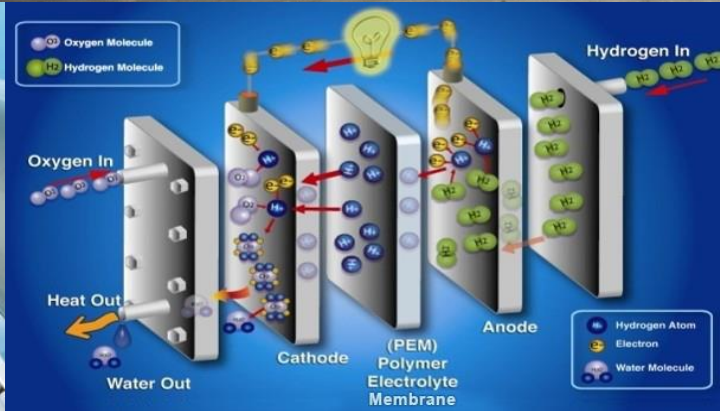


U.S. Department of Energy Hydrogen and Fuel Cells Program

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



Hydrogen and Fuel Cell Supply Chain Development Session

North Canton, Ohio
September 27, 2016

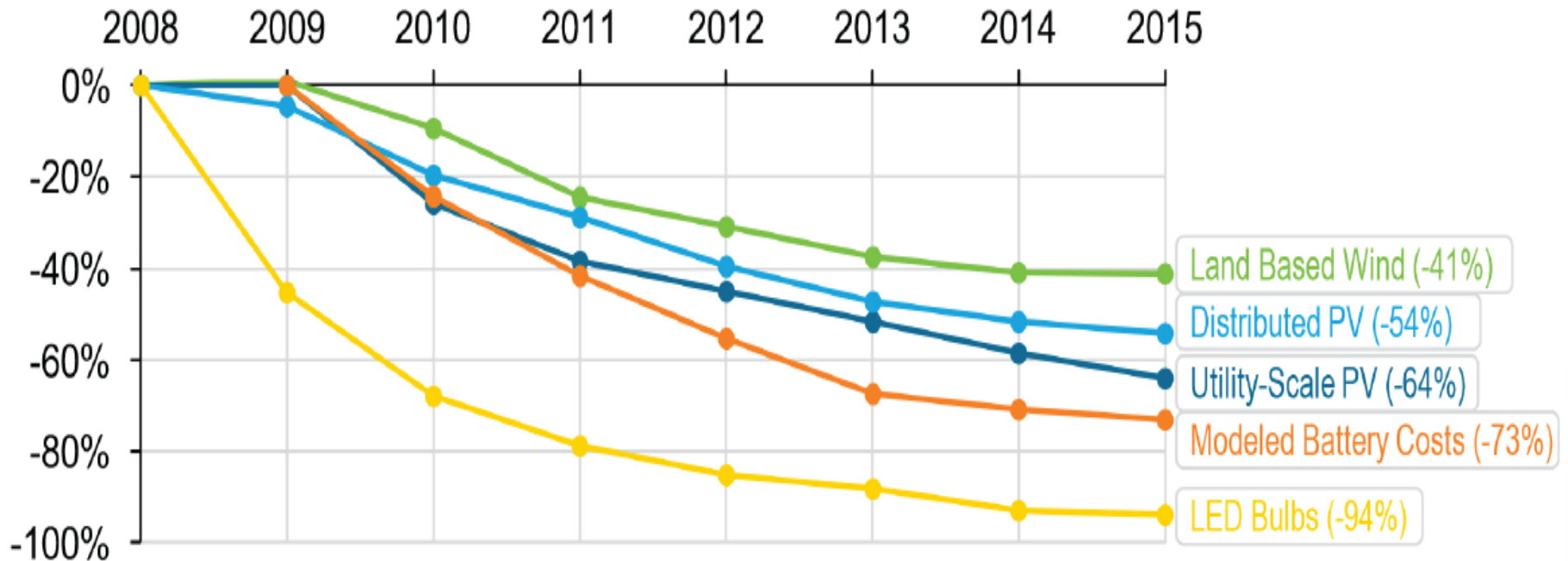
Dr. Sunita Satyapal

Director
Fuel Cell Technologies Office
U.S. Department of Energy

Key Messages

1. Unprecedented cost reduction and market growth in clean energy technologies

Cost Reductions since 2008



Notes: Land based wind costs are derived from levelized cost of energy from representative wind sites. Distributed PV cost is average residential installed cost. Utility-Scale PV cost is the median installed cost. Modeled battery costs are at high-volume production of battery systems, derived from DOE/UJS Advanced Battery Consortium PHEV Battery development projects. LED bulb costs are cost per lumen for A-type bulbs. See full report for full citations and details.

Source: U.S. Department of Energy, Revolution Now, 2016

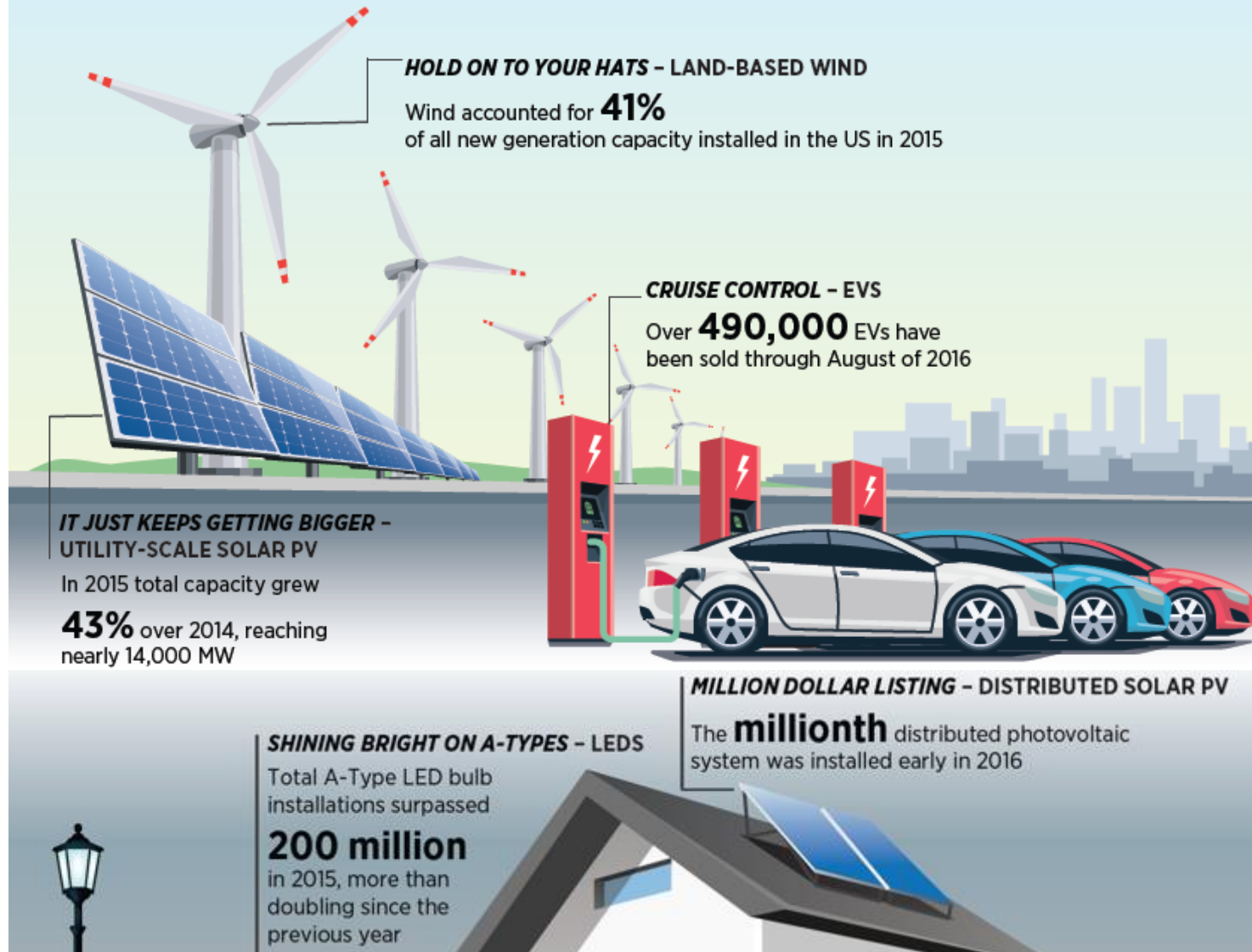
For more information: <http://energy.gov/revolution-now>

The clean energy revolution is real, and it is happening!

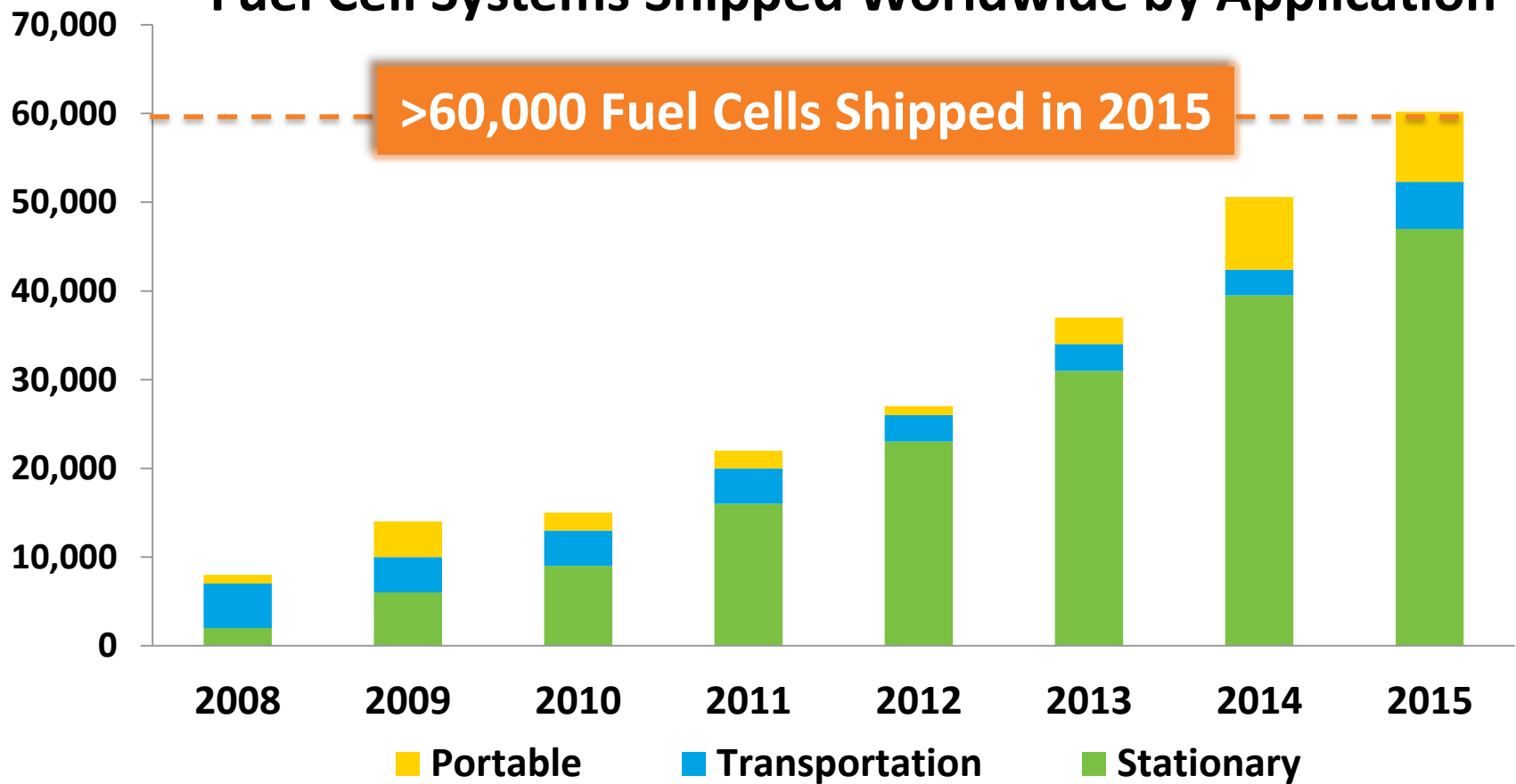
Revolution...Now 2016

Accelerating Clean Energy Deployment

<http://energy.gov/revolution-now>



Fuel Cell Systems Shipped Worldwide by Application



>60,000 Fuel Cells Shipped in 2015

Capacity shipped in 2015 → Approximately **300 MW** & **~2X** → the capacity in 2014

Source: Navigant Research (2008-2013) & E4tech (2014-2015)

Consistent ~30% annual growth since 2010

Commercial FCEVs for the First Time in History



Hyundai Tucson Fuel Cell SUV



Toyota Mirai



Honda FCV

Commercial
FCEVs are
here today!

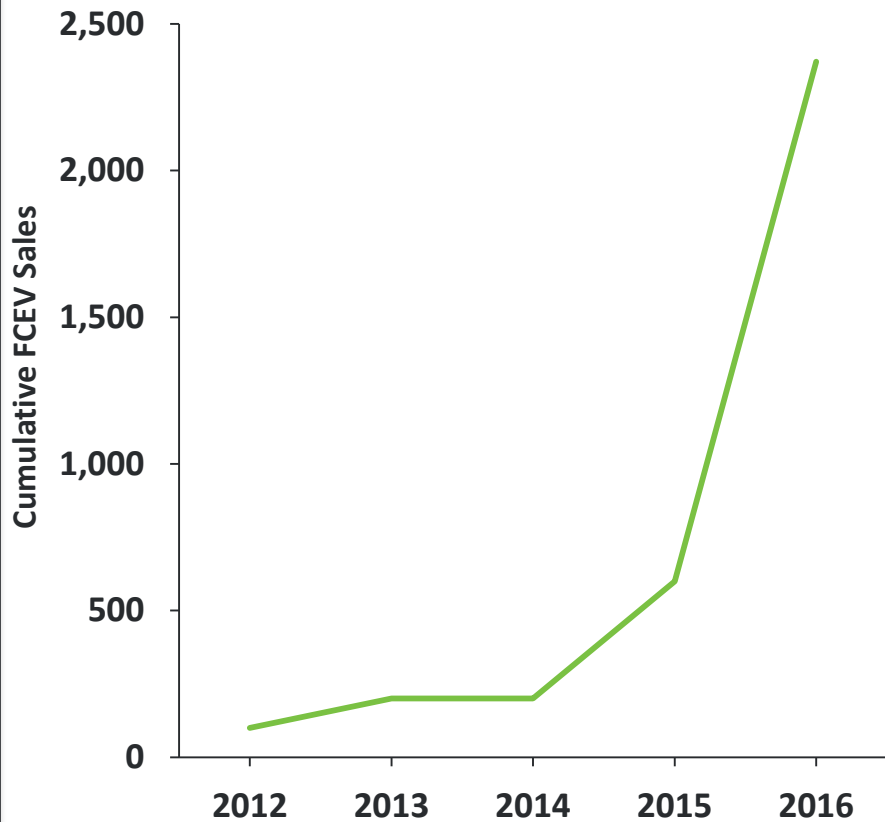
Can reduce total
GHG emissions
50-90% vs. today's
gasoline vehicles

FCEV: Fuel Cell Electric Vehicle
GHG: Greenhouse Gases

Fuel Cell Car Sales and H₂ Stations on the Rise



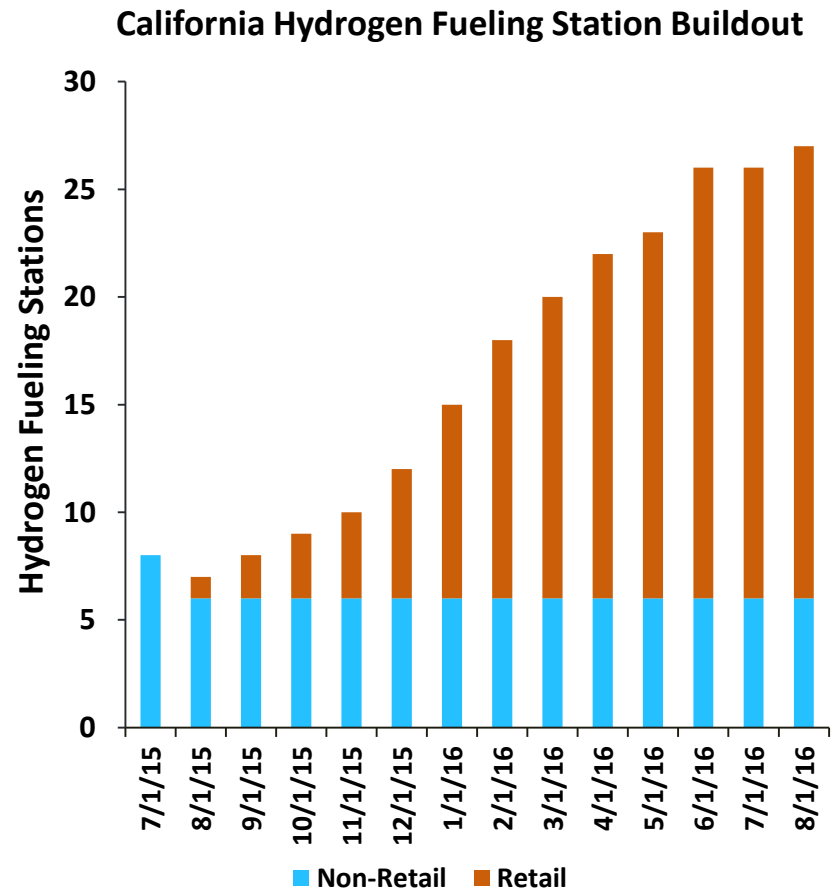
Fuel Cell Car Sales Growing Exponentially



Sources: ANL, Polk registration data, Hybridcars.com, WardsAuto.com



Number of H₂ Stations Increasing Steadily



Sources: California Energy Commission



\$1M Competition: On-site H₂ fueling

Finalist Team Announced!
More at hydrogenprize.org



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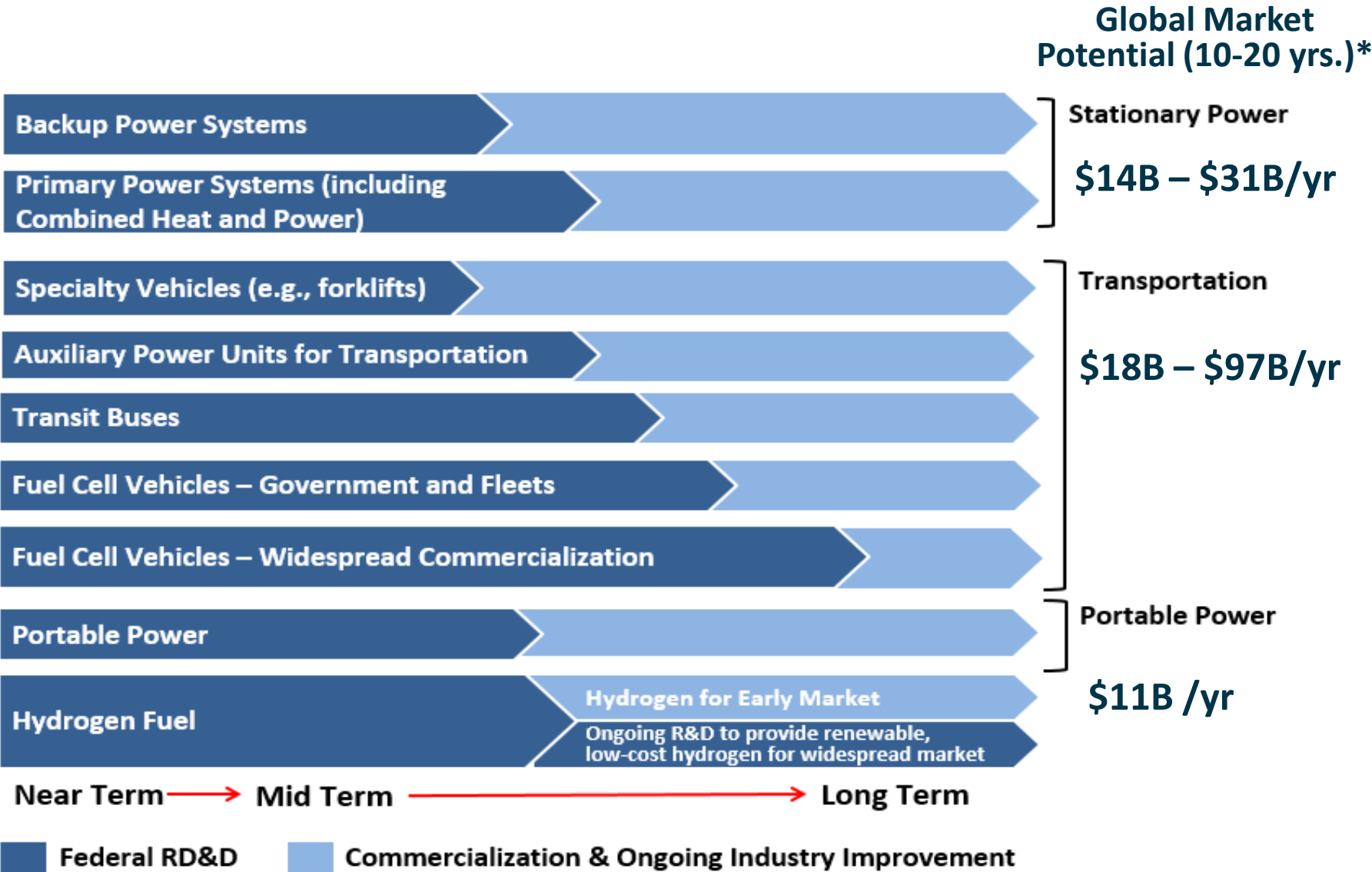
Innovative packaging concepts
Electrolysis 350 and 700 bar



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Email your Feedback
info@teamsimplefuel.com

Hydrogen and Fuel Cell Markets



* Fuel Cell Economic Development Plan, Connecticut Center for Advanced Technology, Inc. (produced for the Connecticut Department of Economic and Community Development), January 2008, http://www.ct.gov/ecd/lib/ecd/CCAT_Fuel_Cell_FINAL_Plan_1-31-08_DECD_w_participants.pdf

**2. Unprecedented
global government
support and industry
collaboration**

Key Driver- Paris Agreement at COP 21

“Let that be the common purpose here in Paris. A world that is worthy of our children. A world that is marked not by conflict, but **by cooperation**; and not by human suffering, but by human progress. A world that’s safer, and more prosperous, and more secure, and more free than the one that we inherited. **Let’s get to work.**”

- President Barack Obama at the launch of COP21



- Doubling U.S. investment in clean energy R&D
 - Spans the innovation spectrum from use-inspired research and applied energy R&D (including demonstration)
 - Includes all clean energy technologies (e.g., renewable energy, energy efficiency, and other DOE Offices)

MISSION INNOVATION
Accelerating the Clean Energy Revolution

H₂ and Fuel Cells Highlighted

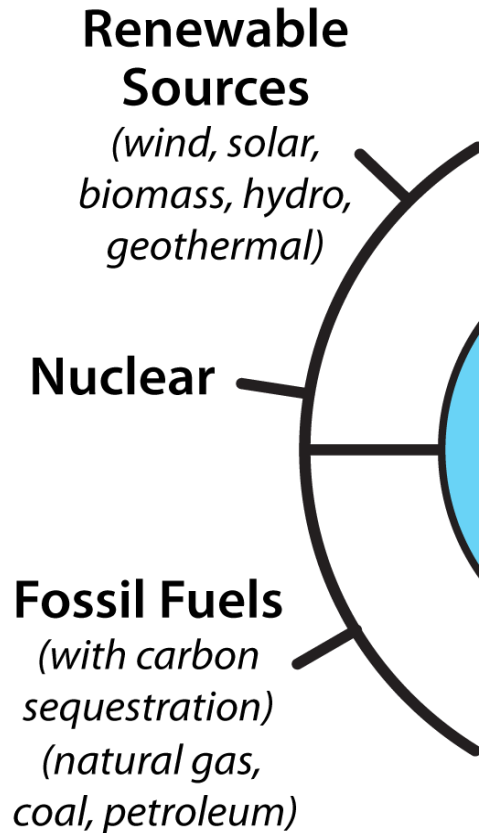
Mission Innovation Clean Energy R&D Focus Areas

	AUSTRALIA	BRAZIL	CANADA	CHILE	CHINA	DENMARK	EUROPEAN UNION	FRANCE	GERMANY	INDIA	INDONESIA	ITALY	JAPAN	KINGDOM OF SAUDI ARABIA	MEXICO	NORWAY	REPUBLIC OF KOREA	SWEDEN	UNITED ARAB EMIRATES	UNITED KINGDOM	UNITED STATES	
INDUSTRY & BUILDINGS	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
VEHICLES & OTHER TRANSPORTATION	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●		●	●
BIO-BASED FUELS & ENERGY	●	●	●		●	●	●	●	●	●	●	●			●	●	●	●	●	●	●	●
SOLAR, WIND & OTHER RENEWABLES	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
NUCLEAR ENERGY	●	●	●		●												●		●	●	●	●
HYDROGEN & FUEL CELLS	●	●	●			●	●	●	●	●			●	●		●	●			●	●	●
CLEANER FOSSIL ENERGY		●	●		●	●			●	●	●			●			●					●
CO ₂ CAPTURE, UTILIZATION & STORAGE	●	●	●		●	●	●	●	●				●	●	●	●	●		●	●	●	●
ELECTRICITY GRID	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●
ENERGY STORAGE	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●
BASIC ENERGY RESEARCH	●		●			●	●	●	●	●	●	●	●	●		●		●	●			●

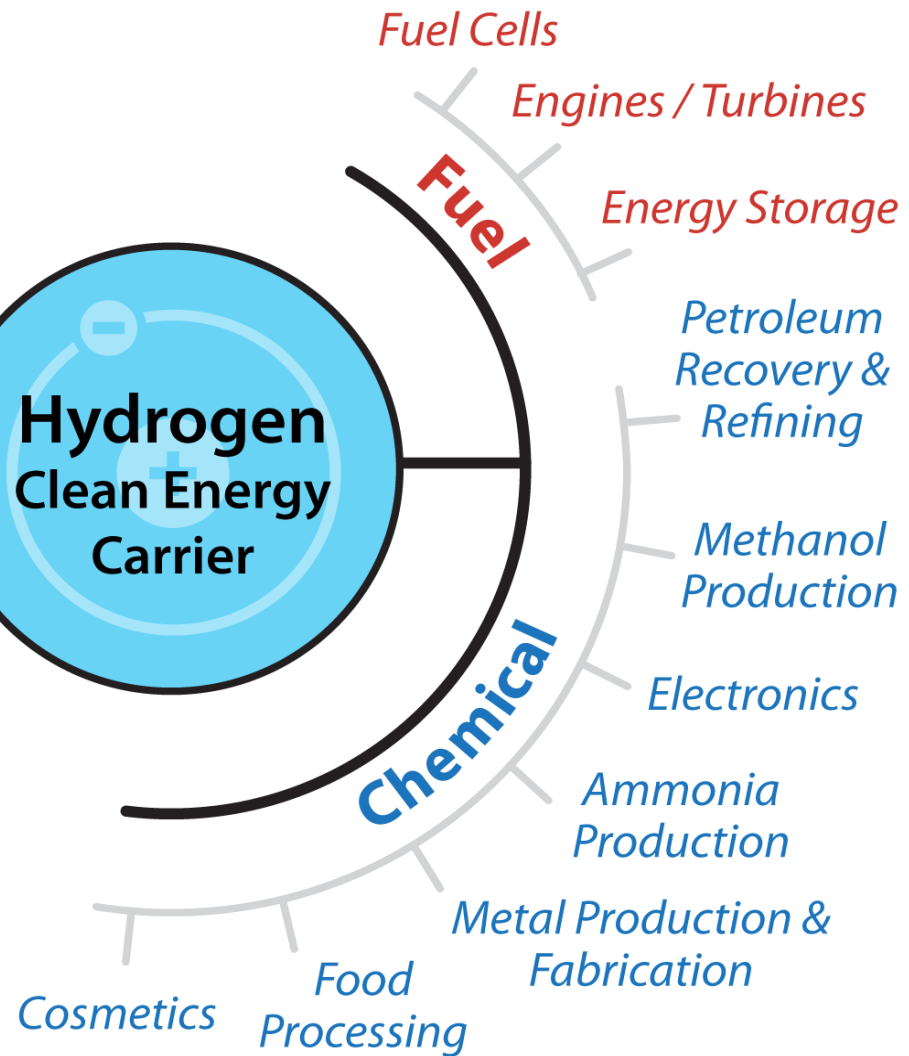
Indicators are for key areas of R&D investment, but do not imply a comprehensive representation of a country's full R&D portfolio.

Hydrogen- An energy carrier and feedstock

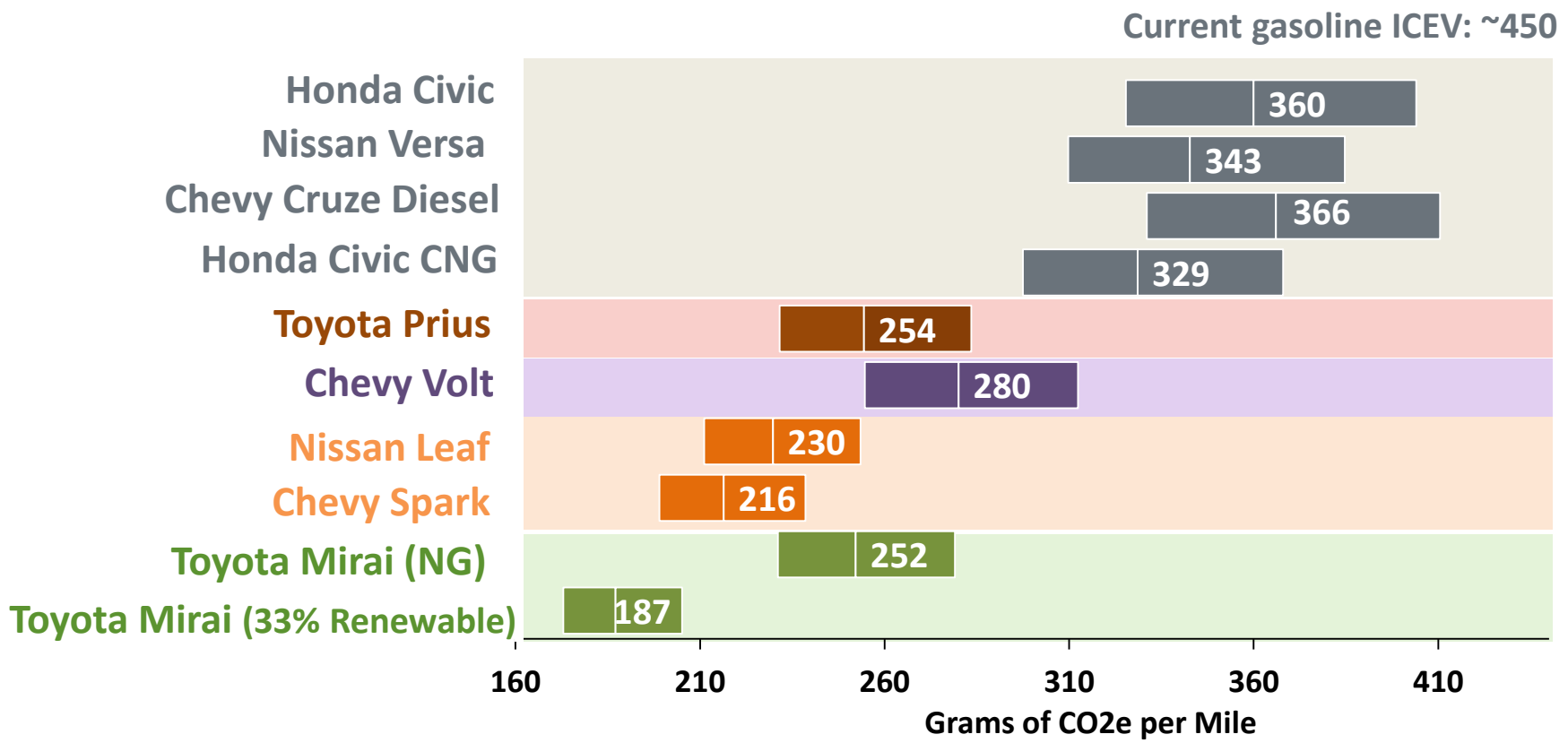
Diverse Energy Sources



Diverse Applications



Low, Medium & High GHGs/Mile for 2015 Technology



**3. Need to address
remaining challenges to
enable market
penetration and success**

DOE Activities: RDD&D



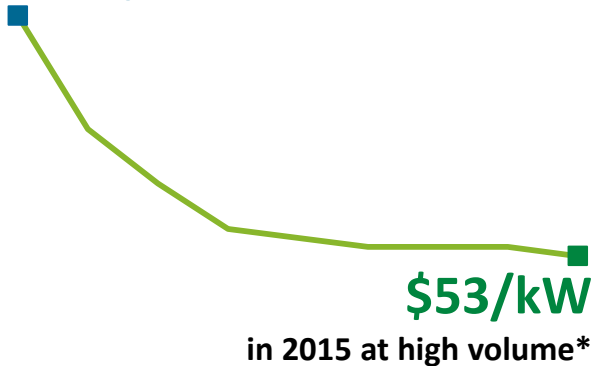
1.

Research & Development

Fuel Cells

- Cut cost in half since 2007
- 5X less platinum
- 4X increase in durability

\$106/kW in 2007



*\$280/kW low volume



2.

Demonstration

Forklifts, back-up power, airport cargo trucks, parcel delivery vans, marine APUs, buses, mobile lighting, refuse trucks

>220 FCEVs, >30 stations, >6M miles traveled

World's first tri-gen station
 H₂ technology station in Washington D.C.

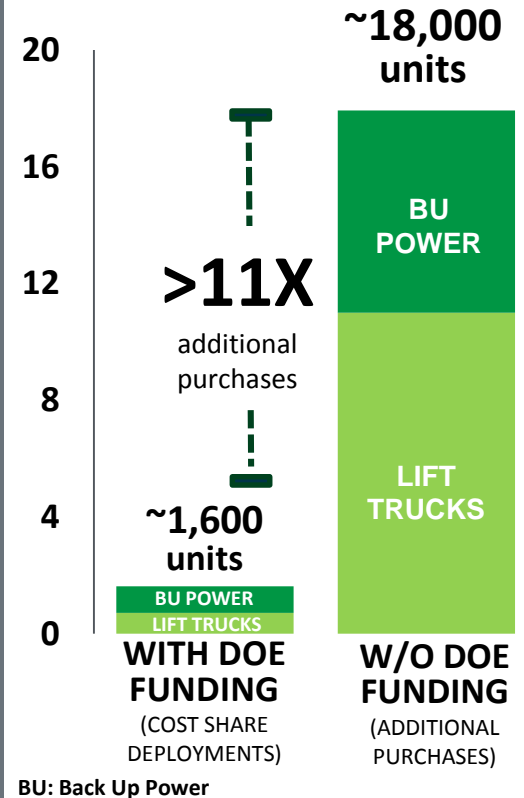


FCEV: Fuel Cell Electric Vehicle



3.

Deployment



BU: Back Up Power

Examples of consortia supporting R&D



Supporting Deployment



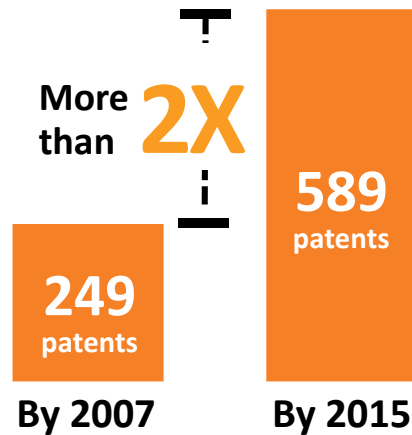
Collaboration to address H₂ Infrastructure Barriers

Examples of Impact: H₂ and Fuel Cells



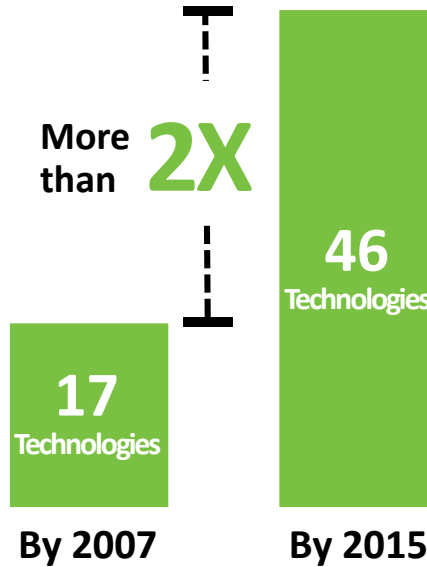
Innovation

Cumulative Number of **Patents** due to DOE funds



Commercialization

Cumulative Number of **Commercial Technologies** Entering the Market



Economy and Environment

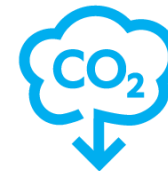
U.S. Job Potential*

360K to 675K jobs in fuel cells and hydrogen 

Job gains across **41 industries**

* 2008 DOE Employment Study currently being updated

GHG Emission Reduction



More than **50% - 90%** per vehicle

GHG: Greenhouse Gases

Examples of Commercial Technologies

- Catalysts
- Fuel Cell System Components
- Tanks
- Electrolyzers

Impact of DOE Investment on Industry

Revenues

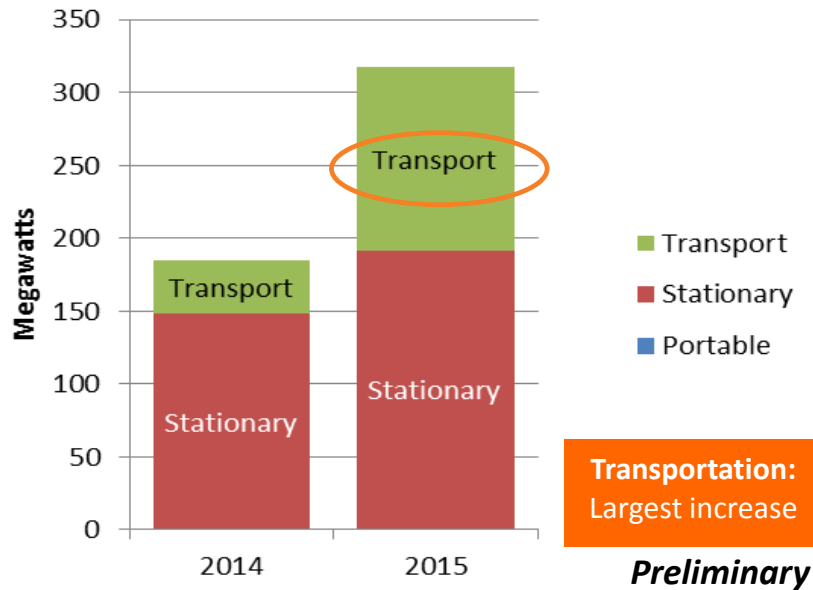
More than **7X** the DOE Investment

Additional Investment

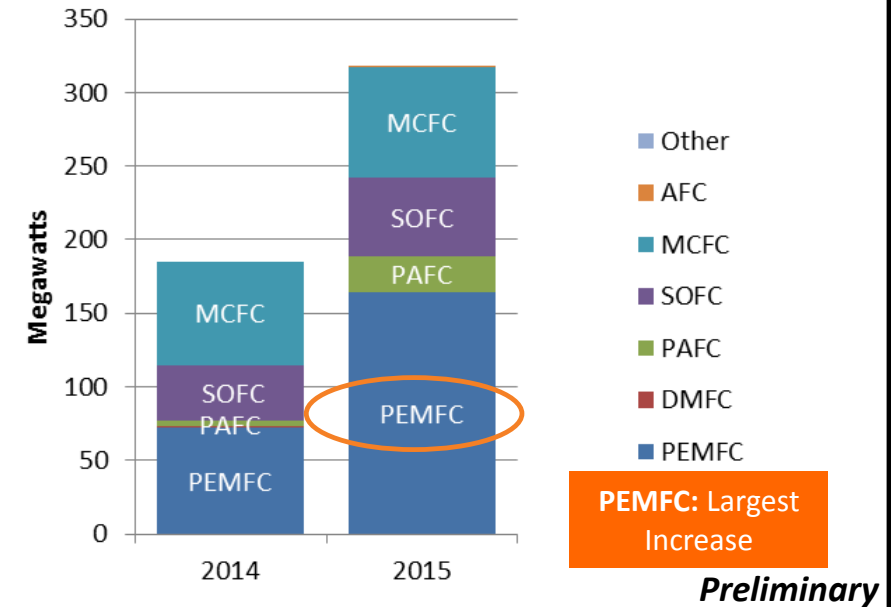
More than **5X** the DOE Investment

*for selected companies

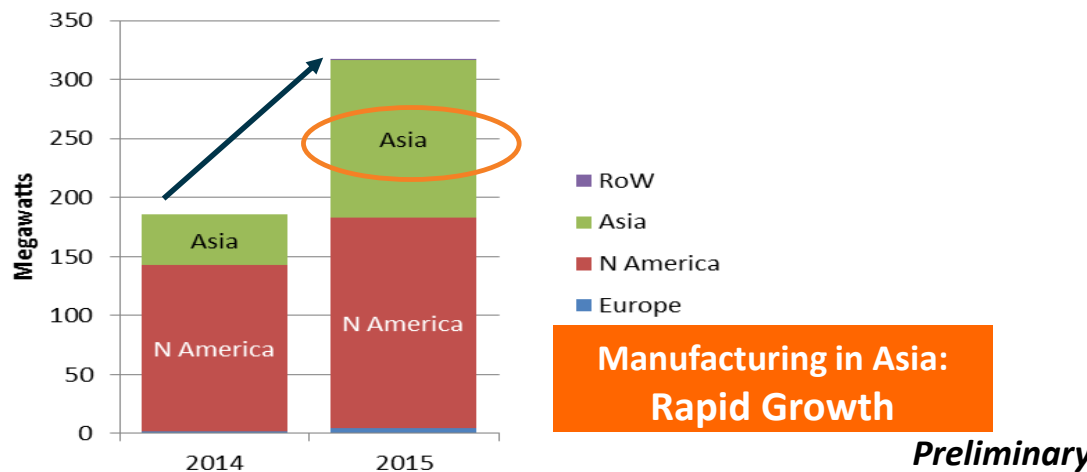
Worldwide Shipments by Application



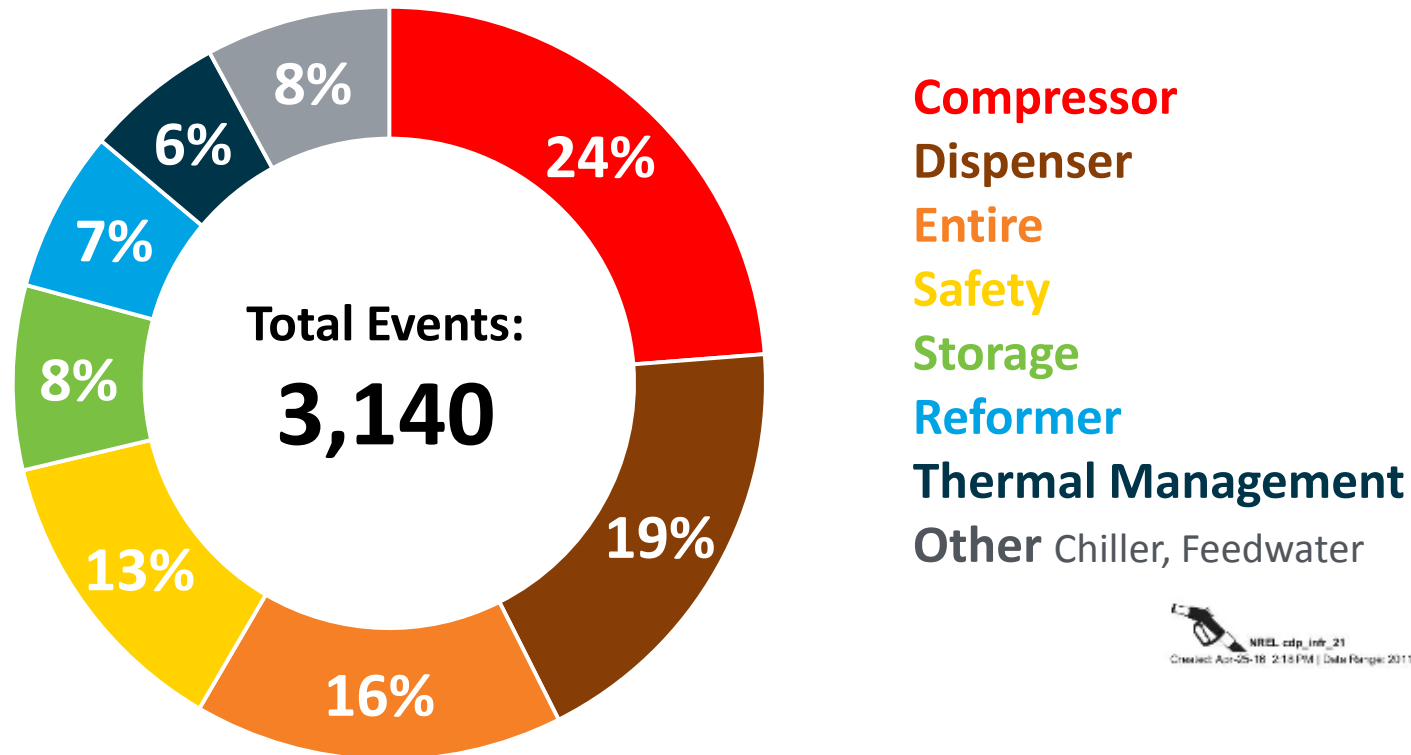
Worldwide Shipments by Fuel Cell Type



Worldwide Shipments by Region of Manufacture



Example: Sources of H₂ Infrastructure Maintenance



Most maintenance related to **compressors** and **dispensers**

Contamination is a key issue: See Database www.nrel.gov/hydrogen/system_contaminants_data/
To participate: techval@nrel.gov

Providing insights to guide H₂ infrastructure activities and to maximize impact

H₂ Infrastructure Development Requires Multiple Supply Chains



Station
planning
supply chain



Construction
supply chain



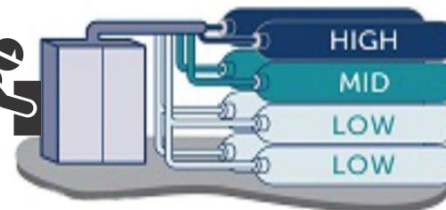
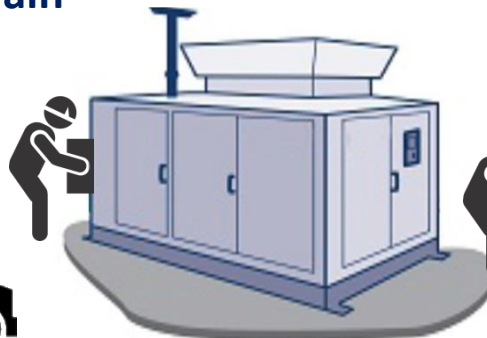
Hydrogen supply chain



**Manufacturing
Supply Chain
for H₂
infrastructure
components
(compressors,
nozzles, hoses,
etc.) is one key
piece of this
puzzle!**



Station
equipment supply
chain



Station O&M supply chain

New DOE Efforts to enable robust supply chain

Integrated Network of Regional Technical Centers



Activities

(Examples)

- Hold supply chain exchanges
- Promote cooperation between suppliers & developers, and standardization of component specifications

Locations

- East Coast (CCAT)
- Midwest (OFCC)
- Central States (NREL)
- West Coast (UC Irvine)

Global Competitiveness Analysis including:

- Global Cost Breakdown
- Design for Manufacturing & Assembly
- Value Stream Mapping

GLWN.org

Fuel Cell and H₂ Opportunity Center

- Comprehensive **online database**
- **Project activities include:**
 - Encourage **supplier engagement**
 - Release and maintain **public directory**
 - Conduct **outreach campaign** (social media, etc.)



Resources

“Toolbox” online:



- HyRAM
- HDSAM
- H2FAST
- H2A
- JOBS and more

Available now at:

<http://energy.gov/eere/fuelcells/hydrogen-analysis-toolbox>



H2Tools.org

Hydrogen Safety
Resources

HYDROGEN FUEL CELL NEXUS
Hydrogen and Fuel Cell Supply Chain Database

COMPANY TYPES PRODUCTS MATCHMAKER EDUCATION RESOURCES

Fuel Cell Vehicle

Catalyst
Compressor/Expander
Electrodes
Electrolyzer
Gauges
High Pressure Plumbing
Hydrogen Pump/Ejector
MEAs
Power Electronics
Reactant Management
Sensors
Testing

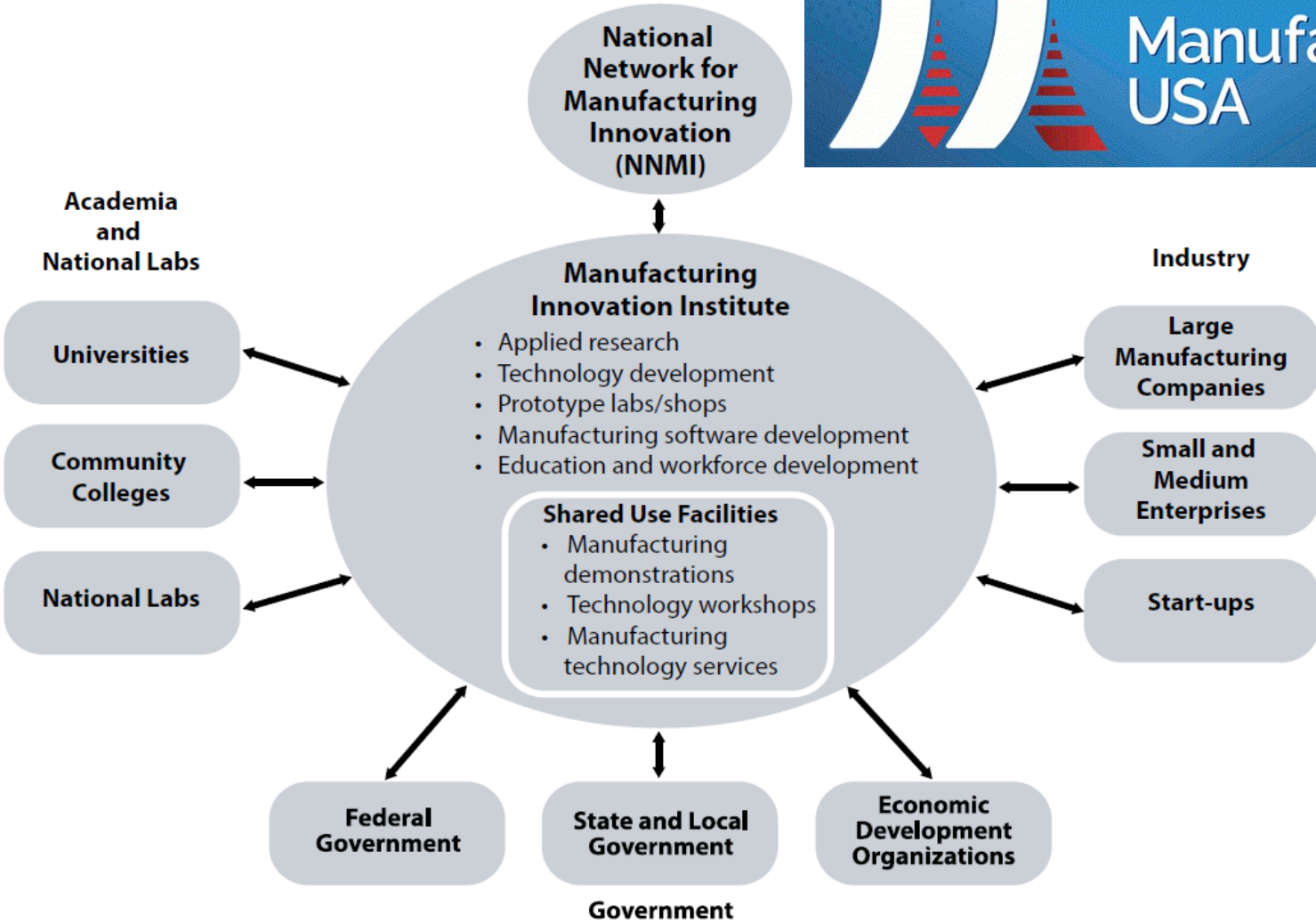
membrane electrode assembly (MEA)

power electronics
vessels & vessel liners
compressor expander
battery
MEA

Dispensing Storage Compression Generation

www.HFCnexus.com

Supplier engagement & collaboration & information readily and publicly accessible



For more information: www.manufacturing.gov

Manufacturing USA National Network for Manufacturing Innovation



9 Institutes launched, 6 more in planning stages

Objectives

1. Increase **communication** between OEMs and hydrogen and fuel cell component suppliers.
2. Support establishment of a **web-accessible database** with Virginia Clean Cities.
3. **Standardize** component and subsystem component specifications.
4. Develop strategies to lower cost, increase performance, and increase durability of components.



Status:

- Working group identifies pathways to standardization of components and subsystems – **in progress**

Accomplishments:

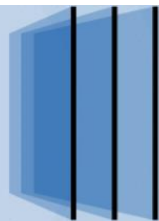
- **An integrated network** of regional Technical Exchange Centers:
 - East Coast (CCAT)
 - Midwest (OFCC)
 - Central States at NREL's National Fuel Cell Technology Evaluation Center
 - West Coast (UC Irvine)
- **The Technical Exchange Centers:**
 - Collect and catalog non-proprietary product information from regional suppliers and OEMs – **Hand off to Virginia Clean Cities (VCC)**
 - Maintain a supplier contact list to introduce OEMs to suppliers – **Hand off to VCC**
 - Hold annual supply chain exchanges - **2 held fiscal year**

Project Objectives

1. **Expand the domestic supply chain** of hydrogen components and systems.
2. **Scale-up of the fuel cell and hydrogen supply chain** by building and populating a comprehensive communications database.
3. **Drive U.S. companies to the website** via an aggressive outreach campaign.
4. **Advance hydrogen fuel cell suppliers** in the transportation, utility, industrial, commercial, and residential sectors, with a focus on the transportation sector

Progress

- ✓ Website launched: <http://hfcnexus.com/>
- ✓ Server space acquired from James Madison University
- ✓ Website design, graphics and user interface in development
- ✓ Developing branding and launch in cooperation with Department of Energy
- ✓ Data entry of 220 hydrogen and fuel cell companies into website for initial database
- ✓ Developing the Matchmaker Interface

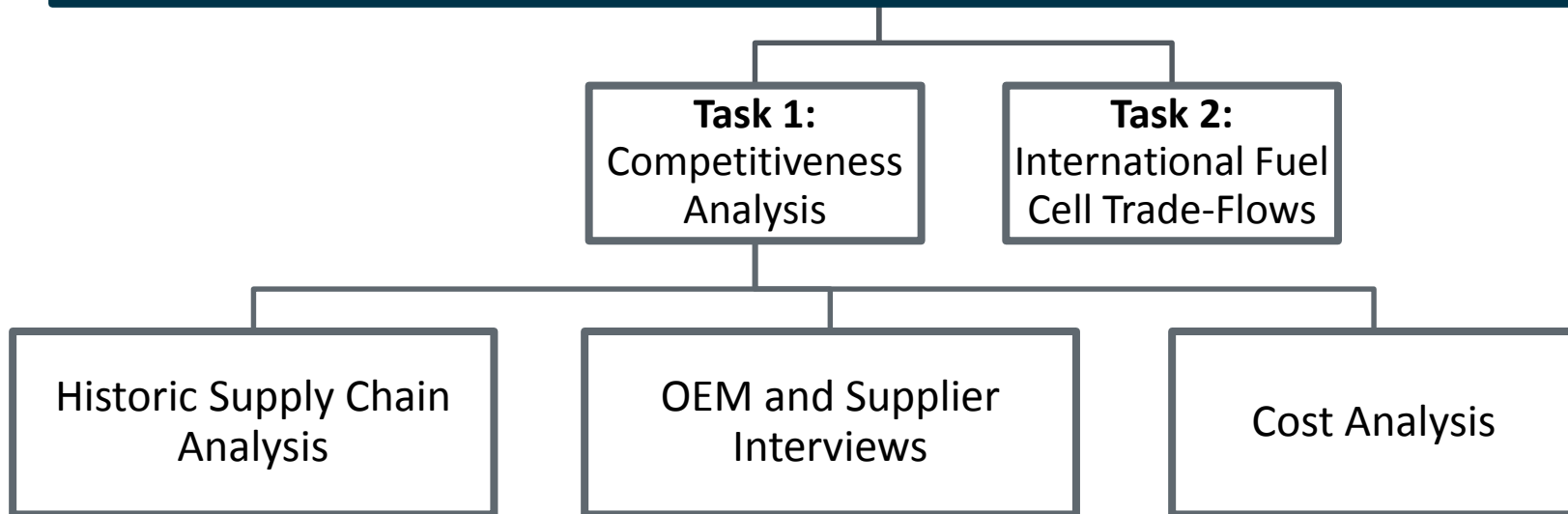


HYDROGEN
FUEL CELL
NEXUS

The US Hydrogen and
Fuel Cell Directory

Clean Energy Supply Chain and Manufacturing Competitiveness Analysis for Hydrogen and Fuel Cells

U.S Department of Energy Project DE-EE-0006935

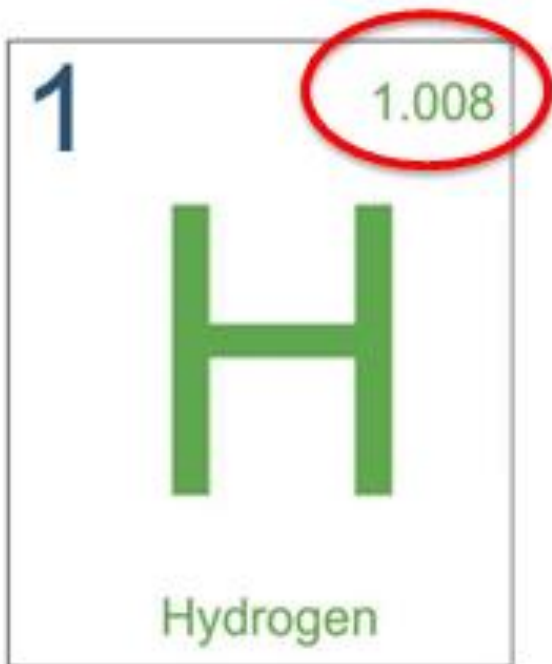


Project Summary

- **Study the state of hydrogen and fuel cell manufacturing**
- **Characterize the factors that impact the global competitiveness of fuel cell- and hydrogen-related manufacturing**



National Hydrogen &
Fuel Cell Day | 10-08



**10-08: National
Hydrogen &
Fuel Cell Day**
(Held on its very
own atomic-
weight-day)

Job Resources and Outreach for Veterans

Outreach & Education



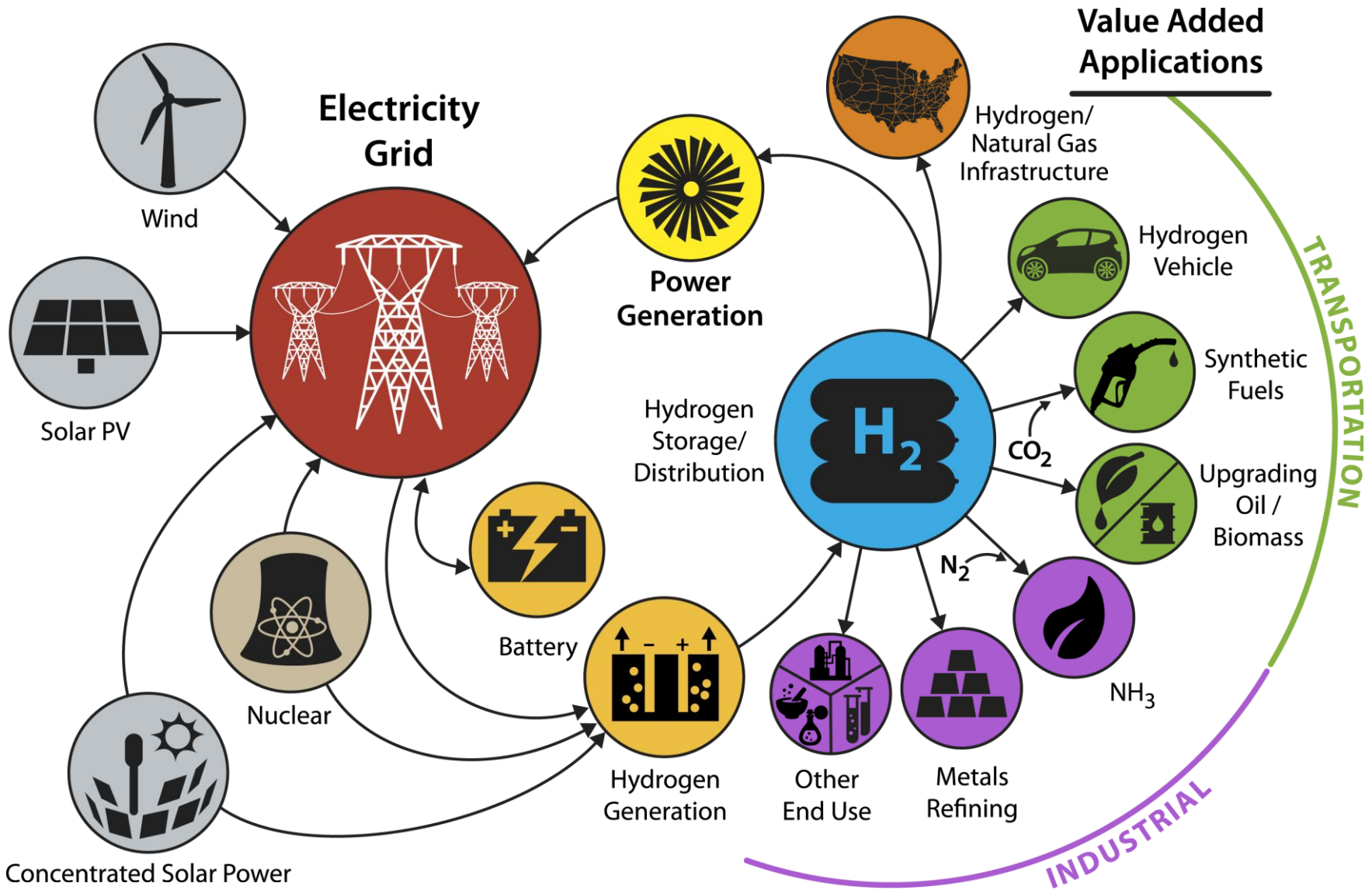
- **San Diego Military Community Transition Summit:** April 21, California
- **Camp Pendleton Military Summit:** Sep. 28-29, California
- **Joint Base Lewis McChord Military Summit:** Oct. 12-13, Tacoma, WA
- **Hawaii Transition Summit,** October 18, 19, Honolulu, Hawaii

Resources & Models



- **JOBS Models**
 - JOBS and economic impacts of Fuel Cells (JOBS FC)
 - JOBS and economic impacts of Hydrogen infrastructure (JOBS H2)
 - <http://JOBSmodels.es.anl.gov>
- **Employment Report Update**





*Illustrative example, not comprehensive

*Illustrative example, not comprehensive
Source: NREL

Overarching Goal: Enable a robust, high quality and low cost domestic supply chain for the hydrogen and fuel cell industry across applications

Today's session: 9 am to 2:45 pm

- 1. Present industry status, challenges, supply chain needs/gaps**
- 2. Enhance interaction between OEMs, developers, system integrators and supply chain/component participants**

Post session:

Individual supply chain and developer exchange



Napoleon Hill

“It is literally true that you can succeed best and quickest by helping others to succeed”

Thank You

Sunita Satyapal, Director

Nancy Garland, Technology Manager, Manufacturing R&D

Greg Kleen, Project Manager, Education & Outreach, Technology Acceleration

Fuel Cell Technologies Office

hydrogenandfuelcells.energy.gov