

## Progress and Accomplishments in Hydrogen and Fuel Cells

The U.S. Department of Energy's (DOE's) efforts have advanced the state of the art of hydrogen and fuel cell technologies—making significant progress toward overcoming key challenges to widespread commercialization.

### Reducing Cost and Improving Durability and Performance of Fuel Cells

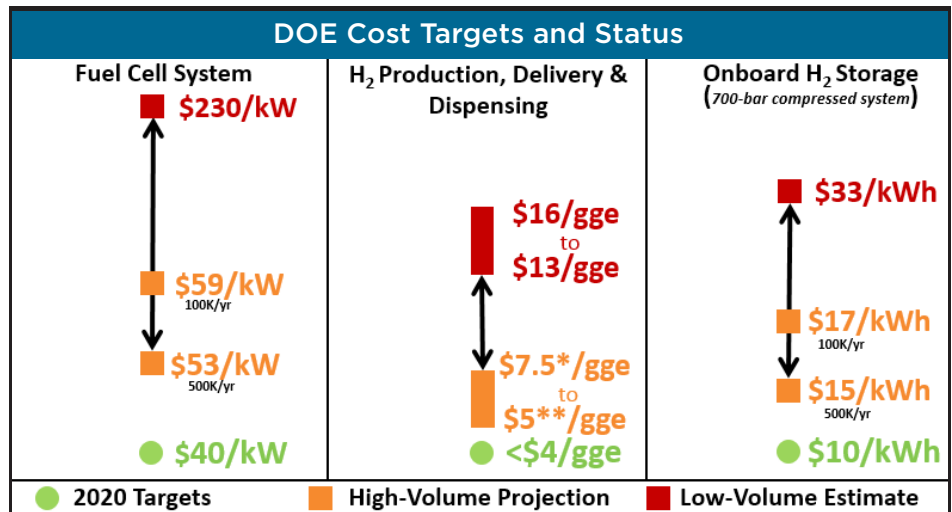
- ✓ **Reduced high volume automotive fuel cell costs by 50% since 2007.**

Cost reductions reflect numerous advances, including a 5x reduction in the platinum content of fuel cell catalysts and the development of durable membrane electrode assemblies. Modeled cost is \$53/kW when produced at 500,000 units per year and \$60/kW when produced at 100,000 units per year.

- ✓ **Quadrupled fuel cell durability since 2006.** Demonstrated more than 4,000 hour (120,000 miles) durability of fuel cell systems in vehicles operating under real-world conditions with only 10% degradation.

### Improving Technologies for Producing, Delivering, and Storing Hydrogen

- ✓ **Reduced the cost of dispensed hydrogen.** Projected costs of hydrogen production, delivery and dispensing for 700 bar fueling (assuming high volume production and widespread deployment) have been



\*Based on Electrolysis \*\* Based on NG SMR

reduced to ~\$5-7/gge, making it nearly cost competitive with gasoline.

- ✓ **Reduced the cost of producing hydrogen from renewables.** The cost of electrolyzers has been reduced by 80% since 2002.
- ✓ **Accelerated hydrogen production R&D.** Achieved world record in direct photoelectrochemical hydrogen production and screened more than 1,000 materials for thermochemical hydrogen production.
- ✓ **Launched H2FIRST and developed the world's first HyStEP Device.** Through the Hydrogen Fueling Infrastructure Research and Station Technology (H2FIRST) project, a prototype Hydrogen Station Equipment Performance (HyStEP) testing device was developed. The designs are now publically available for replication and the device is currently being used in California enabling new stations to meet fueling protocol requirements.

- ✓ **Reduced the cost of advanced compressed onboard hydrogen storage systems.** Updated high volume cost projection for 700 bar compressed hydrogen storage systems to \$15/kWh (a 12% reduction since 2013).

- ✓ **Lowered cost of stationary hydrogen storage.** Reduced the capital cost of 875 bar stationary hydrogen storage by more than 30% since 2011, from \$1,450/kg to \$1,000/kg through wire wrapped pressure vessels.

- ✓ **Created hydrogen station analysis tools.** Launched the Hydrogen Financial Analysis Scenario Tool (H2FAST), an online tool to provide in-depth financial analysis of hydrogen refueling stations, and released the Hydrogen Refueling Station Analysis Model (HRSAM) to determine the levelized cost of hydrogen dispensing.

### Launched Consortia

- ✓ **Launched consortia to leverage lab resources for key challenges and to accelerate projects.** Activities are aligned with DOE's Energy Materials Network (EMN), and will support the Energy Department's materials research and advanced manufacturing priorities.

### Infrastructure Partnership

In 2013, DOE and other stakeholders launched H2USA, a public private collaboration focused on hydrogen infrastructure. More than 50 members include federal and state agencies, the fuel cell trade association, automakers, hydrogen providers, fuel cell developers, and national laboratories.

**H<sub>2</sub>USA**

### Examples of consortia supporting R&D



**FCPAD**  
FUEL CELL PERFORMANCE AND DURABILITY  
Fuel Cell Performance & Durability



**HyMARC**  
Hydrogen Materials Advanced Research Consortium  
Advanced H<sub>2</sub> Storage Materials



**ElectroCat**  
Electrocatalysis Consortium  
PGM-Free Catalysts for Fuel Cells



**HydroGEN**  
Advanced Water Splitting Materials  
Renewable H<sub>2</sub> Production

### Safety, Codes & Standards

- ✓ **Trained more than 36,000 first-responders and code officials.** Training completed through online and in-classroom courses.
- ✓ **Released first-of-its-kind hydrogen resource.** Launched H2Tools, a free, online best practices and national hydrogen safety training resource for emergency responders.

### Technology Acceleration

- ✓ **Advanced manufacturing quality control techniques.** Developed quality control techniques to detect defects during manufacturing of fuel cell components, now being licensed for commercialization.
- ✓ **Achieved more than 6.3 million driving miles.** Independently validated more than 200 fuel cell vehicles on the road, including from Daimler, GM, Honda, Hyundai, and Toyota with a solid track record of performance.

- ✓ **Demonstrated durability of fuel cell vehicles to be 4,100 hours.** The vehicles are on track to meet the 5,000 hour target (equivalent to 150,000 miles of driving).
- ✓ **First commercial sale of hydrogen in the United States.** Launched the first hydrogen station in the United States to receive the seal of approval for commercial sale of hydrogen fuel in California.
- ✓ **Deployed the World's first fuel cell airport GSE fleet.** Deployed fleet of zero-emissions, hydrogen-powered airport ground support equipment (GSE) trucks with FedEx at the Memphis airport.
- ✓ **Proven field operation for network resilience.** Validated the operation of fuel cells for backup power during Hurricane Sandy and in power disruptions across states.

### Encouraging a Growing Market





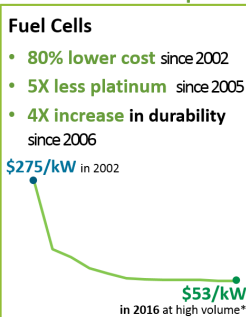
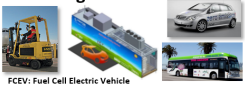
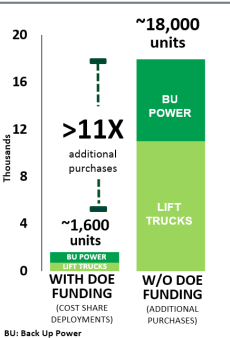
- ✓ **Increased Commercial Fuel Cell Deployments.** Deployed 1,600 early market fuel cell forklifts and backup power units enabling more than 18,000 systems to be deployed or on order by industry without DOE funding, demonstrating true market transformation impact.
- ✓ **Continued commitment to widespread commercialization.** DOE funding has led to nearly 580 patents, more than 40 commercial technologies, and almost 65 emerging technologies.

### For More Information

More information on the Fuel Cell Technologies Office is available at <http://www.hydrogenandfuelcells.energy.gov>.

### References

For specific information and references, visit the Fuel Cell Technologies web site at <https://www.energy.gov/eere/fuelcells/accomplishments-and-progress>.

DOE Impact - H2 and Fuel Cells		DOE FCTO Activities - RDD&D	
<div style="background-color: #f4a460; padding: 5px; text-align: center;"><b>Innovation</b></div> <div style="text-align: center;">  <p><b>More than 580 patents</b> enabled by DOE funds</p> </div> <div style="background-color: #76b82a; padding: 5px; text-align: center;"><b>Commercialization</b></div> <div style="text-align: center;">  <p><b>More than 30 commercial products</b> in today's market enabled by DOE funds</p> </div>	<div style="background-color: #0070c0; padding: 5px; text-align: center;"><b>Job Potential*</b></div> <div style="text-align: center;">  <p><b>360,000 to 675,000 Jobs</b> in fuel cells and hydrogen</p> </div> <div style="text-align: center;">  <p><b>Job gains across 41 industries</b></p> <p><small>*2008 DOE Employment Study currently being updated</small></p> </div>	<div style="background-color: #0070c0; padding: 5px; text-align: center;"><b>Research &amp; Development</b></div> <div style="text-align: center;"> <p><b>Fuel Cells</b></p> <ul style="list-style-type: none"> <li>• 80% lower cost since 2002</li> <li>• 5X less platinum since 2005</li> <li>• 4X increase in durability since 2006</li> </ul>  <p><small>*\$230/kW low volume, \$59/kW at 100k units</small></p> </div>	<div style="background-color: #0070c0; padding: 5px; text-align: center;"><b>Demonstration</b></div> <div style="text-align: center;"> <p><b>Forklifts, back-up power, airport cargo trucks, parcel delivery vans, marine APUs, buses, mobile lighting, refuse trucks</b></p> <p><b>&gt;220 FCEVs, &gt;30 stations, &gt;6M miles traveled</b></p> <p><b>World's first tri-gen station H<sub>2</sub> technology station in Washington D.C.</b></p>  <p><small>FCEV: Fuel Cell Electric Vehicle</small></p> </div>
		<div style="background-color: #0070c0; padding: 5px; text-align: center;"><b>Deployment</b></div> <div style="text-align: center;">  <p><b>&gt;11X additional purchases</b></p> <p><b>~1,600 units WITH DOE FUNDING (COST SHARE DEPLOYMENTS)</b></p> <p><b>~18,000 units BU POWER LIFT TRUCKS W/O DOE FUNDING (ADDITIONAL PURCHASES)</b></p> <p><small>BU: Back Up Power</small></p> </div>	