Overview: DOE Fuel Cell Technologies and H2@Scale

Dr. Dimitrios Papageorgopoulos, Program Manager, Fuel Cell Technologies Office

Hydrogen and Fuel Cells for Data Center Applications Project Meeting
March 20, 2019 – Seattle Washington
Hydrogen is 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

Very High Specific Energy

About three times more energy by mass than gasoline. But worse in terms of volume.

Clean, sustainable, versatile, and efficient energy carrier
An exciting time for hydrogen and fuel cells

650 Fuel Cell Power Shipped (MW) worldwide in 2017*

Sales in 2017
- 70,000 fuel cell units shipped*
- Global sales for electrolysers estimated at over 100MW/year**

*DOE and E4tech
**Courtesy of NOW, E4tech and partners: A collaborative effort to assess electrolyzer market potential

Over 6,500 fuel cell cars sold or leased in the United States. Over 360 mi driving range.
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
More stationary and mobile applications

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

Fuel cells used to power new World Trade Center in NYC

Increasing orders of fuel cell forklifts by warehouses and stores in the U.S.

Over 240 MW of fuel cell stationary power installed across more than 40 US states
International Commitment Ramping Up

Source: IPHE
Applications and Funding of Hydrogen and Fuel Cells

Examples of Application in the United States

- **Backup Power**
  - Over **>240MW**

- **Forklifts**
  - More than **23,000**

- **Fuel Cell Buses**
  - More than **>30**

- **H₂ Retail Stations**
  - **39**

- **Fuel Cell Cars**
  - Over **6,500**

EERE Fuel Cell Technologies Office Funding

- **From 2013 to 2018**
  - **$529M**

- **Covering H₂ and Fuel Cell Activities in 32 states and DC**

Hydrogen Stations: Examples of Plans Across States

- **California**
  - 1,000 stations by 2030

- **Northeast**
  - 12 – 20 stations planned

- **HI, OH, SC, NY, CT, MA, CO, UT, TX, MI, and others**
  - with interest

Prime recipients only
Update on FCTO Focus Areas

**Early R&D Focus**

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

- Energy security
- Energy resiliency
- Strong domestic economy

**Early R&D Areas**

<table>
<thead>
<tr>
<th>Fuel Cells</th>
<th>Hydrogen Fuel</th>
<th>Infrastructure R&amp;D</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Cost, durability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Components - catalysts, electrodes, etc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Increase focus beyond LDVs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Cost of production across pathways</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Cost and capacity of storage, including bulk/energy storage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Cost and reliability of infrastructure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Delivery components, supply chain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Safety</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Enabling**

Leveraging industry and labs through the Consortia Approach

- Core Consortium Team (Consortium Lead, Deputy Lead, & Technical Partners: National Labs)
- FOA
  - University & Non-Profit
  - Industry
  - National Lab

LDV: Light Duty Vehicle
DOE Cost Status and Targets for R&D

### Fuel Cell R&D

<table>
<thead>
<tr>
<th>System</th>
<th>Production, Delivery &amp; Dispensing</th>
<th>Onboard Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>$230/kW*</td>
<td>$16/kg*</td>
<td>$24/kWh</td>
</tr>
<tr>
<td>$180/kW*</td>
<td>$13/kg</td>
<td></td>
</tr>
<tr>
<td>$50/kW</td>
<td>$10/kg* to $5/kg**</td>
<td>$17/kWh</td>
</tr>
<tr>
<td>$45/kW</td>
<td>$&lt;4/kg</td>
<td>$15/kWh</td>
</tr>
<tr>
<td>$30/kW</td>
<td></td>
<td>$8/kWh</td>
</tr>
</tbody>
</table>

**Ultimate Targets**

- $30/kW
- $180/kW*
- $50/kW
- $45/kW

**High-Volume Projection**

- $230/kW
- $180/kW*
- $50/kW
- $45/kW

**Low-Volume Estimate**

- $30/kW
- $180/kW*
- $50/kW
- $45/kW

---

1 kg = gallon of gasoline equivalent or gge

---

**Notes:**

- Based on commercially available FCEVs
- Based on state of the art technology
- Range assumes current production from NG and delivery and dispensing.
- Highest possible cost at high vol., assumes H2 from electrolysis at $5/gge and delivery via pipelines and liquid tankers at $5/gge
- Lowest possible cost at high vol., assumes H2 from SMR at $2/gge and delivery via tube trailer at $3/gge
H₂@Scale: Enabling affordable, reliable, clean, and secure energy across sectors
Potential: High capacity and long term energy storage

- Hydrogen can offer long duration and GWh scale energy storage
- Analysis shows potential for hydrogen to be competitive at > 10 hours

Source: Hydrogen Council

Source: NREL (preliminary)
Strategy: Partnerships to enable H₂@Scale

**Early-Stage R&D**
- Department of Energy
  - Fuel Cells R&D
  - H₂ Fuel R&D
- Other Federal Agencies

**Demonstration, Deployment & Commercialization**
- Private Sector
  - Industry, Other Agencies, States
  - Partnerships
  - FCHEA, CaFCP, OFCC, CT, HI, CO, NJ, etc.

**H₂@Scale Consortium**
Analysis and R&D Projects Underway

H₂ Demand

2030

H₂@Scale Consortium

Over 20 projects with DOE Labs, Industry, States

Nearly 30 million metric tons of potential hydrogen demand in the U.S.

Source: Elgowainy, et al, ANL
Just Announced: Funding for H₂@Scale and Trucks

H₂@Scale - Up to $31M
H₂ production, storage and utilization concepts
Concept Papers due 4/8
Full Apps due 5/29

Trucks – Up to $15M
H₂ storage, refueling technologies and fuel cell R&D
Concept Papers due 3/29
Full Apps due 5/15

More information on the EERE Exchange Website or Grants.gov
Collaboration: New H₂ Safety Partnership

Leverages new partnership to promote collaboration on safety

U.S. DOE’s

Pacific Northwest National Laboratory

AIChE

April 1-2, AIChE Meeting, LA
<table>
<thead>
<tr>
<th>Stakeholder Engagement to support early stage R&amp;D</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Celebrate Hydrogen &amp; Fuel Cell Day</strong></td>
</tr>
<tr>
<td>October 8 or 10/8</td>
</tr>
<tr>
<td><strong>Use Safety Information and Training Resources</strong></td>
</tr>
<tr>
<td><strong>Attend workshops enabling H2@scale</strong></td>
</tr>
<tr>
<td>• Datacenters: March 20 in Seattle, WA</td>
</tr>
<tr>
<td>• H2@Rail: March 26-27 in Lansing MI</td>
</tr>
<tr>
<td>• H2@Ports: Oct 2019, San Francisco, CA (tentative)</td>
</tr>
</tbody>
</table>

**H2tools.org**

Download for free at: [energy.gov/eere/fuelcells/downloads/increase-your-h2iq-training-resource](energy.gov/eere/fuelcells/downloads/increase-your-h2iq-training-resource)

Sign up to receive hydrogen and fuel cell updates

www.energy.gov/eere/fuelcells/fuel-cell-technologies-office-newsletter

Learn more at: energy.gov/eere/fuelcells
Save the Date

2019 Annual Merit Review

April 29 - May 1, 2019
Washington, DC
hydrogen.energy.gov
Thank you

Dr. Dimitrios Papageorgopoulos
Program Manager, Fuel Cells
Fuel Cell Technologies Office
Dmitrios.Papageorgopoulos@ee.doe.gov

Dr. Sunita Satyapal
Director
Fuel Cell Technologies Office
Sunita.Satyapal@ee.doe.gov

Dr. Ned Stetson
Program Manager, H₂ Fuel
Fuel Cell Technologies Office
Ned.Stetson@ee.doe.gov

energy.gov/eere/fuelcells