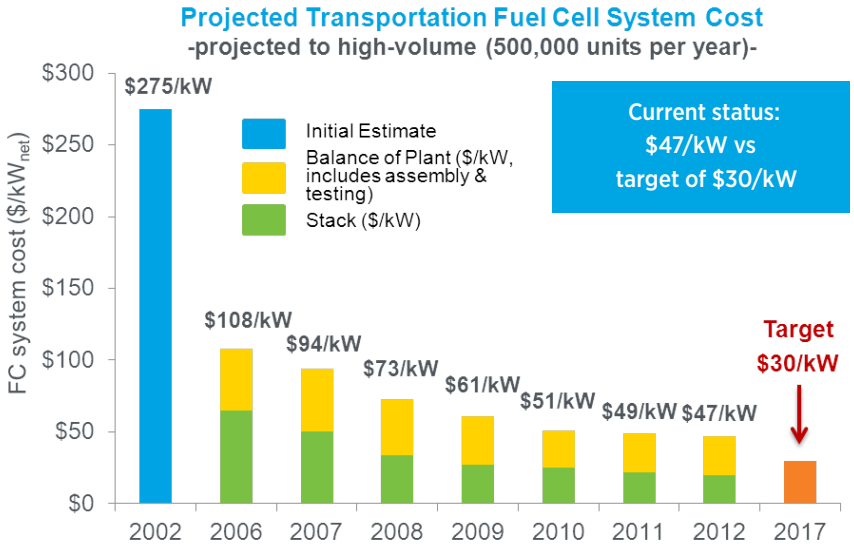
Progress and Accomplishments in Hydrogen and Fuel Cells

The U.S. Department of Energy's (DOE's) efforts have greatly advanced the state of the art of hydrogen and fuel cell technologies—making significant progress toward overcoming many of the key challenges to widespread commercialization. DOE has also made major advances by demonstrating and validating the technologies under real-world conditions, supporting early markets through Recovery Act deployments, and leveraging domestic and international partnerships to advance the pace of commercialization.



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

Reduced the cost of automotive fuel cells by more than 35% since 2008 and more than 80% since 2002 (from $275/kW in 2002 to $47/kW in 2012, based on projections to high-volume manufacturing).[1]

These cost reductions reflect numerous individual advances in key areas, including the development of durable membrane electrode assemblies (MEAs) with low platinum group metal (PGM) content.[2]

Demonstrated more than 2,500 - hour (75,000 miles) durability of fuel cell systems in vehicles operating under real-world conditions, with less than 10% degradation. This is more than double the maximum durability of 950 hours demonstrated in 2006.[3]

Improved the performance of stationary fuel cells, including development of a solid-oxide fuel cell for micro-combined heat and power applications with an almost 25% increase in system power density, which has enabled a more than 30% reduction in stack volume and a 15% reduction in stack weight.[4]

Developed advanced manufacturing methods and materials that enabled a 50% decrease in the cost of gas diffusion layers since 2008.[5]

Improving Technologies for Producing, Delivering, and Storing Hydrogen

Reduced the cost of producing hydrogen from natural gas. Projected costs of hydrogen (assuming high-volume production and wide-spread deployment) have been reduced to approximately <$2.00/gallon gasoline equivalent (gge) produced (< ~$4.00/gge produced, delivered and dispensed), for a wide range of natural gas prices — a cost that is competitive with gasoline.[6]

Reduced the cost of producing hydrogen from renewable resources. Costs have been reduced for several pathways, including water electrolysis using wind energy and reforming of bio-derived liquids.[7] Key examples of advances include: reducing the cost of electrolyzer stacks by more than 80% since 2002[8,9] and improving the photosynthetic conversion of sunlight in hydrogen-producing microalgal cultures from 3% to 25%.[10]

Reduced the cost of delivering hydrogen to the end-user. In the last few years, projected costs have been reduced by 40% for tube-trailer delivery of high-pressure gas, 20% for pipeline delivery of high-pressure gas, and 15% for tanker truck delivery of liquid hydrogen.[11]

Improved the capacity of hydrogen storage systems. DOE has developed a novel "cryo-compressed" tank concept for hydrogen storage and made improvements that increased the gravimetric and volumetric capacity of these systems by approximately 50% since 2007.[12] DOE's three hydrogen storage materials centers of excellence produced more than 400 potential materials for hydrogen storage—leveraging the efforts of multiple university, industry, and national lab partners. Among the key accomplishments in materials-based hydrogen storage are the identification and characterization of new materials with more than 50% improvement in capacity since 2004 and the improvement of kinetics for specific metal hydride materials by a factor of more than 60.[13] The properties of the hydrogen storage materials examined have been incorporated in a publicly accessible, searchable database that was accessed by visitors from 55 countries in its first four months available.

Real-world Demonstrations and Technology Validation

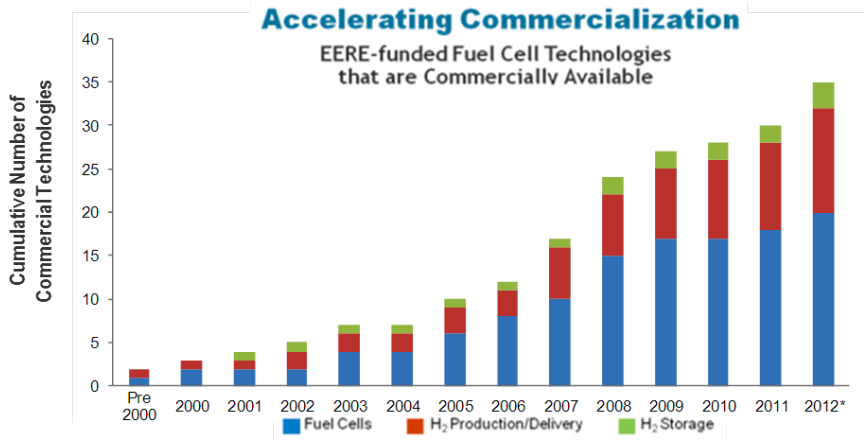
Deployed more than 180 fuel cell electric vehicles and 25 hydrogen fueling stations in learning demonstrations. The vehicles have traveled more than 3.6 million miles in more than 500,000 trips, and the fueling stations have produced or dispensed more than 152,000 kg of hydrogen and completed more than 33,000 refuelings (some of this hydrogen was used by vehicles that were not part of the Hydrogen Learning Demonstration). These demonstrations have validated the status of several key technologies in integrated systems operating under real-world conditions. Key results include demonstrating fuel cell system efficiency of up to 59% (more than double the efficiency of gasoline internal combustion engines), fuel cell system durability of 2,500 hours (about 75,000 miles), and a driving range of more than 250 miles between refueling. DOE also validated one vehicle capable of achieving up to 430 miles on a single fill.[14]

DOE demonstrated the world's first "tri-generation" station (capable of co-producing hydrogen, heat, and power) at the Fountain Valley wastewater treatment facility in California. The station has co-produced electricity and hydrogen with 54% efficiency and will provide up to 100 kg of hydrogen a day, enough to fuel 25 to 50 vehicles. The system has achieved a hydrogen recovery rate of 75-85%.

Early Market Deployments through the American Recovery and Reinvestment Act

DOE awarded $42 million under the American Recovery and Reinvestment Act (Recovery Act) to accelerate the commercialization and deployment of fuel cells. These efforts have deployed over 1,200 fuel cells, primarily in backup power and forklift applications. Success in these early markets is helping pave the way for longer term success of fuel cells in larger markets, such as transportation.

- Industry participants provided approximately $54 million in cost-share funding—for a total of nearly $96 million. These funds are helping to deploy fuel cells across several industries, including bringing high-profile companies into the fuel cell arena, such as Sprint, AT&T, FedEx, Whole Foods, Sysco, Wegmans, and Coca-Cola.
- Successful deployments have led to industry orders of more than 3,500 fuel cell forklifts and 1,300 fuel cell backup power installations with no DOE funding. These projects support fuel cell manufacturers like ReliOn, Plug Power, and Altergy—helping to create high-tech manufacturing jobs, and keep these jobs in the U.S.
- As of October 2012, over 91% of Recovery Act funds have been spent, resulting in over 1,200 fuel cells deployed and over a million hours of operation.



DOE funding has led to 363 patents, 35 commercial technologies, and >65 emerging technologies. DOE's impact: ~$70M in funding for specific projects was tracked and found to have led to nearly $200M in industry investment and revenues.[15]

Companies that have successfully commercialized products developed with Program funding include 3M, DuPont, Fuel Cell Energy, Nuvera, Proton Energy Systems, Plug Power, Quantum, United Technologies, and many others.

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 http://www1.eere.energy.gov/hydrogenandfuelcells/accomplishments.html.

Governmental and Global Partnerships

DOE established the Hydrogen and Fuel Cell Interagency Task Force to coordinate research, development, and demonstration (RD&D) as well as federal adoption of hydrogen and fuel cell technologies. The Task Force includes representatives of ten federal agencies.

DOE also works with the **International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE)**—a partnership involving 17 countries and the European Commission—to foster international cooperation and RD&D, common codes and standards, and information sharing. In addition, the Department coordinates with more than 25 countries through the **International Energy Agency's (IEA's)** two implementing agreements on hydrogen and fuel cells.

U.S. DEPARTMENT OF ENERGY
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March 2013
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