H2@Scale: Progress, Opportunities and Needs

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EERE Fuel Cell Technologies Office (FCTO)

Early R&D Focus

Applied research, development and innovation in emerging hydrogen and fuel cell technologies leading to:

- Energy security
- Energy resiliency
- Strong domestic economy

Early R&D Areas

Fuel Cells

- PGM- free catalysts
- Durable MEAs
- Electrode performance

Hydrogen

- Production pathways
- Delivery components
- Advanced materials for storage

Infrastructure

- Safety
- Manufacturing
- Delivery components
- Others

Impact

- 60% Lower Fuel Cell Cost
  - $124/KW at high-volume
  - $50/KW at low-volume

- Greater Fuel Cell Durability
  - 4X more hours of fuel cell lifetime since 2006

- 80% Lower Electrolyzer Cost
  - for H₂ production since 2002

PGM = Platinum group metals
MEA = Membrane Electrode Assembly
Hydrogen is one part of an ‘all of the above’ portfolio

H₂ can be produced from diverse domestic sources

Many applications rely on or could benefit from H₂

Clean, sustainable, versatile, and efficient energy carrier
Upward trend with global fuel cell shipments

![Graph showing fuel cell power shipped (MW) from 2014 to 2017.]

- **2014**: 100 MW
- **2015**: 200 MW
- **2016**: 300 MW
- **2017**: 650 MW

- **Stationary**: Pink
- **Portable**: Blue
- **Transportation**: Green

**Source**: DOE and E4Tech

**650 MW** fuel cell power shipped worldwide

**70,000** fuel cell units shipped worldwide

**Approximately** $2 Billion fuel cell revenue

**Electrolyzers**: Over 100MW/year estimated global sales

*Courtesy of NOW, E4tech and partners: A collaborative effort to assess electrolyzer market potential*
An exciting time for the transportation sector

Commercial fuel cell electric cars are here

Nearly 5,000 sold or leased in the United States

- **Honda Clarity**
- **Hyundai Tucson Fuel Cell SUV**
- **Toyota Mirai**

- No petroleum, no pollution
- Refuels in minutes
- More than 360 mi driving range
- Over 60 mpgge
Long-Range, Heavy Duty Applications Emerging

Fuel cell buses in CA surpass 19M passengers

Fuel cell delivery and parcel trucks starting deliveries in CA and NY

Industry demonstrates first heavy duty fuel cell truck in CA
Stationary Power Applications Emerging

Fuel cells provided backup power during Hurricane Sandy in the U.S. Northeast

Fuel cell power for maritime ports demonstrated in Honolulu, Hawaii

Fuel cells used to power new World Trade Center in NYC

Over 240 MW of fuel cell stationary power installed across more than 40 US states
Multiple H₂ and Fuel Cell Applications in the U.S.

U.S. Snapshot

- **>240MW** Backup Power
- **>20,000** Forklifts
- **>30** Fuel Cell Buses
- **35** H₂ retail stations
- **Nearly 5,000** fuel cell cars

States with Growing Interest

**Latest News: 200 stations by 2025 in CA**

- More than **$180M**
  - States have invested in H₂ infrastructure in the past decade*

**CA**
- 200 stations planned
- Over 30 public stations open
- $150M invested
- $235M announced in 2018

**HI, OH, SC, NY, CT, MA, CO, UT, TX, MI, and others with interest**
- Over $27M invested
- 12-25 stations planned in the NE

*Excludes recent announcement from CA to invest $235M in electric vehicles
H₂@Scale concept
Vision

H2@Scale: Enable affordable, reliable, clean and secure energy across sectors
H₂@scale: Enabling affordable, reliable, clean, and secure energy across sectors

More information at: www.energy.gov/eere/fuelcells/h2-scale
The Duck’s belly is getting bigger

Two Concerns:

- **Low Net Load:** flexibility to reduce baseload generation resources is limited

- **High Ramp Rates in Evening:** flexibility of other generation to ramp up is limited

Can be addressed by

Source U.S. DOE Solar Energy Technologies Office
Lab testing electrolyzers’ value for ancillary services

First Ever Validation of Frequency Regulation with Electrolyzers

Lab testing shows dynamic response within seconds and potential for grid services
Integrated control & dispatch of renewable hydrogen

**Goal:** Demonstrate a 100% renewable hydrogen end-to-end supply chain

**System integrates:**

1. Autonomous controlled hydrogen export terminal
2. Frequency regulation and demand response through control and dispatch of electrolyzer and battery systems
3. Optimized dispatch of electricity to meet customer demand.

**Impact:** Reduced operating costs, increased renewable H₂ production from highly integrated projects
Hydrogen Energy Storage is Scalable

One hydrogen cavern could provide ~ 100 GWh energy storage.

Hydrogen can be used to monetize surplus electricity from the grid, or remote, off-grid energy feedstock (e.g. solar, wind) for days to months.
H2@Scale: Nationwide Resource Assessment

Labs assess resource availability. Most regions have sufficient resources.

Red: Only regions where projected industrial & transportation demand exceeds supply.
H₂@Scale: Value to industrial processes?

Electrical power plant cooling

- Over 16,000 H₂ cooled generators worldwide
- Less delivery logistics, inventory management, 1-2 yr payback and improved efficiency
- Potential $2B addressable market

Source: Proton

Iron Refining, Steel manufacturing

- More energy efficient when hydrogen used as reductant at high temperatures
- Potential annual savings of over $100,000 for a 100,000 ton/year plant

Source: EERE Advanced Manufacturing Office, Berry Metal
Global Hydrogen Infrastructure Activity Underway

- **U.S. (California)**
  - 200 stations by 2025

- **Japan**
  - 40,000 cars by 2020,
  - 800,000 by 2030
  - Up to 400 stations by 2023
  - 100 stations by 2019

- **Germany**
  - 40,000 cars by 2020,
  - 800,000 by 2030
  - Up to 400 stations by 2023
  - 160 stations by 2020,
  - 320 by 2025

- **South Korea**
  - 10,000 cars by 2020,
  - 630,000 by 2030
  - 100 stations by 2020 and
  - 520 by 2025

- **China**
  - 50,000 cars by 2025, 1M by 2030
  - 300 stations by 2025, 1,000 by 2030

- **France**
  - 1,000 cars by 2020
  - 100 stations by 2019

- **Germany**
  - 200 stations by 2025
IPHE: International Partnership for H₂ and Fuel Cells in the Economy

- **Share** information on H₂ and fuel cells, lessons learned, best practices
- **Increase** international **collaboration** to accelerate progress

Launched 2003 and includes 18 countries and the European Commission

- Australia
- Austria
- Brazil
- Canada
- China
- European Commission
- France
- Germany
- Iceland
- India
- Italy
- Japan
- Republic of Korea
- Norway
- Russian Federation
- South Africa
- United Kingdom
- United States

U.S. elected as Chair
May 2018
H₂@Ports and H₂@Rail Initiatives

- Collaboration with DOT-Maritime Administration (maritime) & DOT-Federal Railroad Administration (rail)

- Conduct R&D to assess the technical and economic potential of hydrogen use for:
  - Seaport Applications
  - Prime propulsion & auxiliary railway locomotives
Opportunities for outreach and to increase awareness

Celebrate National Hydrogen & Fuel Cell Day
October 8 or 10/08
(Held on its very own atomic-weight-day)

Information and Training Resources to Increase Awareness

H2tools.org

Learn more at: energy.gov/eere/fuelcells

Download for free at:
energy.gov/eere/fuelcells/downloads/increase-your-h2iq-training-resource
Thank You

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