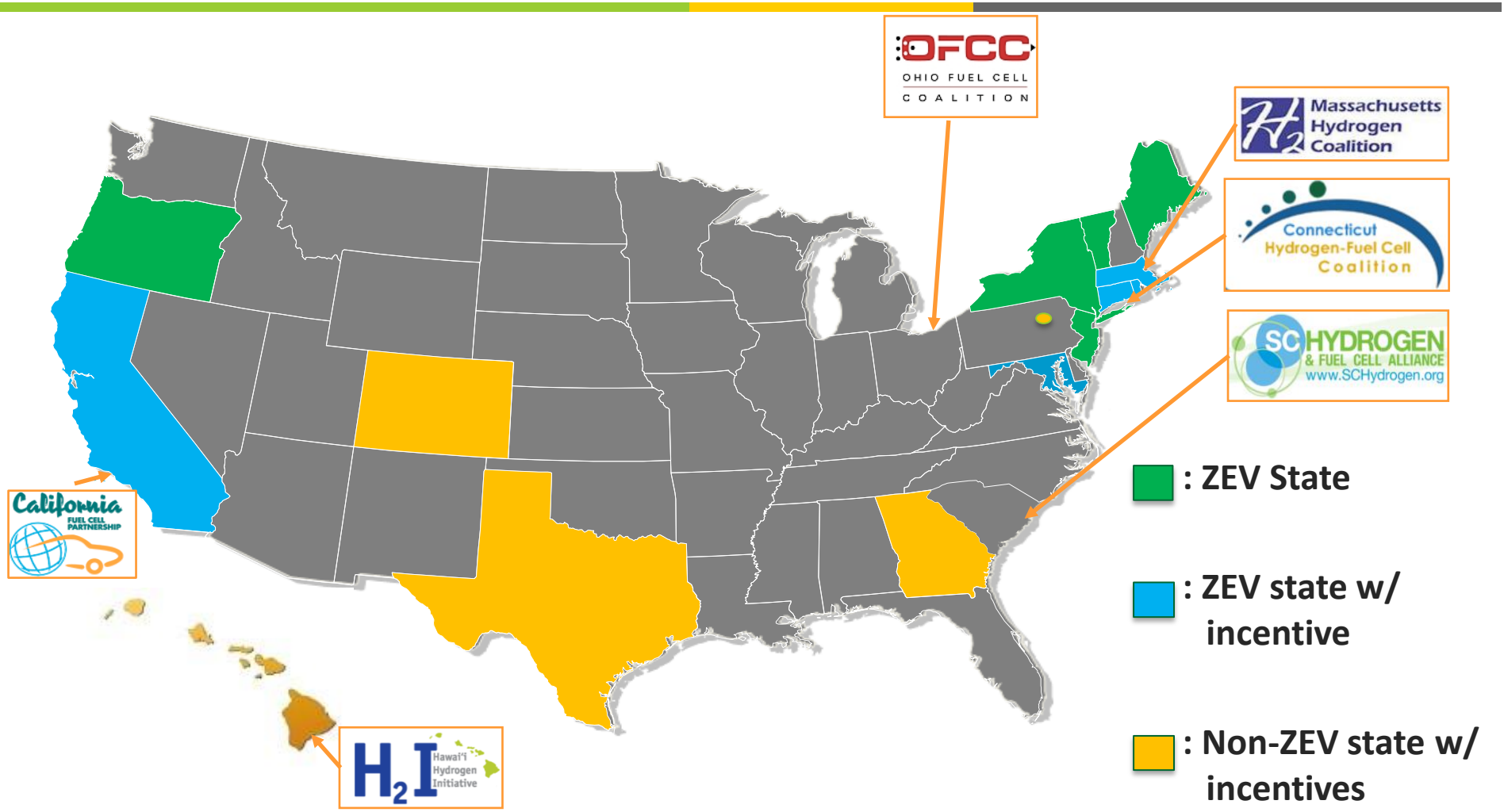
H_2FIRST

H_2USA's Working Groups

- **Hydrogen Fueling Station**
- **Locations Roadmap**
- **Financing Infrastructure**
- **Market Support & Acceleration**

More than 45 partners working towards adoption of FCEVs and H_2

State Incentives and Partnerships



Source: NCSL

9 states (4 ZEV states) offering incentives for FCEVs and H_2 station deployments

Selling into Real Markets

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- **Market Pricing Dynamics for Fuel**
  - Cost + Margin vs. Value Pricing
  - Fungible vs. Non-fungible fuels
  - Cross-fuel pricing effect relative to the next best alternatives

- **Can we achieve commodity pricing in a regulated market where the fuel delivers value?**

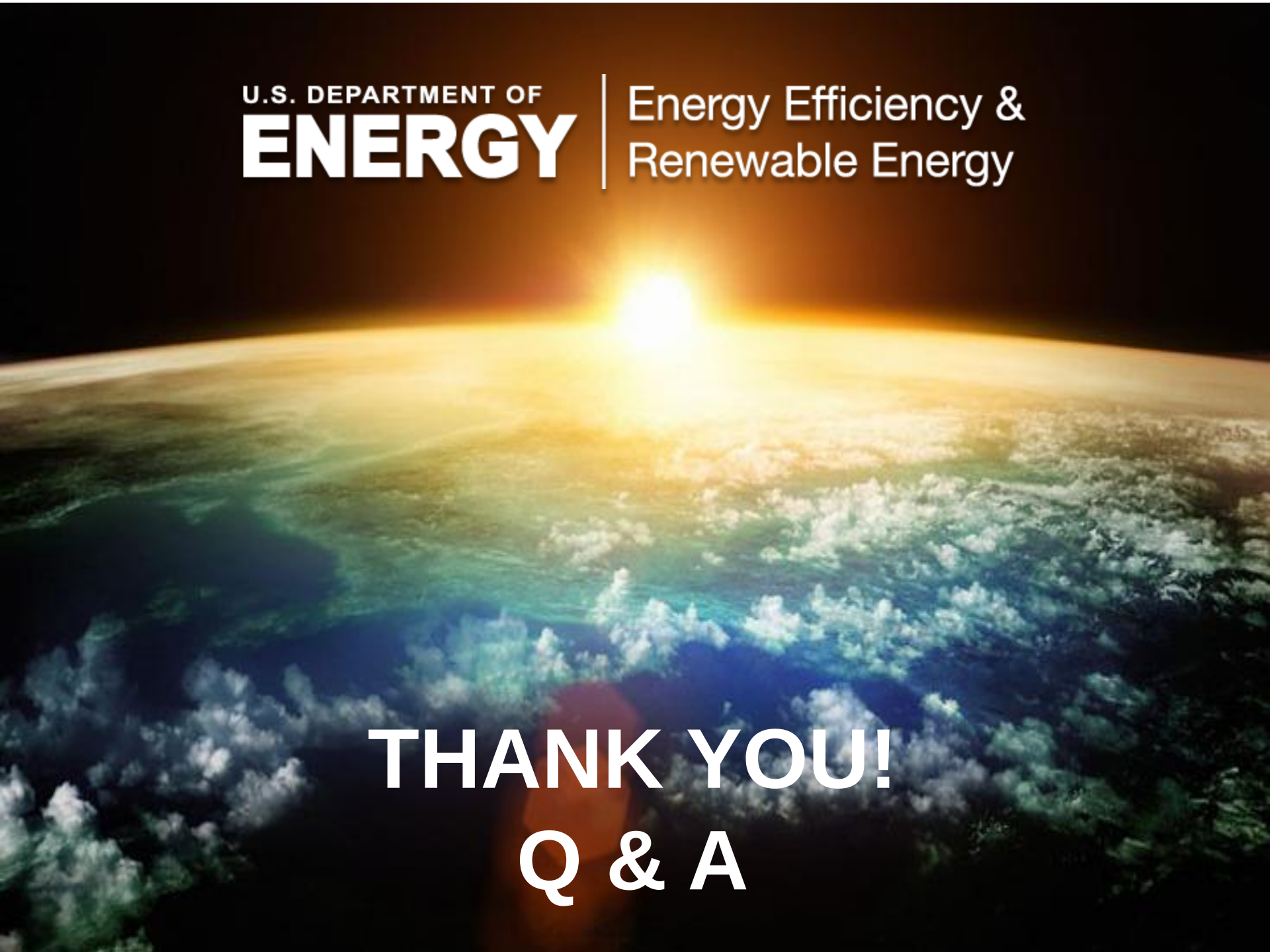
- **Consumer valuation of TCO, ROI, and Payback**
  - Direct cost competitiveness through technology alone is challenging
  - Alternative business and financing models
  - Strong policy to drive market and consumer behavior

More research and consideration needs to be given to real market behavior

Recap

- Why Hydrogen?
- All-of-the-Above Strategy
- Getting off the Asymptote
- Leading the Pack
- Delivering on Value
- Dealing with a Good Dilemma
- Selling into Real Markets

Renewable H2 and FCEV are a linchpin in achieving our 2050 GHG goals >80%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THANK YOU!
Q & A