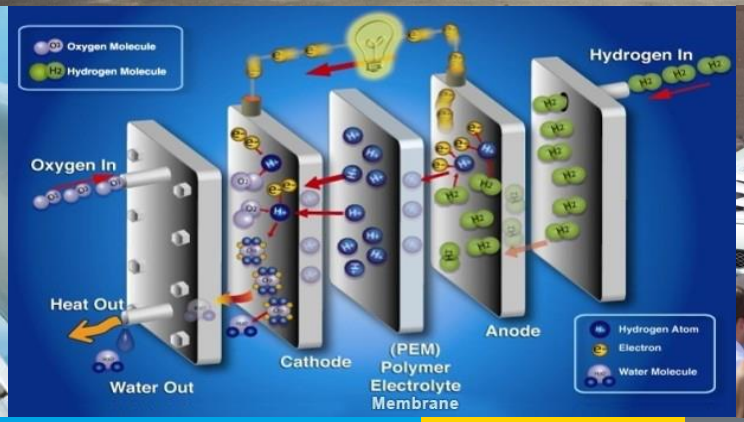
U.S. Department of Energy Hydrogen and Fuel Cells Program

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

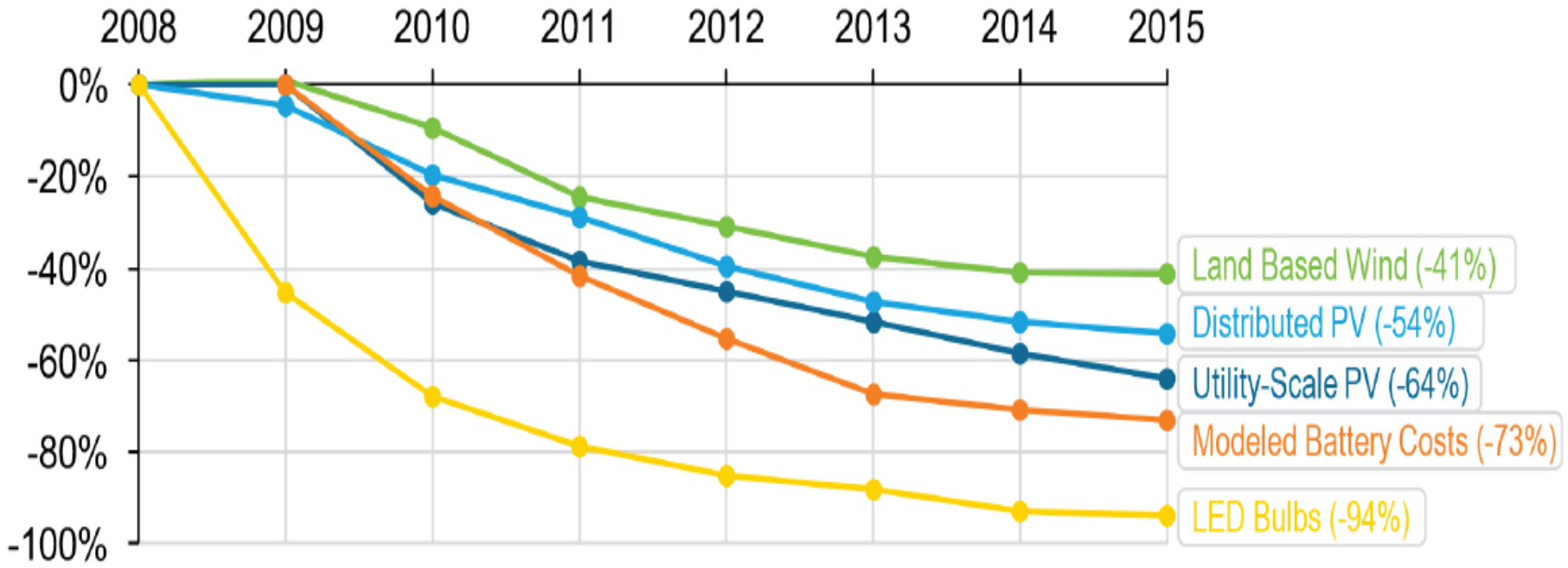
Director
Fuel Cell Technologies Office
U.S. Department of Energy

Key Messages

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

A Revolution Now

Cost Reductions since 2008

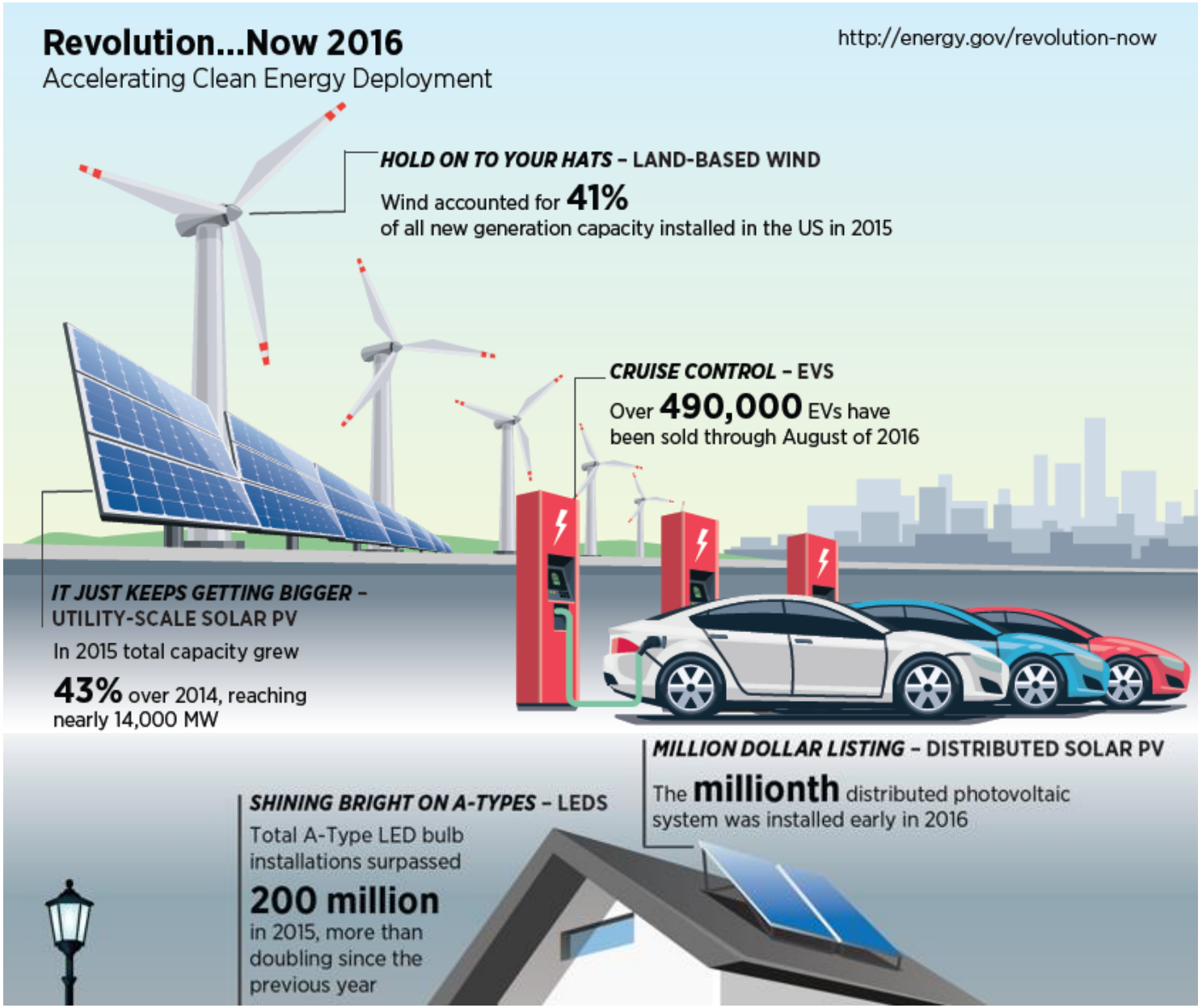


Notes: Land based wind costs are derived from levelized cost of energy from representative wind sites. Distributed PV cost is average residential installed cost. Utility-Scale PV cost is the median installed cost. Modeled battery costs are at high-volume production of battery systems, derived from DOE/UIS 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

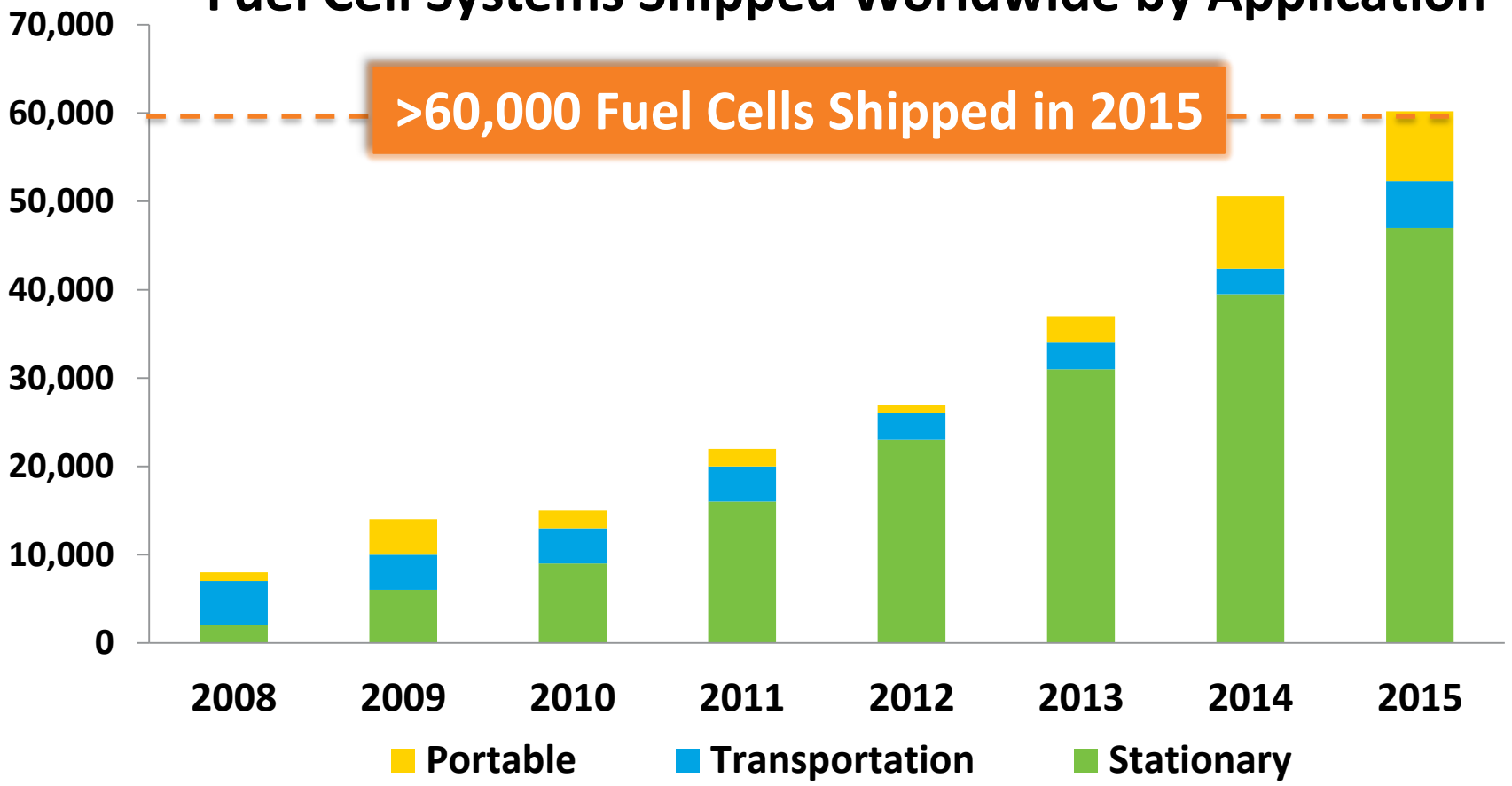
The clean energy revolution is real, and it is happening!

Clean Energy Technologies in the U.S.



Market Growth in Fuel Cells

Fuel Cell Systems Shipped Worldwide by Application



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

Complementing Retail Stations: H_2 Refuel H-Prize

H2refuel
U.S. Department of Energy

$1M Competition: On-site H_2 fueling

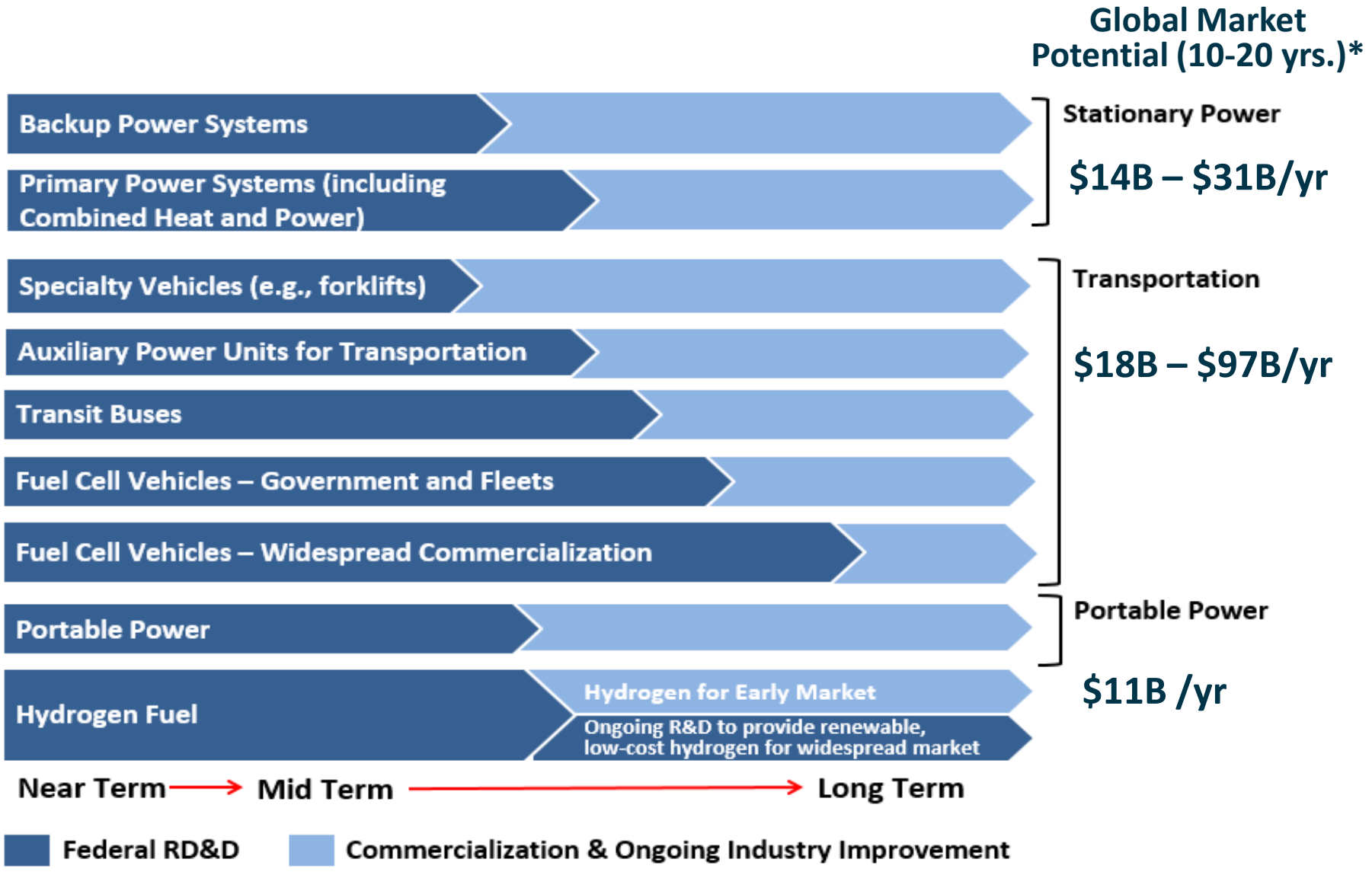
Finalist Team Announced!
More at hydrogenprize.org

simple.fuel.™

Innovative packaging concepts
Electrolysis 350 and 700 bar

Email your Feedback
info@teamsimplefuel.com

Hydrogen and Fuel Cell Markets



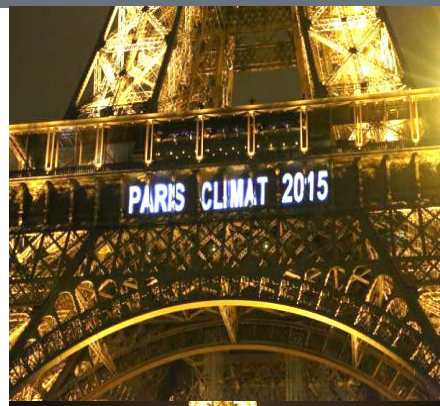
* *Fuel Cell Economic Development Plan*, Connecticut Center for Advanced Technology, Inc. (produced for the Connecticut Department of Economic and Community Development), January 2008, http://www.ct.gov/ecd/lib/ecd/CCAT_Fuel_Cell_FINAL_Plan_1-31-08_DECD_w_participants.pdf

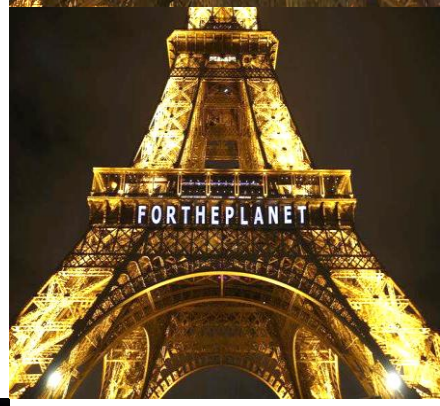
2. Unprecedented global government support and industry collaboration

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





PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

Mission Innovation

- 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

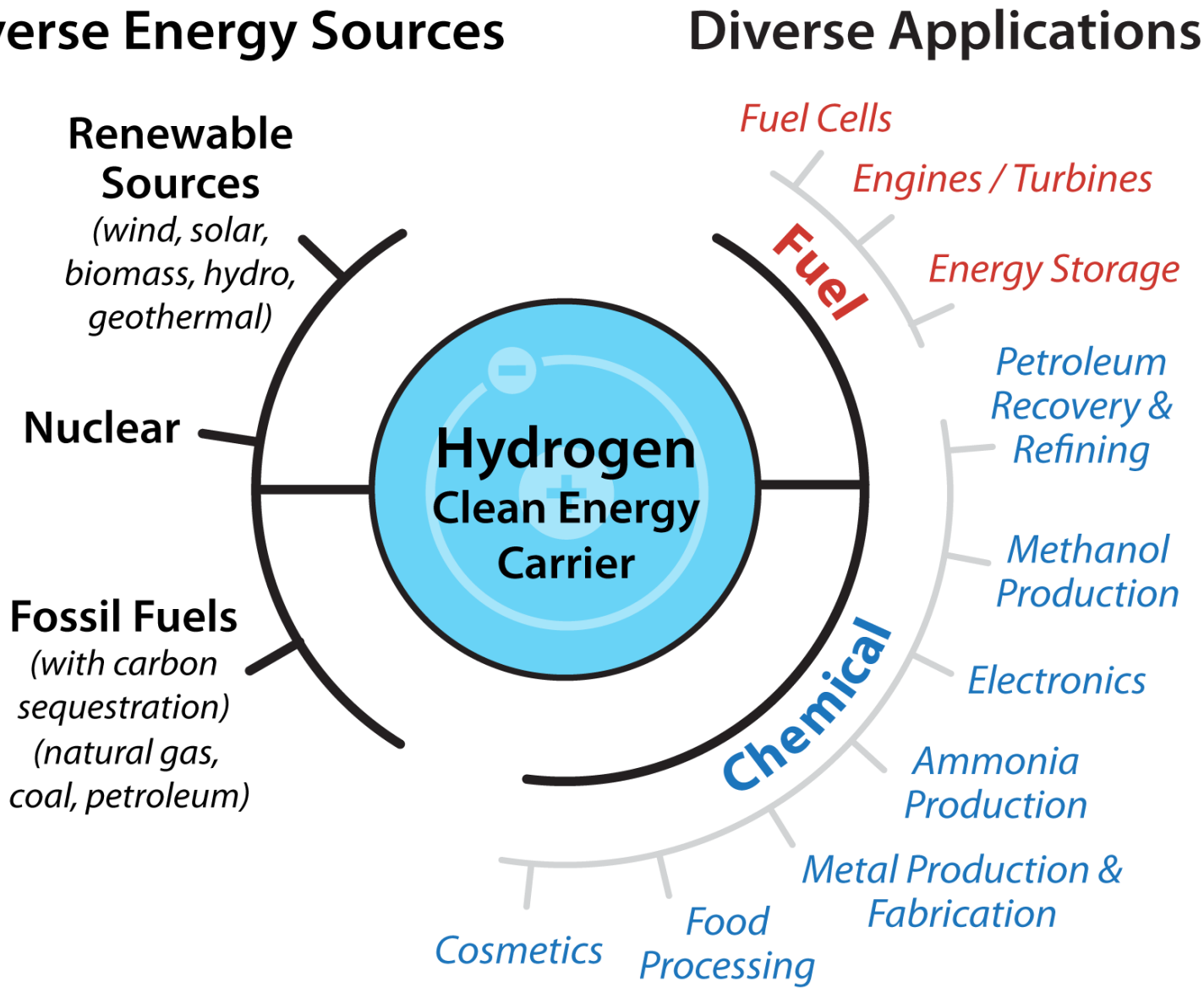
H_2 and Fuel Cells Highlighted

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	●	●	●		●	●	●	●	●				●	●	●	●	●		●	●	●
ELECTRICTY 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



Source: DOE, NREL, Hydrogen and Fuel Cell Program

Life-cycle GHG Emissions- Today's Cars

Low, Medium & High GHGs/Mile for 2015 Technology

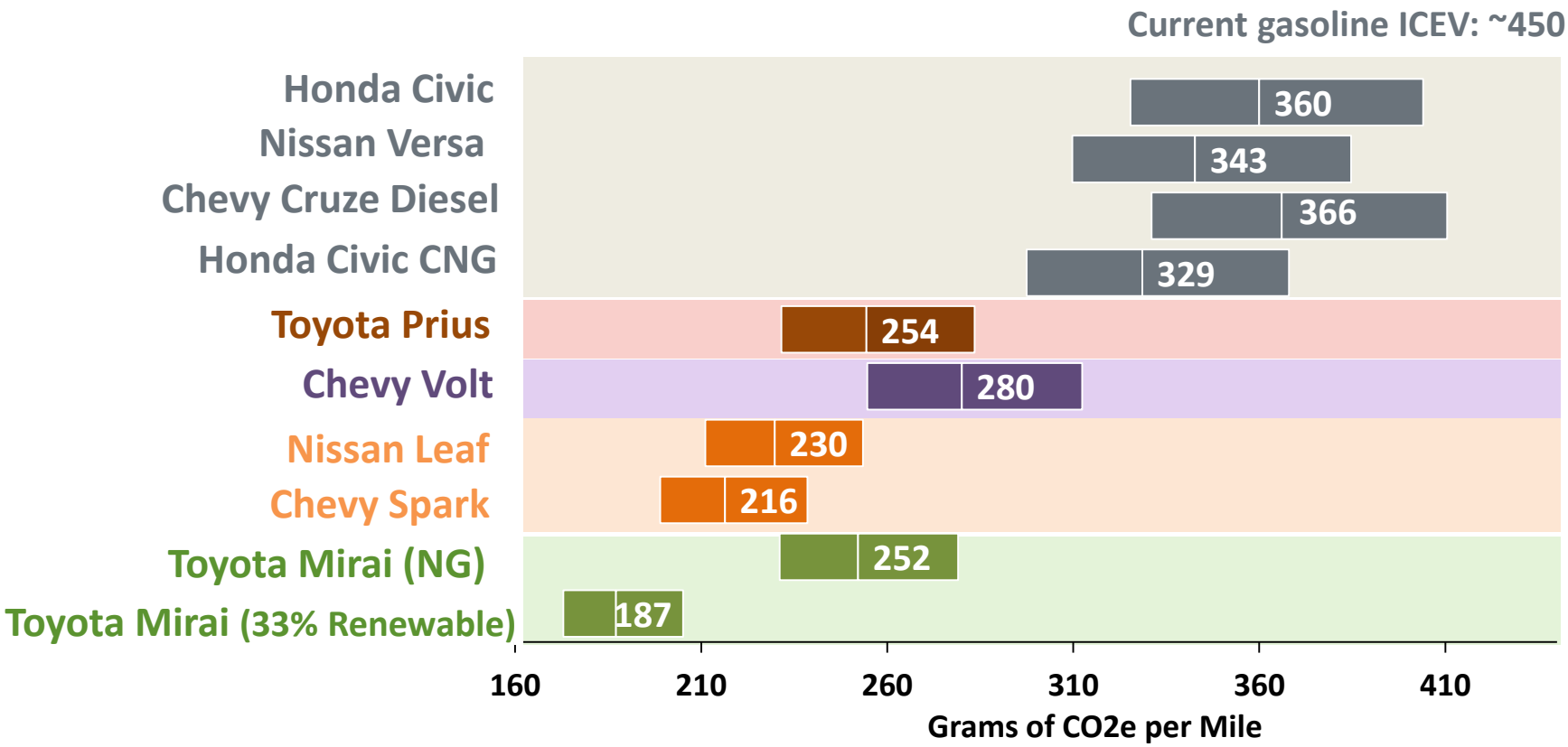
Internal Combustion Engine

Hybrid Electric

Extended-Range Electric

Battery Electric

Fuel Cell Electric



Joint VTO-FCTO Analysis Example

Source: Program Record 16004
(https://www.hydrogen.energy.gov/pdfs/16004_life-cycle_ghg_oil_use_cars.pdf)

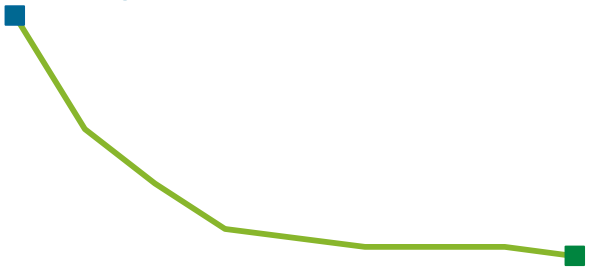
3. Need to address remaining challenges to enable market penetration and success

DOE Activities: RDD&D

1. Research & Development

Fuel Cells

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



*$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

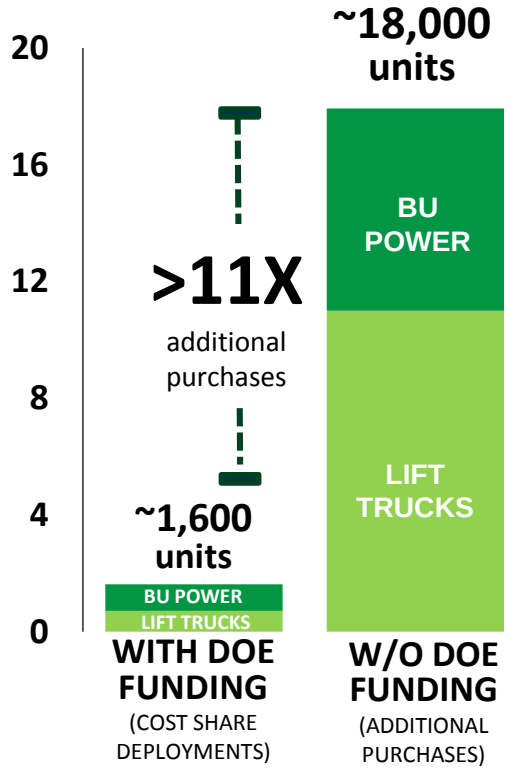
World's first tri-gen station

H_2 technology station in Washington D.C.




FCEV: Fuel Cell Electric Vehicle

3. Deployment



BU: Back Up Power

Examples of consortia supporting R&D

- FCPAD (Fuel Cell Performance and Durability) — Fuel Cell Performance & Durability
- HyMARC — Advanced H_2 Storage Materials
- ElectroCat (Electrocatalysis Consortium) — PGM-Free Catalysts for Fuel Cells
- HydroGen (Advanced Water Splitting Materials) — Renewable H_2 Production

Supporting Deployment

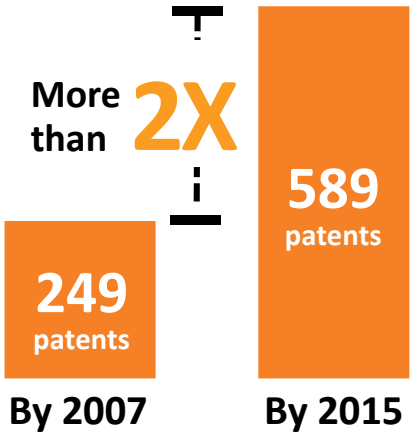
H_2 USA

Collaboration to address H_2 Infrastructure Barriers

Examples of Impact: H_2 and Fuel Cells

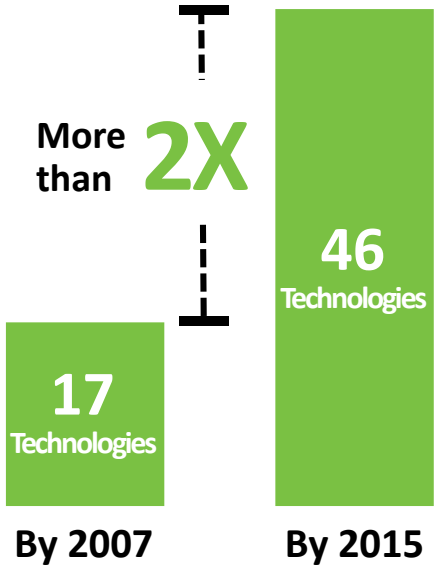
Innovation

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

CO_2

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

GHG: Greenhouse Gases

Examples of Commercial Technologies

- Catalysts
- Fuel Cell System Components
- Tanks
- Electrolyzers

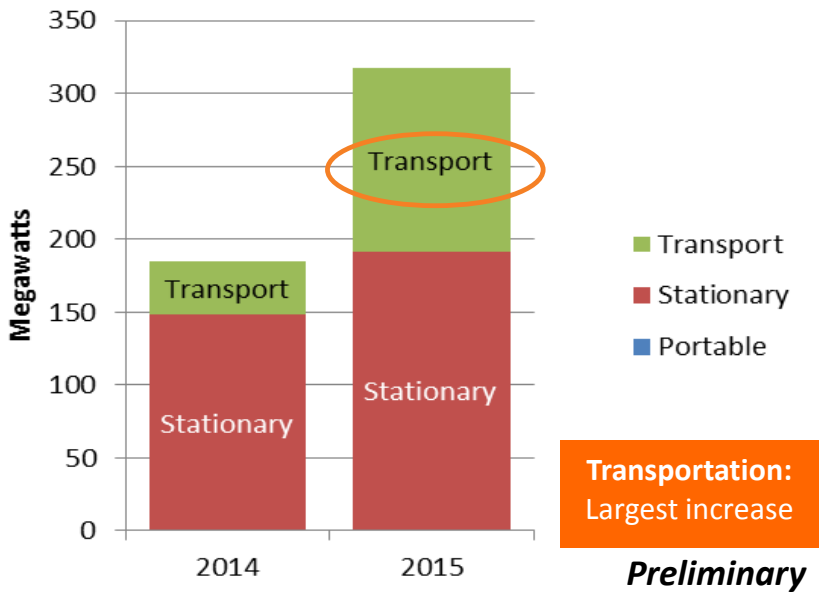
Impact of DOE Investment on Industry

Revenues	Additional Investment
More than 7X the DOE Investment	More than 5X the DOE Investment

*for selected companies

Asia and Transportation Applications: Rapid Growth Areas

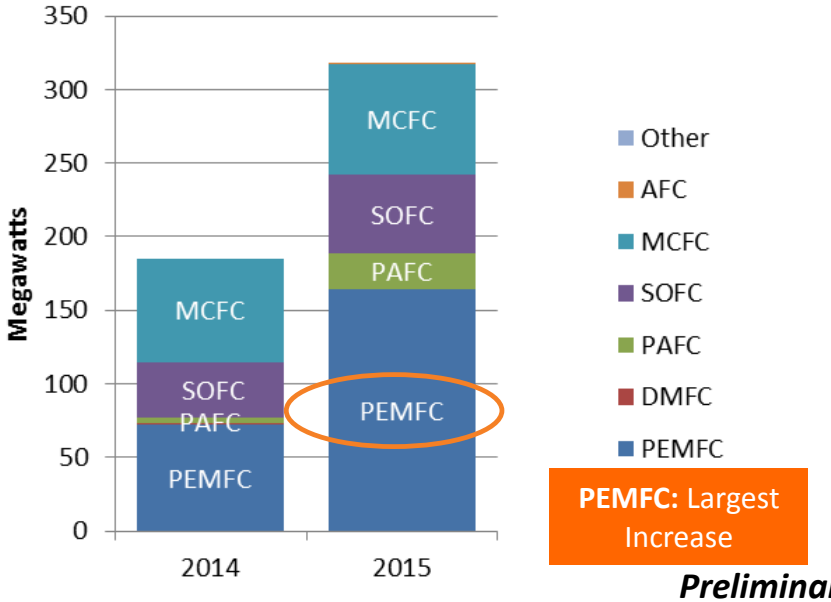
Worldwide Shipments by Application



Transportation: Largest increase

Preliminary

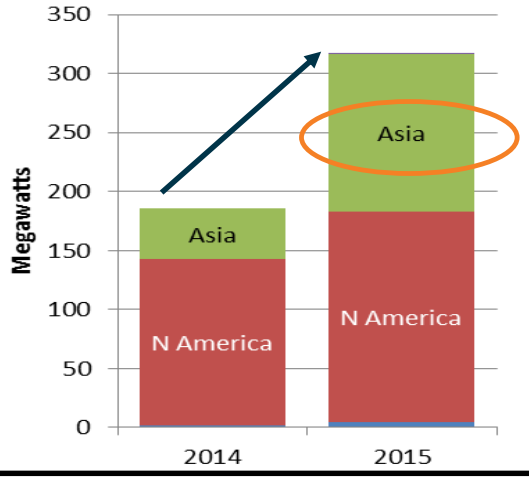
Worldwide Shipments by Fuel Cell Type



PEMFC: Largest Increase

Preliminary

Worldwide Shipments by Region of Manufacture

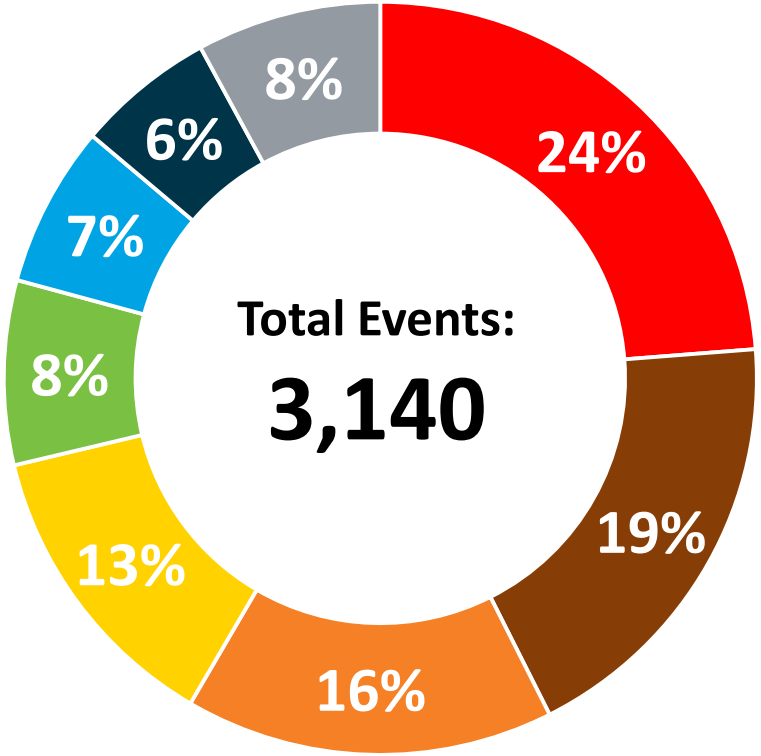


Manufacturing in Asia: Rapid Growth

Preliminary

Real World Operation Challenges

Example: Sources of H_2 Infrastructure Maintenance



Compressor
Dispenser
Entire
Safety
Storage
Reformer
Thermal Management
Other Chiller, Feedwater

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 H_2 infrastructure activities and to maximize impact

H_2 Infrastructure Development Requires Multiple Supply Chains

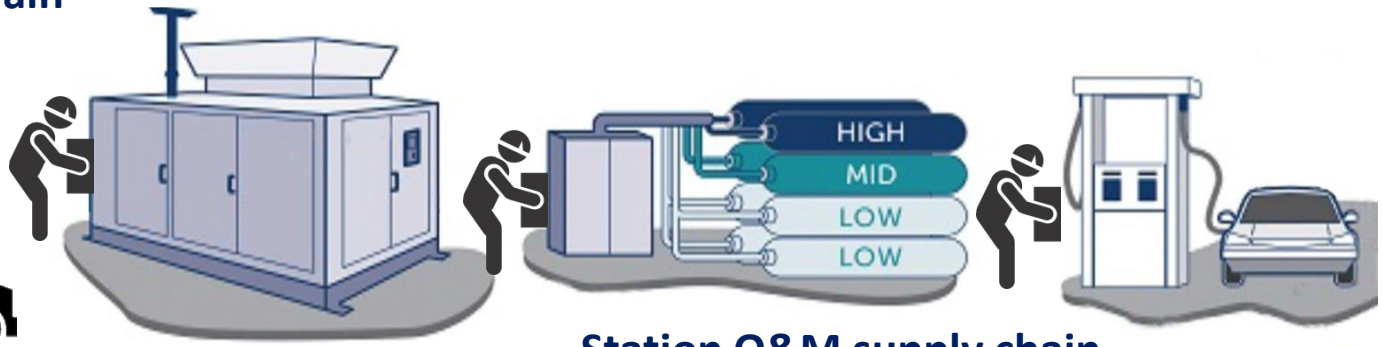
Station planning supply chain

Construction supply chain

Manufacturing Supply Chain for H_2 infrastructure components (compressors, nozzles, hoses, etc.) **is one key piece of this puzzle!**

Station equipment supply chain

Hydrogen supply chain



Station O&M supply chain

New DOE Efforts to enable robust supply chain

Integrated Network of Regional Technical Centers

OFCC
OHIO FUEL CELL COALITION

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 H_2 Opportunity Center

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

Virginia Clean Cities

JAMES MADISON UNIVERSITY

Tools, Models and Databases Online

Resources

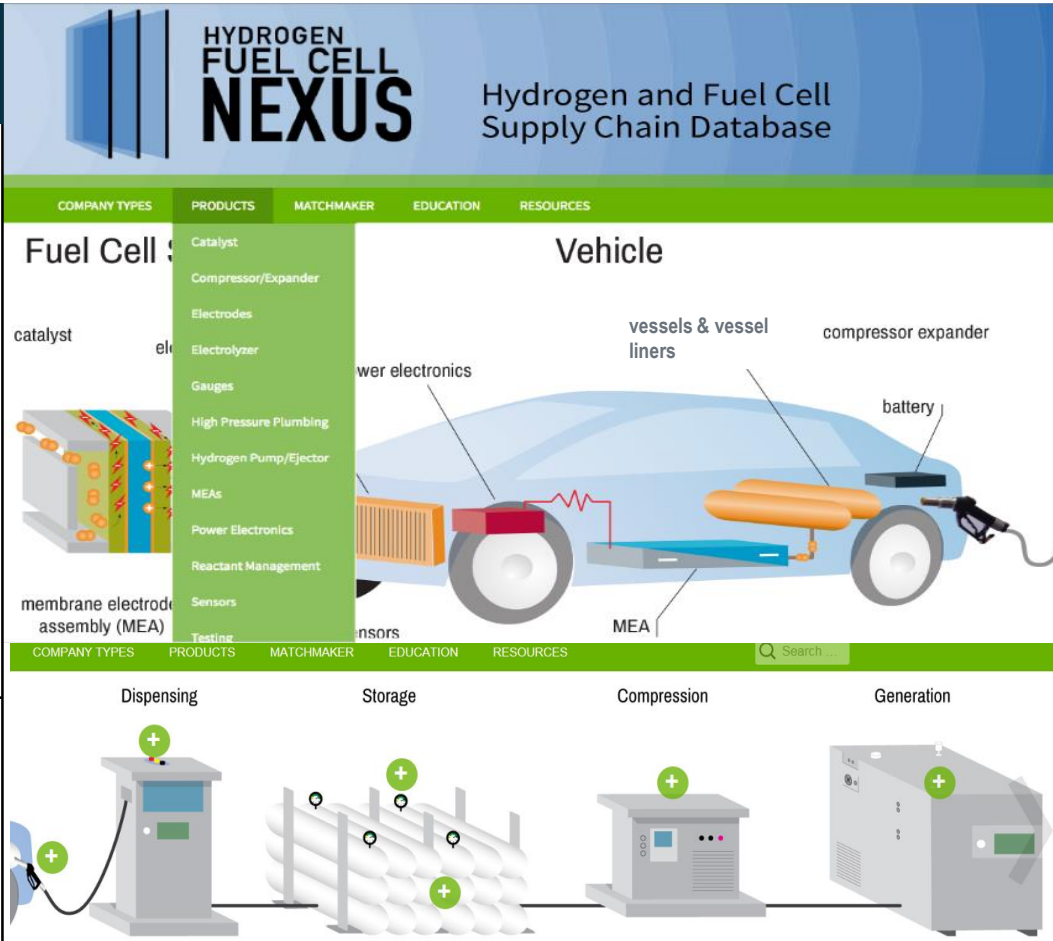
"Toolbox" online:

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

Available now at:
http://energy.gov/eere/fuelcells/hydrogen-analysis-toolbox

H2Tools.org

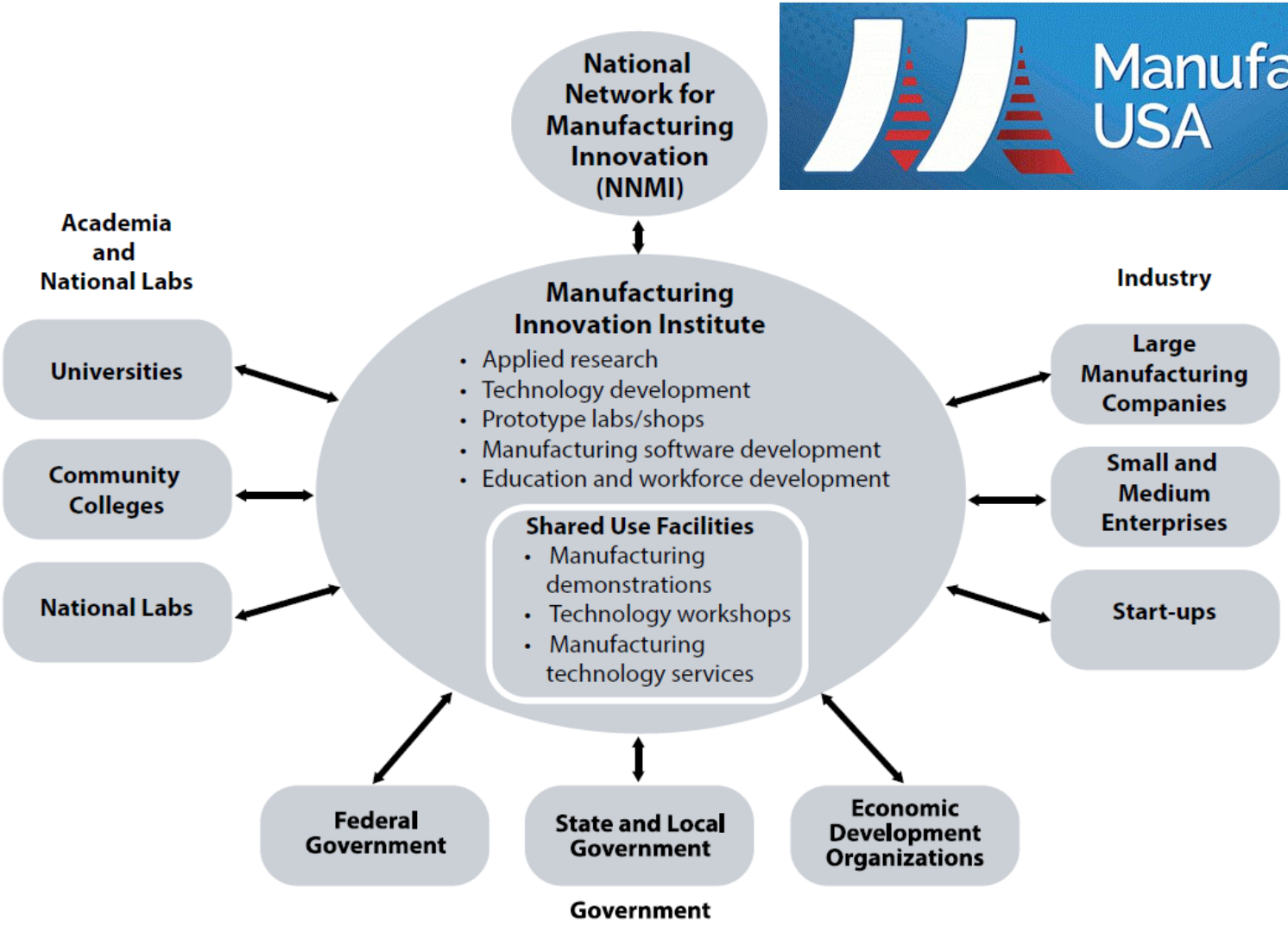
Hydrogen Safety Resources



www.HFCnexus.com

Supplier engagement & collaboration & information readily and publicly accessible

Manufacturing Institutes



For more information: www.manufacturing.gov

Working together to accelerate domestic manufacturing

Manufacturing Institutes

Manufacturing USA

National Network for Manufacturing Innovation

America Makes
National Additive Manufacturing Innovation Institute

DMDII
DIGITAL MANUFACTURING AND DESIGN INNOVATION INSTITUTE

AIM photonics
AMERICAN INSTITUTE for MANUFACTURING INTEGRATED PHOTONICS

CLEAN ENERGY SMART MANUFACTURING INNOVATION INSTITUTE

PowerAmerica

NEXTFLEX

lift
LIGHTWEIGHT INNOVATIONS FOR TOMORROW

afffoa

Advanced Functional Fabrics of America

The Institute for iacmi Advanced Composites Manufacturing Innovation
THE COMPOSITES INSTITUTE

9 Institutes launched, 6 more in planning stages

OFCC - Regional Technical Exchange Centers

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**

Virginia Clean Cities

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

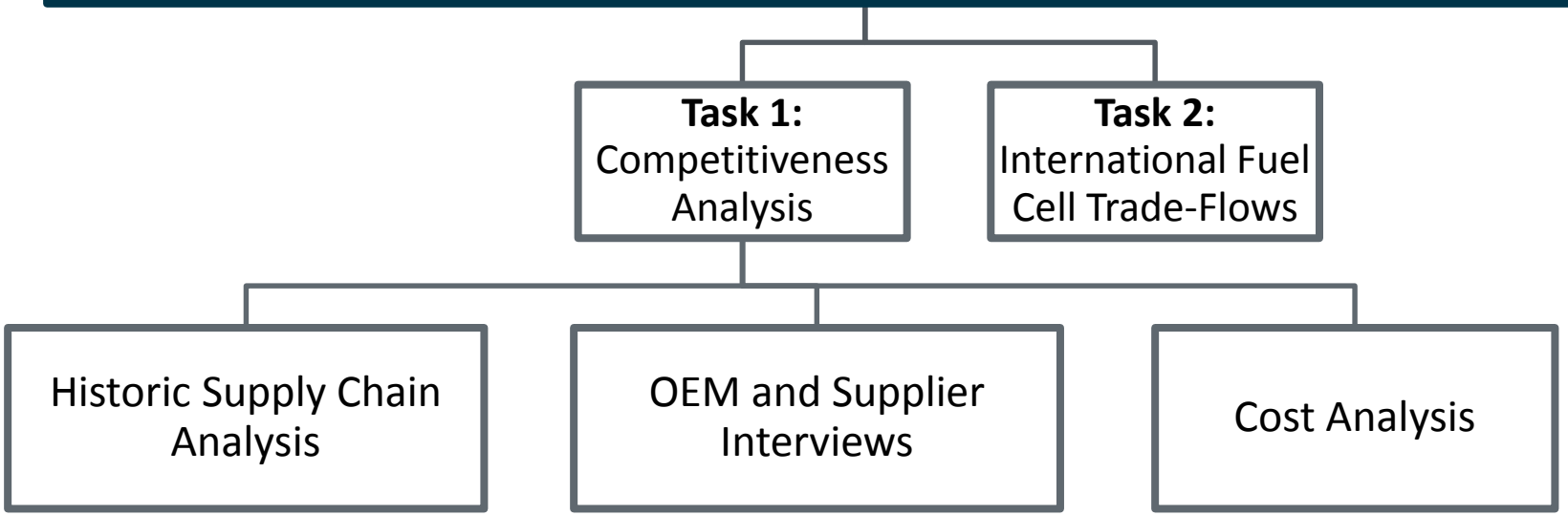
- ✓ Website launched: http://hfcnexus.com/
- ✓ Server space acquired from James Madison University
- ✓ Website design, graphics and user interface in development
- ✓ Developing branding and launch in cooperation with Department of Energy
- ✓ Data entry of 220 hydrogen and fuel cell companies into website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

HYDROGEN FUEL CELL NEXUS
The US Hydrogen and Fuel Cell Directory

GLWN - Global Manufacturing Competitiveness

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

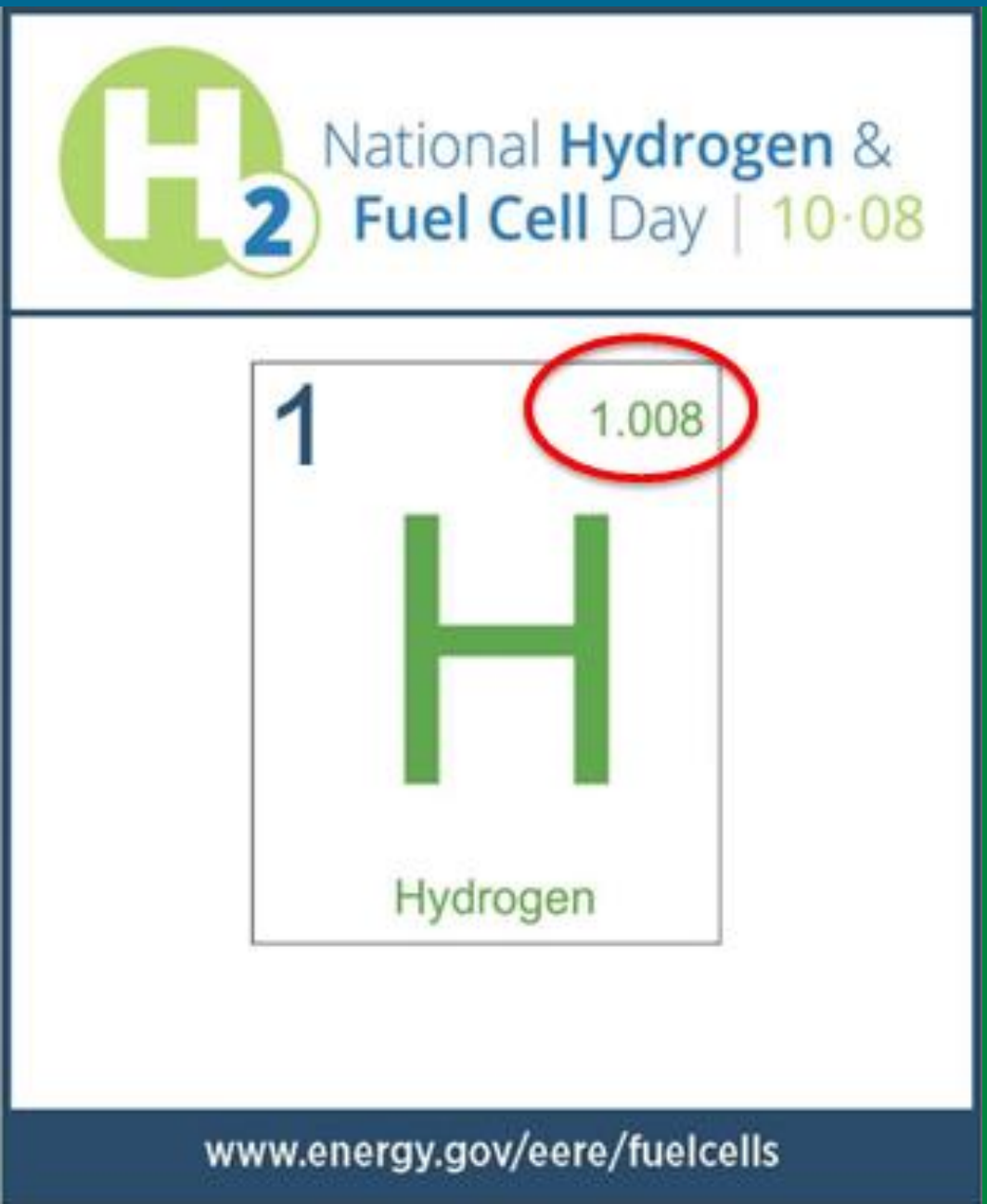
U.S Department of Energy Project DE-EE-0006935



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

Coming up: National Hydrogen and Fuel Cells Day



10-08: National Hydrogen & Fuel Cell Day

(Held on its very own atomic-weight-day)

Job Resources and Outreach for Veterans

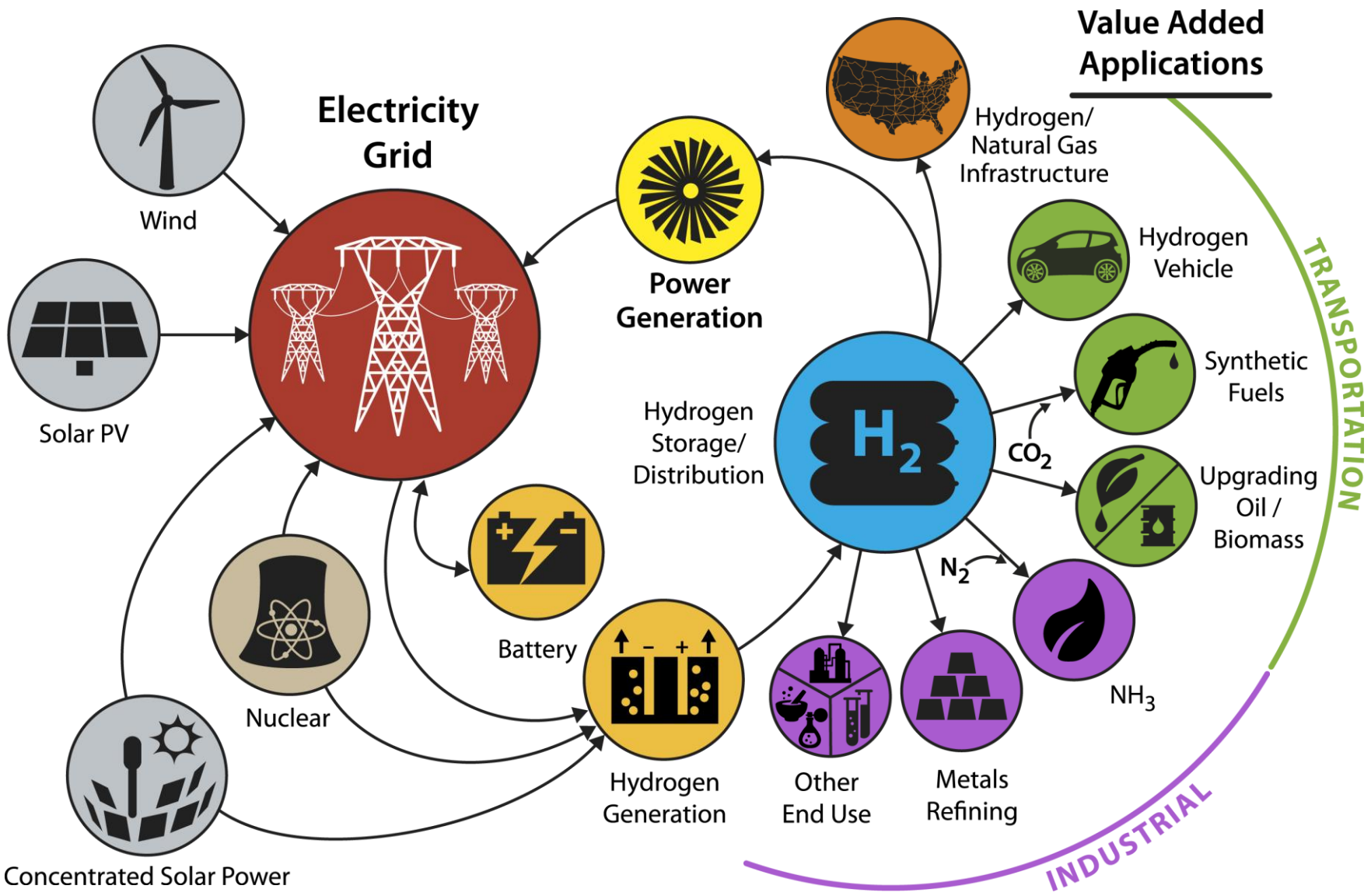
Outreach & Education

- **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**

H2@Scale: Future Focus Area



*Illustrative example, not comprehensive

*Illustrative example, not comprehensive
Source: NREL

Objectives

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