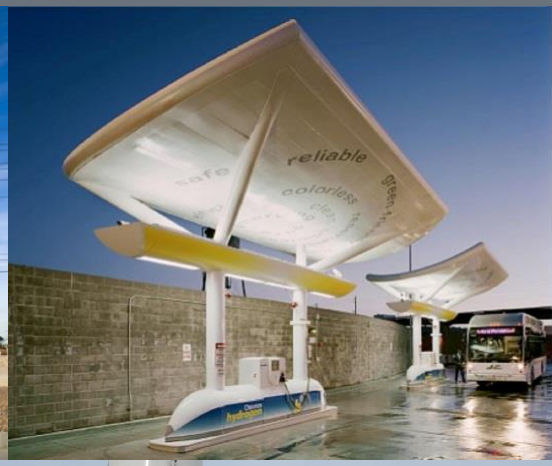
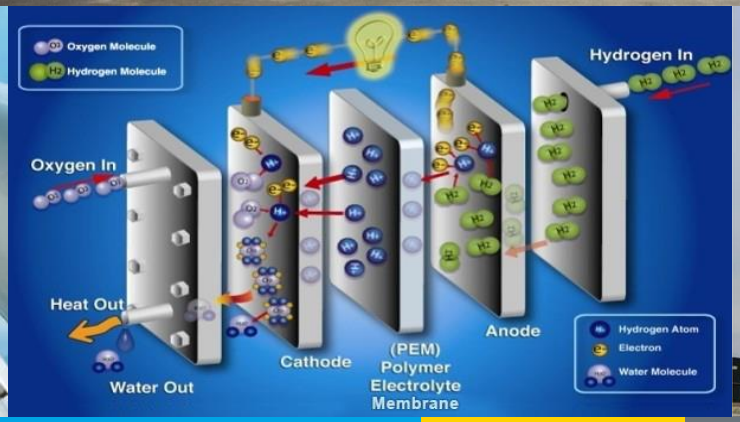
U.S. Department of Energy
Fuel Cell Technologies Office

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





DOE Activities and Progress in Hydrogen and Fuel Cells

Washington D.C.

May 12, 2017

Dr. Sunita Satyapal

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

The Beginning of the DOE Fuel Cell Program…

1970s | **A group from labs, government and industry met at Los Alamos to set the foundation for DOE fuel cell programs**

Lab researchers taught scientists around the world how to fabricate fuel cell electrodes. Group from GM relocated to Los Alamos.

Forty years later, for the first time in history….

Hyundai Tucson Fuel Cell SUV

Toyota Mirai

Honda Clarity

Commercial fuel cell electric cars are here!

Power, performance, petroleum-free, pollution-free

Refuels in minutes

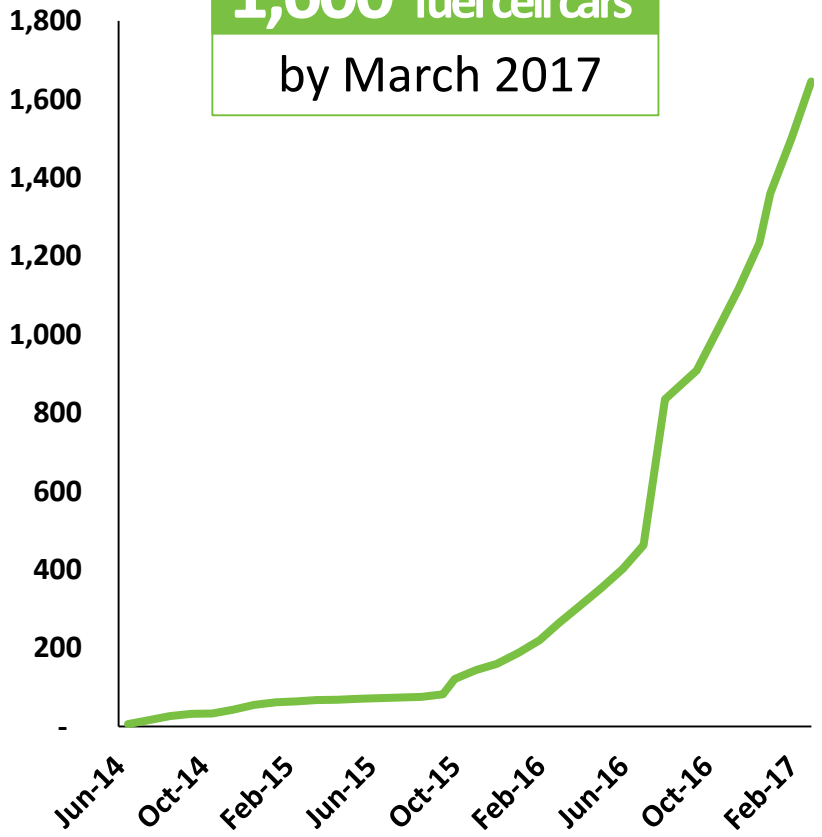
>360 mi driving range

>60 mpgge

Fuel Cell Car Sales and H_2 Stations on the Rise

U.S. Fuel Cell Car Sales Growing Exponentially

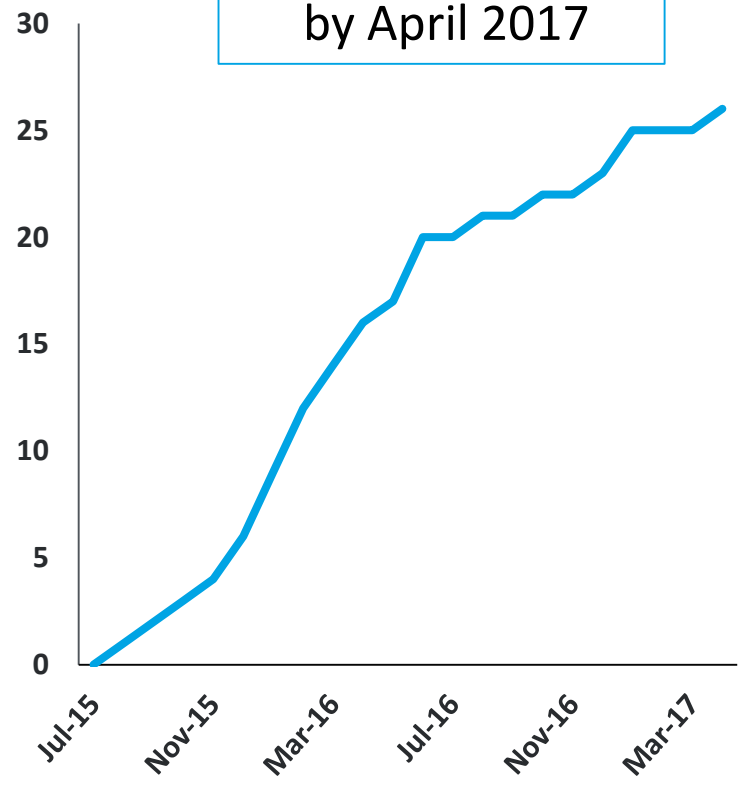
More than **1,600** fuel cell cars by March 2017



Note: Cumulative number of vehicles sold/leased. Source: hybridcars.com

Number of Retail H_2 Stations in CA Increasing

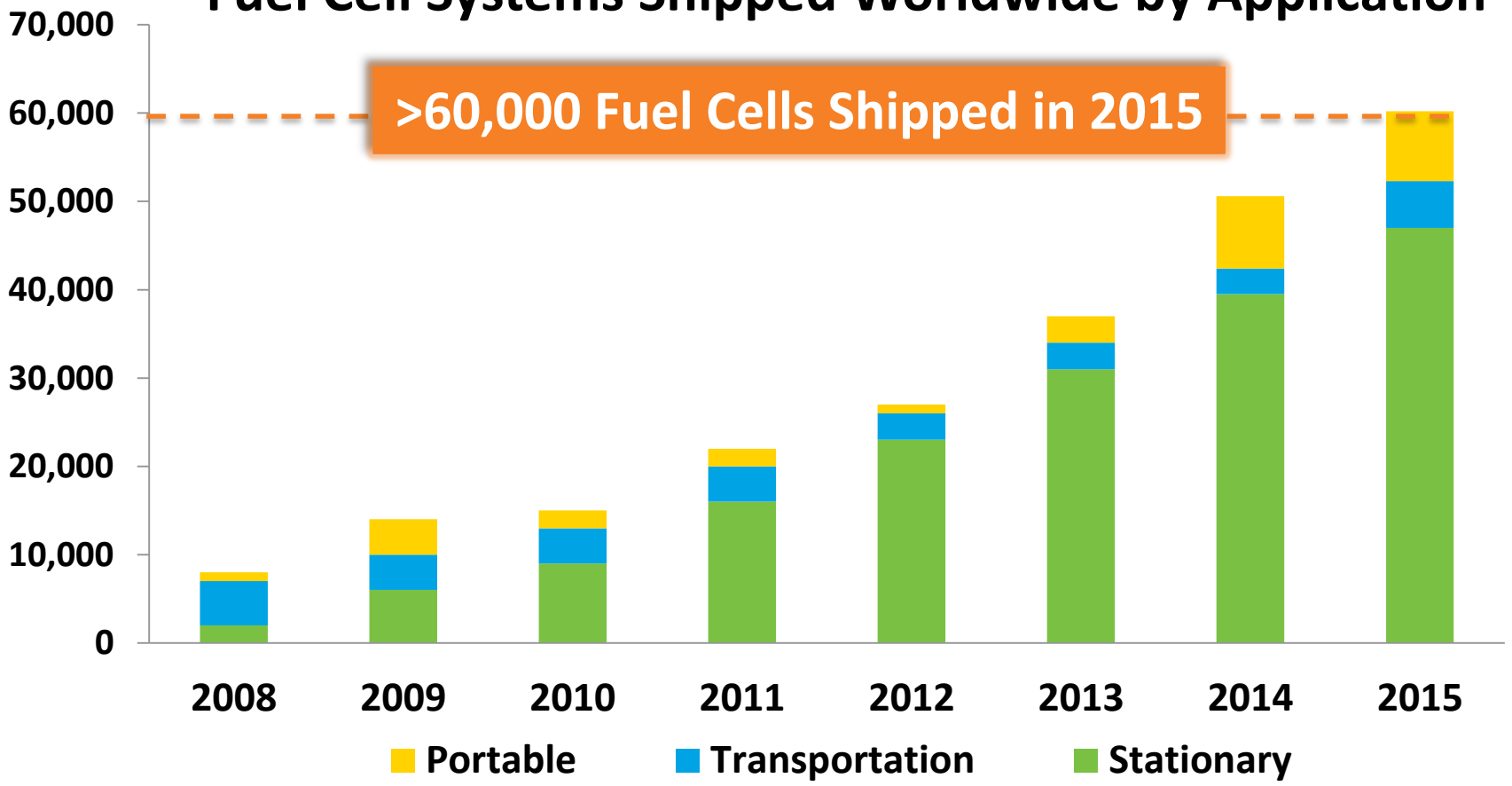
27 Retail H_2 stations by April 2017



Sources: CaFCP

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

Stationary Fuel Cells- Opportunities Emerging

Data centers require non-stop electrical power

Reliable power is vital at hospitals

Supermarkets- growing interest for reliable power

Fuel Cell Stationary Power in the U.S.

Installations

More than
235 MW
in at least
43 states

Top States

- **By unit size:** DE (30 MW) and CT (14.9 MW)
- **By number of units** CA (480 systems)

Source: DOE Fuel Cell Technologies Office. State of the States Report (2016)

New World Trade Center using fuel cells

Fuel Cells: Recent Highlights

Over 10,000 fuel cell forklifts
~ 5 million H_2 refuelings

Fuel cell buses surpass 15M passengers

Industry demonstrates first heavy duty truck

ZH2: U.S. Army and GM collaboration
First of its kind

Fuel Cells: Emerging Applications

World's first hydrogen fuel cell train in Germany

First fuel cell cargo truck at U.S. airport

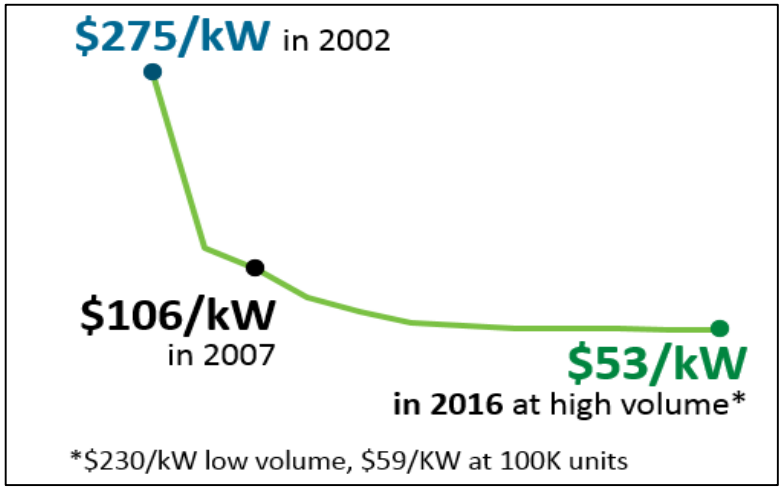
World's first fuel cell for maritime ports

Fuel cell powered lights at Super Bowl

DOE Examples: Enabling Progress

Technology Innovation

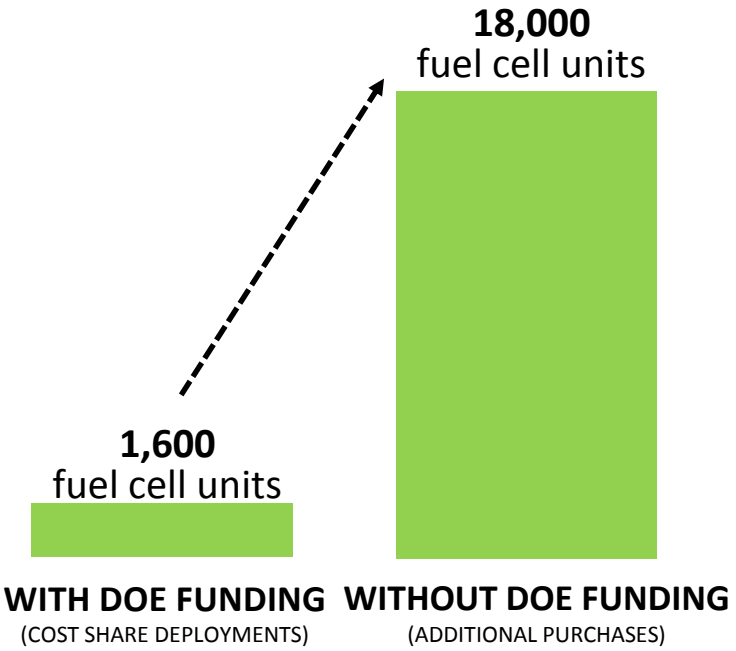
- **Cut fuel cell cost by 80%**



- **Quadrupled fuel cell durability**
- **Enabled >580 patents and 30 technologies in today's market**
- **Validated research advances to guide R&D**
  - **>360 mi** range, >**2X** efficiency of gasoline vehicles

Market Impact

- **Jumpstarted early markets by more than 11X**



- **Catalyzed additional private investment**
- **Over 16,000 jobs in the fuel cell vehicle sector***

*DOE, U.S. Energy and Employment Report (2017)

DOE Hydrogen and Fuel Cells Impact

DOE and industry cost-shared projects enable innovation and lead to industry development, commercialization, and market impact

Example: Energy Efficiency & Renewable Energy (EERE) Fuel Cell Technologies Office

Innovation

More than **580 patents** H_2 and fuel cells

enabled by EERE funds

Market Impact

More than **30** **Technologies** available in today's market

enabled by EERE funds

Job Potential

Today

Approximately **16,000** jobs in the fuel cell car sector

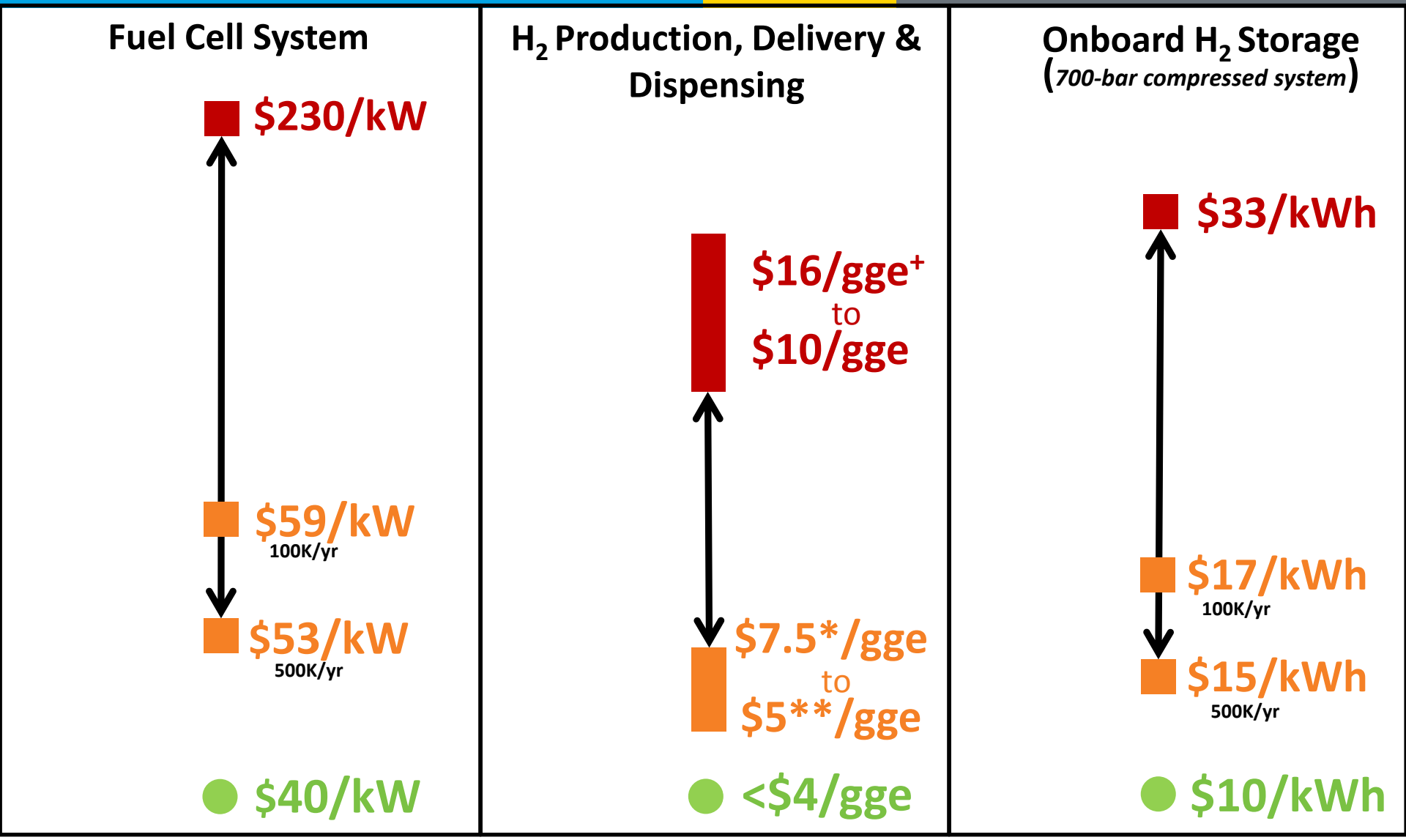
Source: DOE, U.S. Energy and Employment Report (2017)

Future

More than **200,000** jobs from future fuel cell car sales

Under a 20% market penetration scenario.
Source: Preliminary results from employment study update (ANL)

DOE Cost Status and Targets

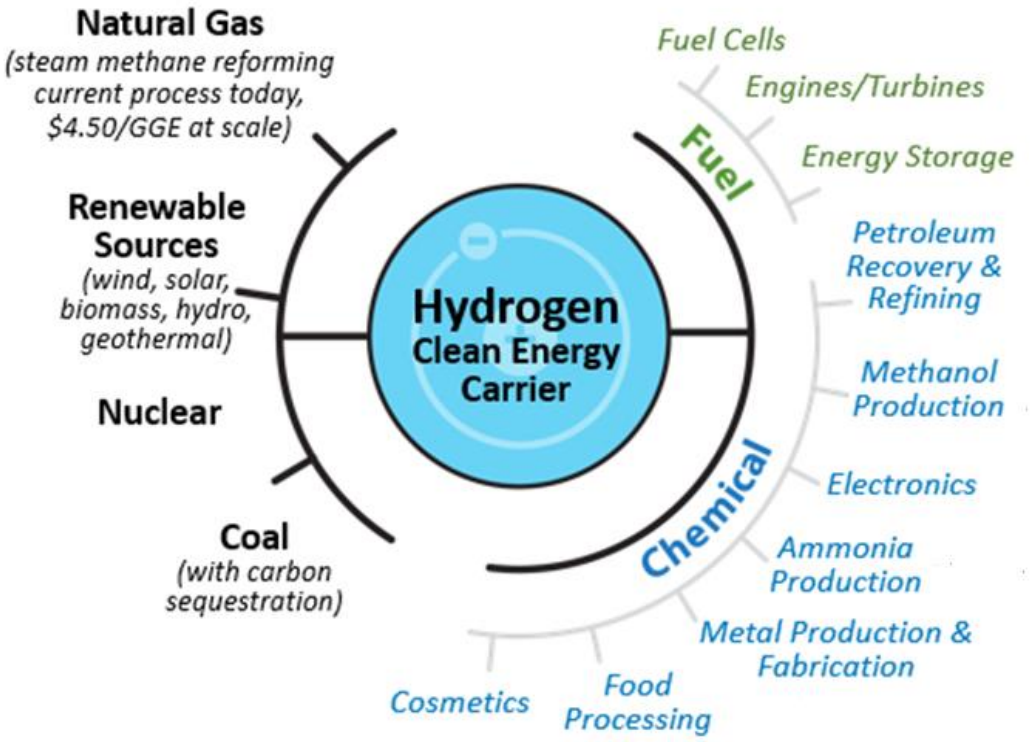


*Based on Electrolysis **Based on NG SMR + Preliminary, updates underway

*For illustration purposes only, not drawn to scale

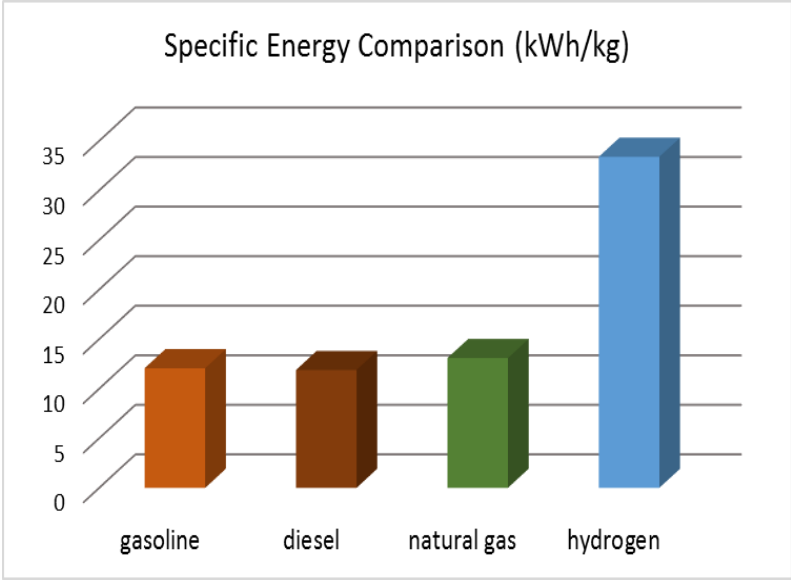
Advantages of hydrogen as an energy carrier

Diverse domestic sources can be used to produce H_2



Many applications rely on or could benefit from H_2

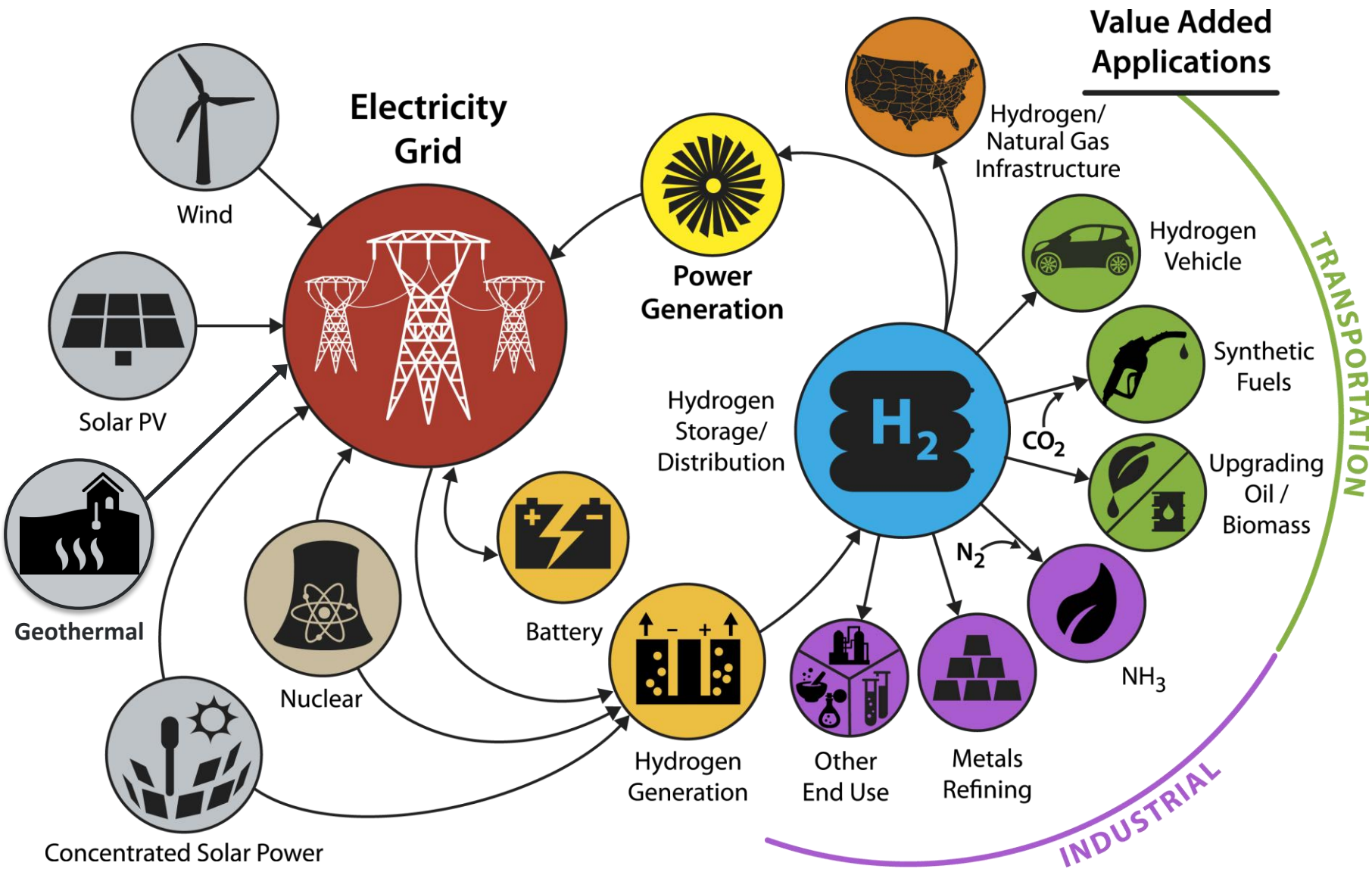
Very High Specific Energy



~ *Three times* more energy by mass than most other fuels but need higher volumes to store

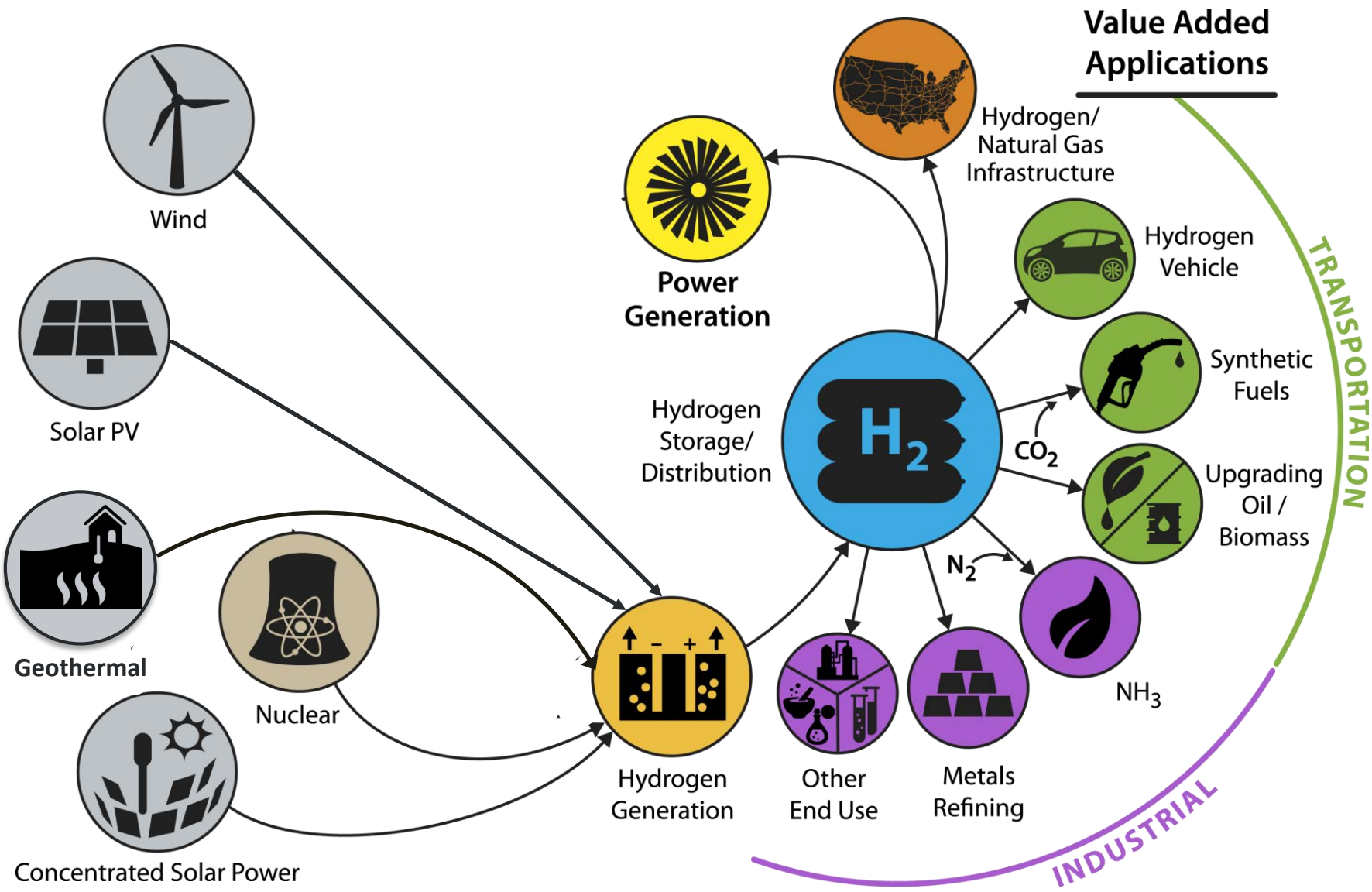
Hydrogen is a versatile, clean, and efficient energy carrier

Conceptual H_2 at Scale Energy System



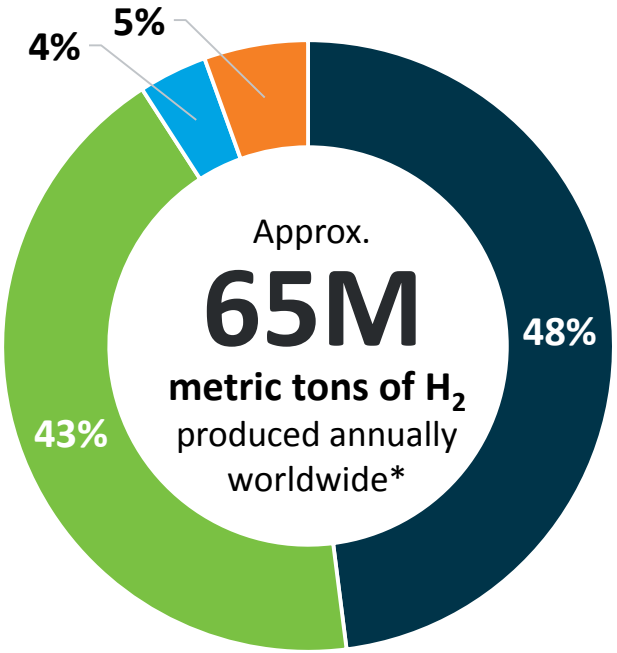
*Illustrative example, not comprehensive
Source: NREL

Conceptual H_2 at Scale Energy System



H_2 Production & Infrastructure: Current Status

Global Annual H_2 Production/Demand



Petroleum Refining

Ammonia Production

Methanol Production

Others including:

- Metal fabrication
- Electronics
- Food Processing

Steam methane reforming of natural gas (SMR): currently most cost-competitive process to produce H_2

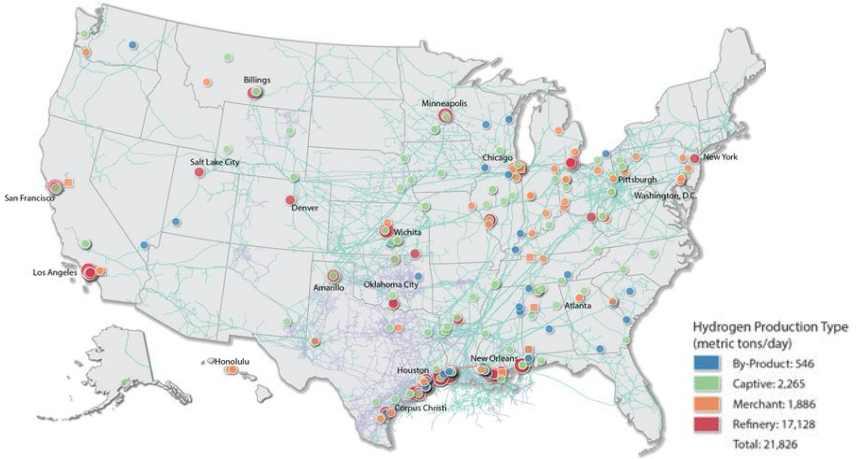
Source: Markets and Markets. Hydrogen Generation Market: Global Trends & Forecasts to 2019, 2014.

Current H_2 Infrastructure:

1,600 miles of H_2 pipeline

>50 H_2 Stations (27 public)

Centralized H_2 production facilities in the U.S.



Source: NREL

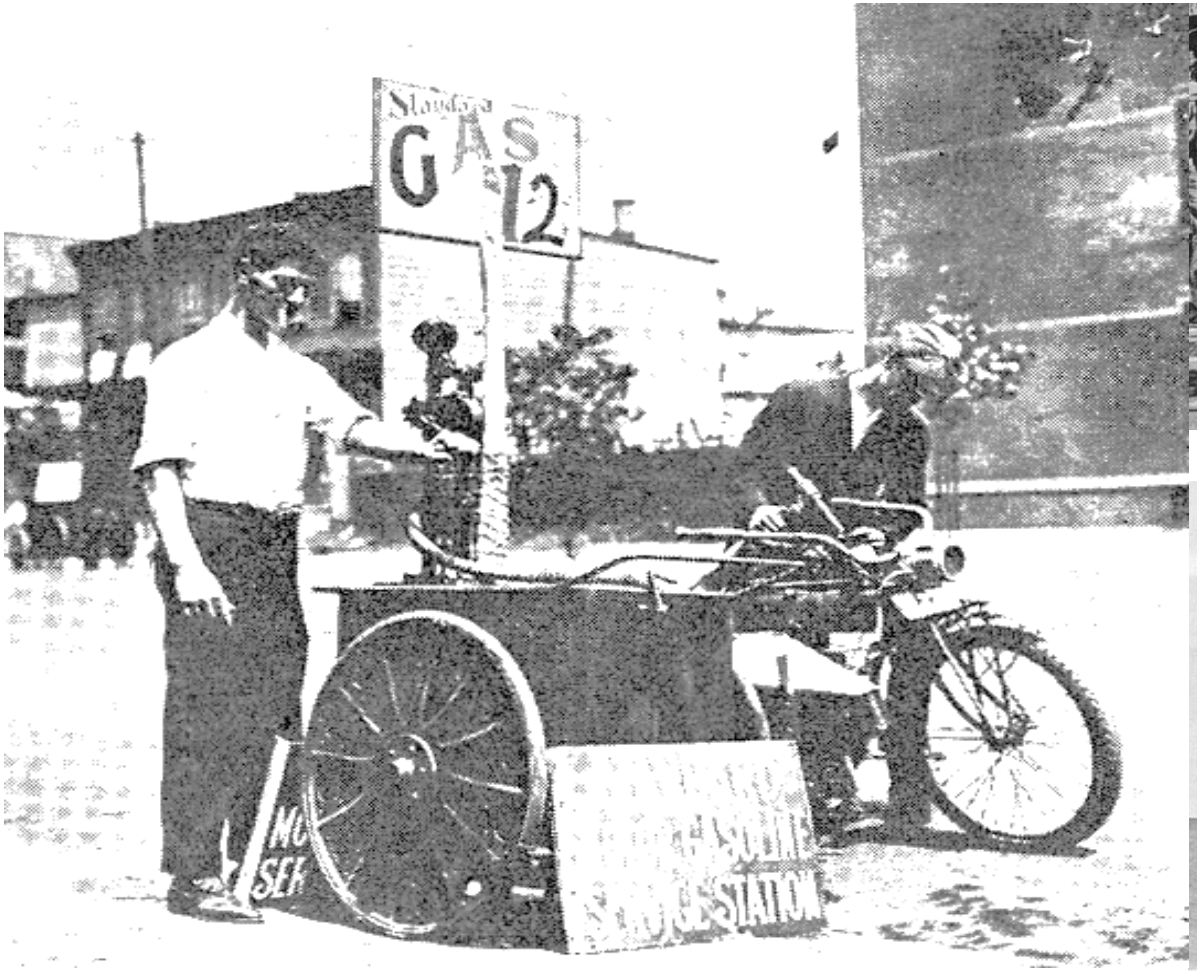
10 million metric tons of H_2 produced every year in the U.S.

Cost- Competitive H_2 Fuel

- **H_2 from Natural Gas** through SMR
- **At-scale** production
- **<$2/gge produced** (low pressure, at source)

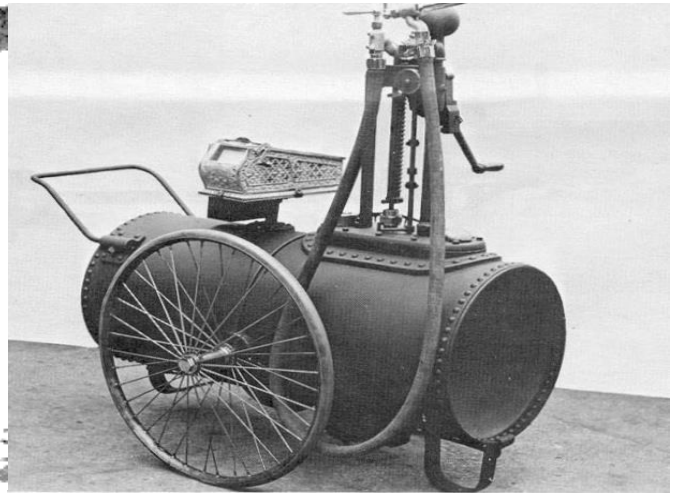
Gasoline History: Many diverse options

Cans, barrels, home models, mobile refuelers, pharmacies, general stores, etc.



Source: M. Melaina 2008.

Source: Vieyra, 1979



Source: Milkues, 1978

Gasoline was made widely available using different means early in history

Complementing Retail Stations: H_2 Refuel H-Prize

H2refuel
U.S. Department of Energy

$1M Competition: On-site H_2 fueling

Winner Announced:
More at hydrogenprize.org

simple.fuel.™

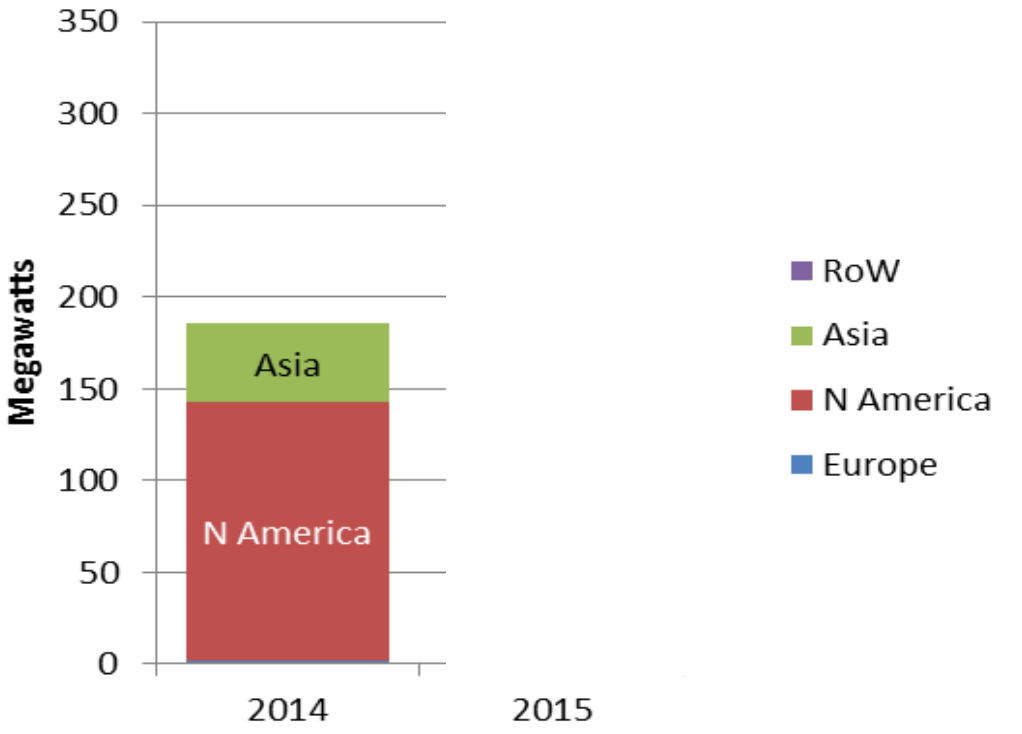
H-Prize Authorized in Energy Independence and Security Act

System Details

- Hydrogen produced via **electrolysis**
- **1 kg H_2 in 15 mins** or less
- **700 bar** refueling

Global Landscape: Recent Trends

Growth in Foreign Manufacturing in Just one Year



International RD&D Commitments in H_2 and Fuel Cells- Examples

Japan: $850M (total) including $350M to showcase H_2 and FCs at the 2020 Olympics

Source: 2014 HTAC Report

EU: $1.5B covered by FC 2 JU, including EU contribution of up to $800M

Source: European Union 2014 http://ec.europa.eu/research/press/jti/factsheet_fch2-web.pdf

Need to strengthen efforts and enable domestic leadership

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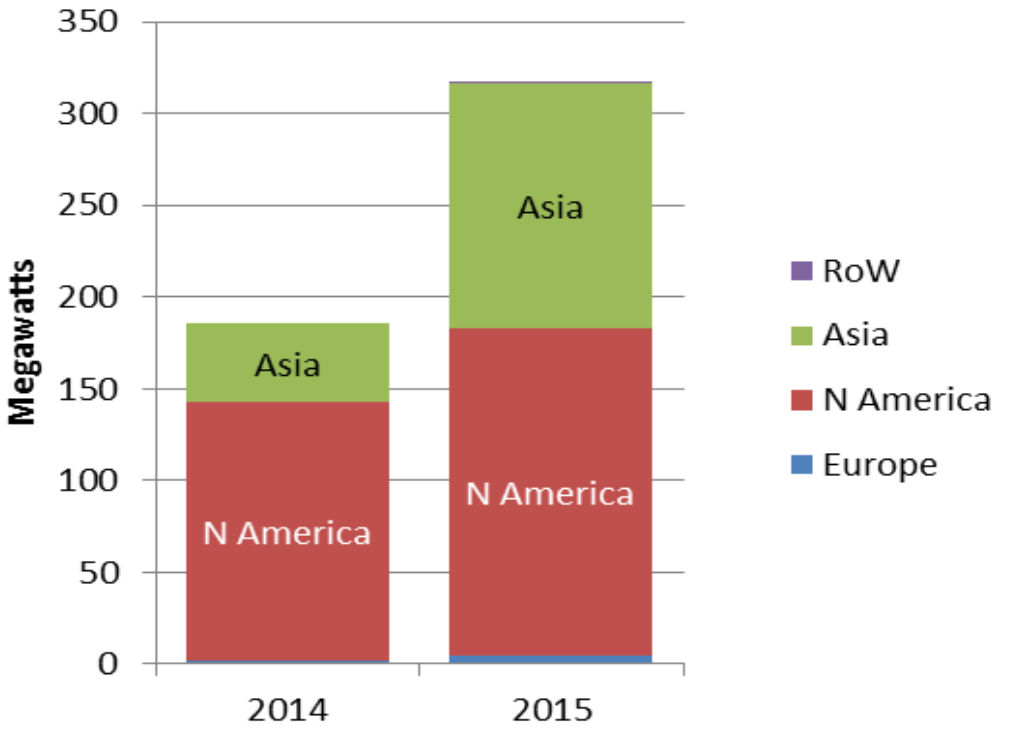

Preliminary

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Need to strengthen efforts and enable domestic leadership

Summary

- **Enable early R&D innovation**
  - **DOE Key Focus: R&D in hydrogen fuels and fuel cells, and H2@Scale**
- **Leverage activities to maximize impact**
  - **Enable infrastructure and cross-sector impacts**
  - **Partnerships- agencies (e.g. DOD), industry, states, etc.**
  - **Collaboration on safety R&D and information sharing**

Save the Dates!

2017 AMR
June 5-9
Washington, DC

National Hydrogen & Fuel Cell Day | 10·08
Participate in social media using
#HydrogenNow #FuelCellsNow

Summer 2018:
AMR and Industry Expo
Washington, DC

Thank You

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hydrogenandfuelcells.energy.gov