I.0 Introduction

The U.S. Department of Energy's Hydrogen and Fuel Cells Program (the Program) conducts comprehensive efforts across a range of technical and non-technical areas to enable the widespread commercialization of hydrogen and fuel cell technologies in diverse sectors of the economy. The Program is coordinated across the U.S. Department of Energy (DOE or the Department), incorporating activities in the offices of Energy Efficiency and Renewable Energy (EERE) led through the Fuel Cell Technologies Office, Science (SC), Nuclear Energy (NE), and Fossil Energy (FE). The Program's efforts are aligned with the Administration's "all-of-the-above" approach to energy and the President's Climate Action Plan and will spark the type of innovation that drives economic growth and creates American jobs, while moving our economy toward cleaner, more efficient forms of energy that will cut our reliance on foreign oil.

With emphasis on applications that will most effectively strengthen our nation's energy security and improve our efforts to cut carbon pollution, the Program engages in research, development, and demonstration (RD&D) of critical improvements in hydrogen and fuel cell technologies, as well as diverse activities to overcome economic and institutional obstacles to commercialization. The Program addresses the full range of challenges facing the development and deployment of the technologies by integrating basic and applied research, technology development and demonstration, and other supporting activities.

In Fiscal Year (FY) 2013, Congress appropriated approximately $122 million for the DOE Hydrogen and Fuel Cells Program. The Program is organized into distinct programs focused on specific areas of RD&D, as well as other activities to address non-technical challenges. More detailed discussions of Program activities and plans can be found in the *Hydrogen and Fuel Cells Program Plan*, as well as in the plans of the program offices—EERE's *Fuel Cell Technologies Office Multi-Year RD&D Plan*; FE's *Hydrogen from Coal RD&D Plan*; and SC's *Basic Research Needs for the Hydrogen Economy*. All of these documents are available at www.hydrogen.energy.gov/roadmaps_vision.html.

In the past year, the Program made substantial progress toward its goals and objectives. In addition to summarizing examples of key technical accomplishments, this report highlights major programmatic accomplishments such as the co-launching of H_2USA, a national public-private partnership to address the barriers to fuel cell electric vehicles (FCEVs) and hydrogen infrastructure.

PROGRESS AND ACCOMPLISHMENTS BY PROGRAM

This report documents more than 1,000 pages of accomplishments achieved by DOE-funded projects in the last year. The following summaries include only a few examples. More details can be found in the individual program introductions, subsequent project reports, and in the corresponding 2013 Annual Merit Review Report and Peer Evaluation Report, which can be found at http://www.hydrogen.energy.gov/annual_review13_report.html.

Fuel Cells

In 2013, the Fuel Cells program introduced several changes in the cost projection assumptions, including an increase in platinum price and an added requirement that the model system must meet the heat rejection target. These changes resulted in an increase in the projected high volume cost of transportation fuel cell systems to $55/kW in 2013. Updating previous numbers with the same assumptions and requirements shows a decrease in cost of more than 50% since 2006. This decrease stems in part from a reduction in platinum-group metal (PGM) loading and an increase in fuel cell power density, allowing the design of smaller and less expensive stacks. An interim fuel cell system cost target of $40/kW by 2020 was introduced in 2013, while the ultimate cost target was maintained at $30/kW. The $40/kW target was selected on the basis of analysis input from the U.S. DRIVE (Driving Research and Innovation for Vehicle efficiency and Energy sustainability) partnership, and responses from a Request for Information.

Successful research and development (R&D) advances continue to address critical issues with catalysts, with an emphasis on platinum levels and durability improvement. Dealloyed PtNi and PtCo catalysts were shown to have oxygen reduction reaction mass activity exceeding the 2017 target of 0.44 A/mg PGM. In addition to their high mass activity, both of these catalysts demonstrated high performance operation at high current in membrane electrode assemblies (MEAs). Researchers also developed meso-structured thin film catalysts through a new annealing process that enables specific activity eight times that of platinum. Improvements in MEAs have led to a 20% decrease since 2012 in PGM total content levels in PtNi nano-structured thin-film catalysts when operating at high temperatures of 90°C and voltages of 0.69 V. This improvement enabled achievement of a catalyst specific power level of 6.0 kW/g in

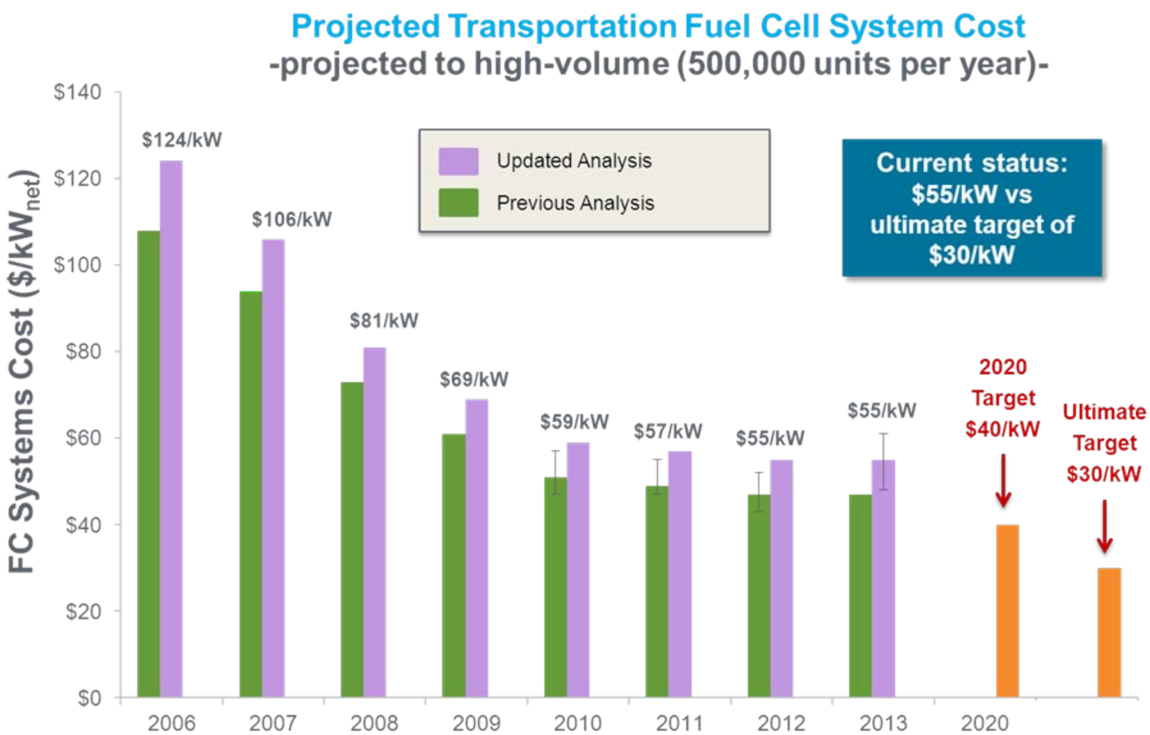


FIGURE 1. Modeled cost of an 80-kW automotive fuel cell system based on projection to high-volume manufacturing (500,000 units/year).[1]

2013, exceeding the program's milestone of 5.9 kW/g. Further R&D is required to achieve the 2020 catalyst specific power target of 8.0 kW/g, and to simultaneously meet catalyst durability targets.

Hydrogen Production

In FY 2013, the Hydrogen Production program continued to focus on developing technologies to enable the long-term viability of hydrogen as an energy carrier for a range of applications with a focus on hydrogen from low-carbon and renewable sources. Progress continued in several key areas, including biological hydrogen production, solar-thermochemical hydrogen (STCH) production, and photoelectrochemical hydrogen production.

For example, FY 2013 efforts in photobiological production led to the demonstration of an almost two times increase in hydrogen evolution rate compared to the wild-type rate for a cyanobacterial strain with a non-native hydrogenase with higher oxygen tolerance and other genetic modifications.[2] A perovskite structure was discovered that produces nine times more hydrogen than CeO_2, the current state-of-the-art metal-oxide redox material for STCH production. In addition, isothermal redox at 1,350°C for the hercynite STCH cycle was shown to be feasible with between three and twelve times the production capacity per mass of active material than hercynite and ceria, respectively, when reduced at 1,350°C and reoxidized at 1,000°C.[3] These results were recently published in *Science* magazine.

In addition, technical progress has reduced the projected costs for hydrogen production in several of the nearer-term pathways. A summary of projected high-volume cost versus targets is shown in Figure 2.

Another key accomplishment in FY 2013 was the completion of the Hydrogen Production Expert Panel (a Hydrogen and Fuel Cell Technologies Advisory Committee subcommittee) report that collected input from industry, academic, and national laboratory experts during a May 2012 workshop. The subcommittee was officially tasked by former Energy Secretary, Dr. Steven Chu, with providing recommendations to enable the widespread production of affordable, low-carbon hydrogen for both near- and long-term markets and key findings were included in the final

1 DOE Hydrogen and Fuel Cells Program Record #13012, http://hydrogen.energy.gov/pdfs/13012_fuel_cell_system_cost.pdf.
2 See project report *II.D.4 Hydrogen from Water in a Novel Recombinant Oxygen-Tolerant Cyanobacterial System* by Philip Weyman.
3 See project report *II.B.3 Solar-Thermal Redox-Based Water Splitting Cycle* by Alan Weimer.

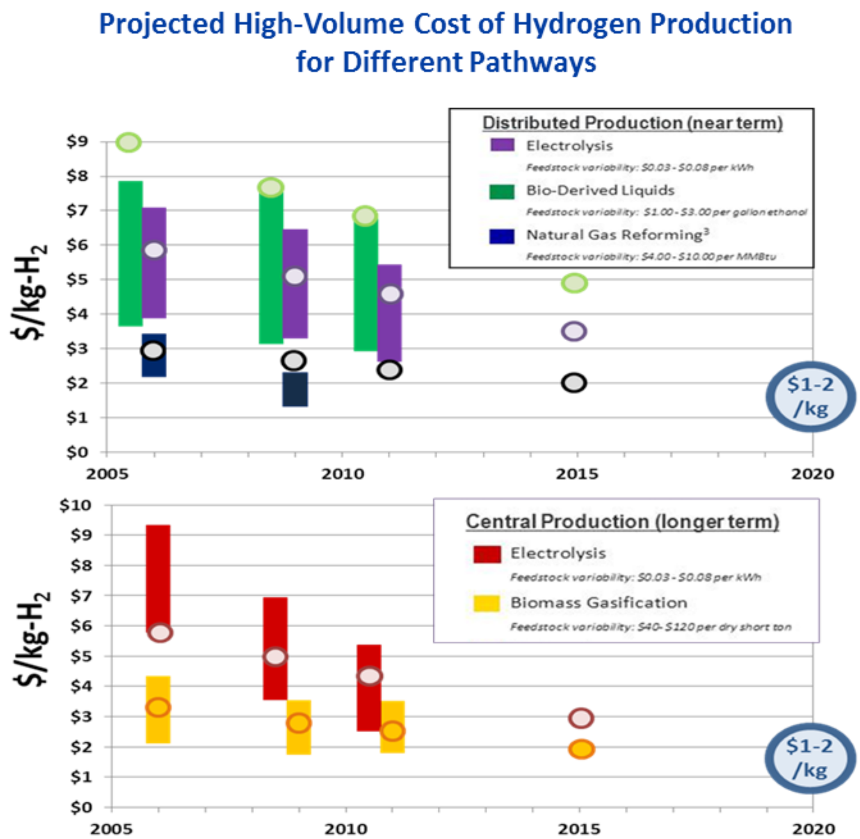


FIGURE 2. Hydrogen Production Cost Status (based on projected high-volume cost)[4]

report that is posted online.[5] The program also signed a Memorandum of Understanding with the National Science Foundation to allow for joint funding of RD&D. A major strategic outcome was a jointly funded parallel solicitation between DOE and the National Science Foundation for longer term hydrogen production R&D from renewables.

Hydrogen Delivery

In FY 2013 the Hydrogen Delivery program focused on identifying the RD&D needs for materials and components for forecourt technologies to reduce capital costs and improve system reliability. Significant cost reduction at the forecourt can be achieved through the use of high-pressure tube trailers and reliable low-cost compression. Optimization of an integrated tube trailer configuration for hydrogen delivery increased the 3,600 psi hydrogen capacity to 800 kg. This results in an increase of 30% relative to the baseline.[6]

The average hydrogen delivery cost status based on nine 700-bar delivery scenarios including pipeline, tube trailer, and liquid delivery in 2011 and 2013 and the 2015 and 2020 delivery targets are shown in Figure 3. The blue circles indicate the 2015 and 2020 cost targets and the dotted line shows the extrapolation of prior year targets against which progress can be mapped. The blue and green bars indicate the range of costs of the 350-bar and 700-bar pathways in 2011 and 2013 respectively.[7]

Developments in centrifugal compression and fiber-reinforced polymer pipelines continue to improve the economics of delivering hydrogen via pipelines. Completion of an initial validation testing of single-stage oil-free centrifugal compressor system in air and in helium at 60,000 rpm confirmed the single-stage compression ratio and thermal stability. Significant improvements in advanced forecourt technologies include a decrease of 50% in the

[4] DOE Hydrogen and Fuel Cells program Record #12002, http://hydrogen.energy.gov/pdfs/12002_h2_prod_status_cost_plots.pdf
[5] Report of the Hydrogen Production Expert Panel (May 2013), http://www.hydrogen.energy.gov/pdfs/hpep_report_2013.pdf
[6] See project report *III.3 Development of High-Pressure Hydrogen Storage Tank for Storage and Gaseous Truck Delivery* by Jon Knudsen and Don Baldwin.
[7] DOE Hydrogen and Fuel Cells Program Record #13013, http://www.hydrogen.energy.gov/pdfs/13013_h2_delivery_cost_central.pdf

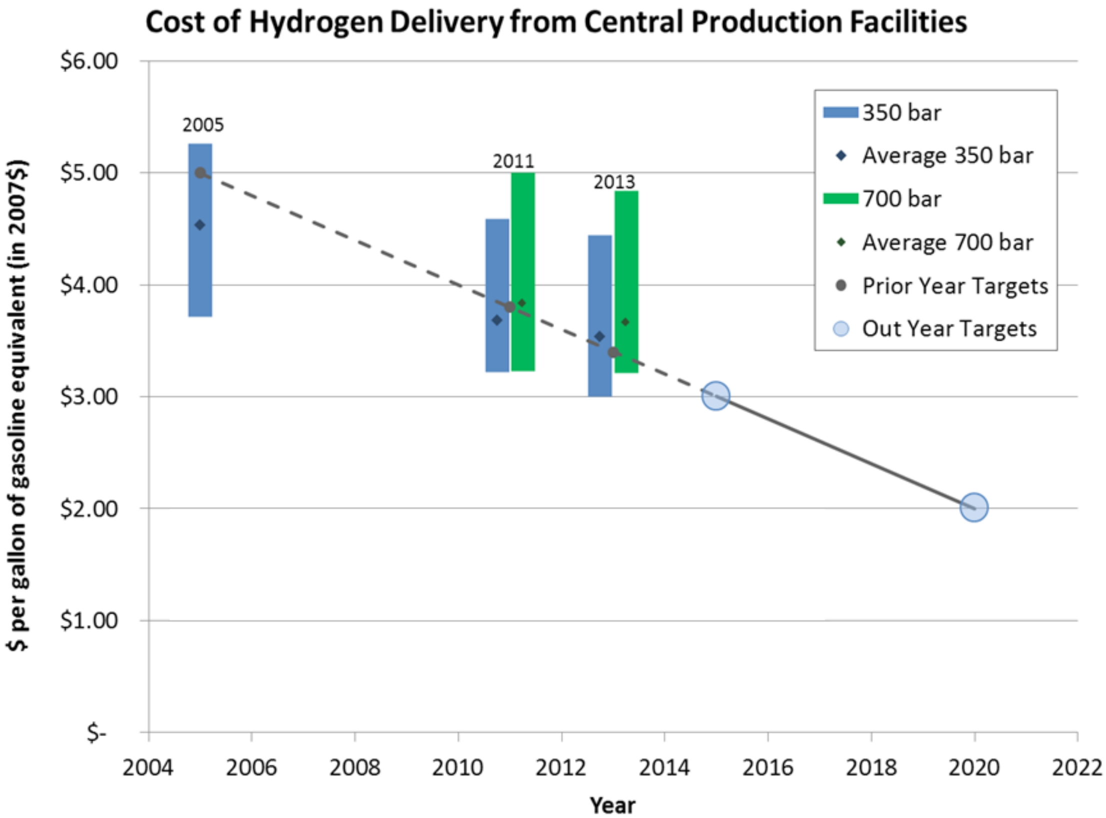


FIGURE 3. Details for the high-volume cost projection assumptions can be found in Record 13013.[8] Based on HDSAM (v2.3) analysis assuming 10% market penetration in a city with a population of 1.5M and a station size of 750 kg/day.

prototype unit cost of an electrochemical compressor since 2007 which was achieved by reducing the cell part count by half. Simultaneously a greater than three-fold increase in the stack current density and a two-fold increase in the cell active area has been achieved, which resulted in higher compressor throughput while lowering the total cells per stack.[9]

In addition to these technical accomplishments, the Hydrogen Delivery program held two workshops to discuss the current status and challenges in these areas. The first workshop, Polymer and Composite Materials Used in Hydrogen Service,[10] was held as a joint workshop with the Safety, Codes and Standards program at the DOE headquarters in October 2012 and the second workshop, Compression, Storage and Dispensing Cost Reduction,[11] was held at Argonne National Laboratory in March 2013.

Hydrogen Storage

In FY 2013, the Hydrogen Storage program focused on development of lower cost precursors and fillers for carbon fiber composites to lower the cost of high-pressure compressed hydrogen systems, system engineering for transportation applications and continued R&D efforts in materials-based storage including metal hydrides, chemical hydrogen storage materials, and hydrogen sorbents.

The Hydrogen Storage program has developed comprehensive sets of hydrogen storage targets for onboard automotive, portable power, and material handling equipment applications. In the near-term, automotive companies plan to commercialize FCEVs that use onboard compressed hydrogen systems, with system cost being one of the most important challenges to commercialization. The program, working with automotive manufacturers through the U.S.

8 DOE Hydrogen and Fuel Cells Program Record #13013, http://www.hydrogen.energy.gov/pdfs/13013_h2_delivery_cost_central.pdf.
9 See project report *III.6 Electrochemical Hydrogen Compressor* by Ludwig Lipp.
10 Polymer and Composite Materials Workshop, http://www1.eere.energy.gov/hydrogenandfuelcells/mtg_poly_comp_materials.html
11 Compression, Storage and Dispensing Cost Reduction Workshop, http://www1.eere.energy.gov/hydrogenandfuelcells/wkshp_hydrogen_csd.html

DRIVE partnership, established onboard automotive hydrogen storage system cost targets of $12/kWh of useable stored hydrogen to be reached by 2017, with $8/kWh of useable storage hydrogen as an Ultimate Full Fleet target.

As a longer-term strategy, the Hydrogen Storage program continues to pursue less mature hydrogen storage technologies that have the potential to satisfy all onboard hydrogen storage targets. Much of this activity is completed through the Hydrogen Storage Engineering Center of Excellence (HSECoE). In FY 2013, the HSECoE completed assessment of hydrogen storage systems for cryo-sorbents and liquid-phase off-board regenerable chemical hydrogen storage material systems. The HSECoE also completed an assessment of chemical hydrogen storage materials and systems that led to a decision to terminate work on these systems due to low probability of identifying materials that meet 8.5 wt% fluid gravimetric requirements and regeneration efficiencies. The HSECoE also completed an assessment of adsorbent system that led to a down selection of both the Hexcel and modular adsorbent tank insert heat exchanger designs for subscale prototype adsorbents systems.[12] Additionally, the HSECoE identified balance-of-plant components for a cryo-sorbent hydrogen storage system with a total mass of less than 9.4 kg and volume of less than 11.6 L exceeding the system targets of 17 kg and 18.5 L.

In FY 2013, the Hydrogen Storage program continued to reduce the cost of compressed hydrogen gas storage tanks by focusing efforts on low-cost, high-strength carbon fiber and advanced tank designs. The program was able

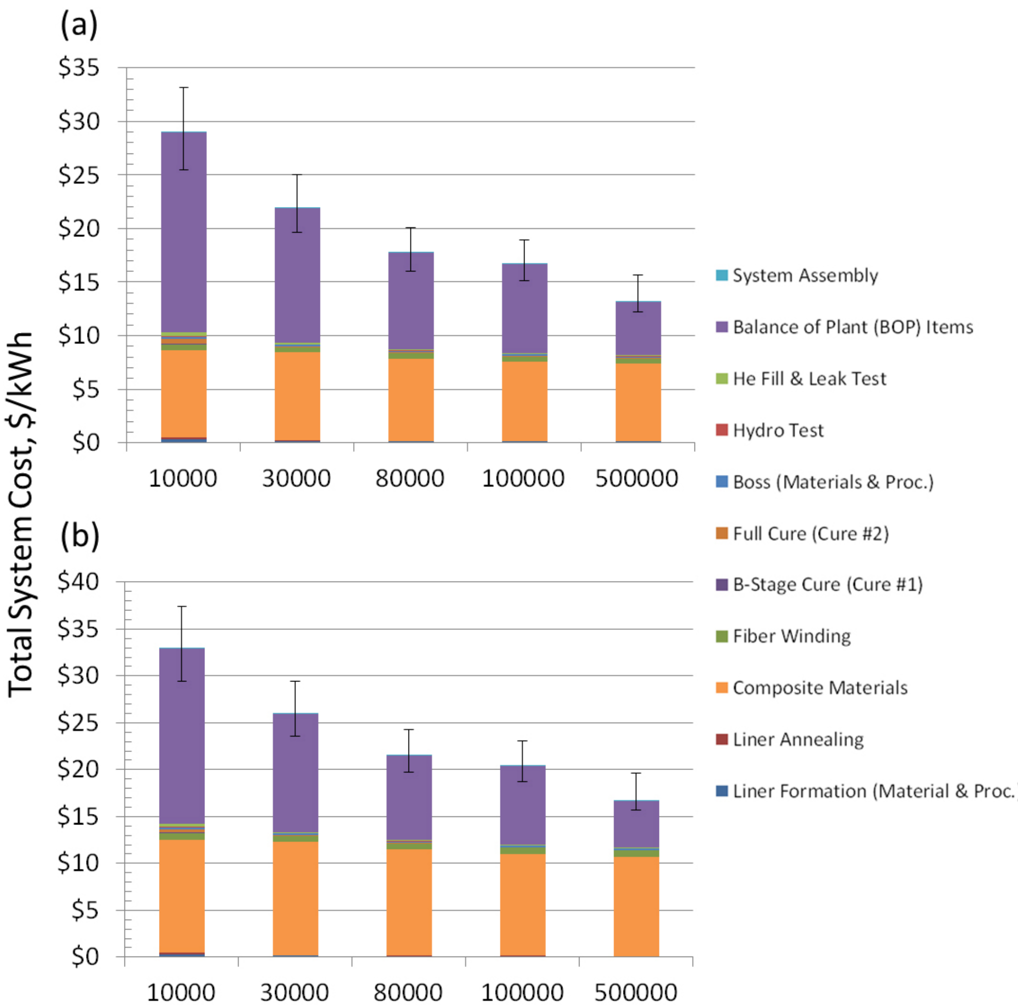


FIGURE 4. Projected costs in 2007$, at various annual manufacturing volumes, for (a) 350-bar and (b) 700-bar compressed hydrogen storage systems, sized to deliver 5.6 kg of hydrogen to the vehicle fuel cell powerplant.[13]

[12] See project report *IV.B.1 Hydrogen Storage Engineering Center of Excellence* by Donald Anton.

[13] DOE Hydrogen and Fuel Cells Program Record #13010, http://hydrogen.energy.gov/pdfs/13010_onboard_storage_performance_cost.pdf

to demonstrate strategies to reduce the cost of pressure vessels by 15% compared to the 2010 baseline of $17/kWh, through modeling and material testing including: testing properties of low-cost resins (led to a 4% cost reduction); testing properties of additives to enhance resin properties (led to a 5% cost reduction); and modeling to demonstrate alternative fiber placement and fiber types (led to a 6% cost reduction).[14]

In FY 2013, the Hydrogen Storage program continued to carry out assessments of hydrogen storage technologies and disseminate proper hydrogen storage material testing and characterization procedures to evaluate material/system performance against requirements of hydrogen fuel cell applications. Updating the Design for Manufacturing Analysis method and validating key performance parameters for pressure vessels was a critical activity and was based on discussions with industry, the U.S. DRIVE partnership, Hydrogen Storage Tech Team, the Storage System Analysis Working Group, Argonne National Laboratory, Pacific Northwest National Laboratory, HSECoE, and project collaborators.

Manufacturing R&D

In FY 2013, manufacturing projects continued in the areas of novel electrode deposition processes for MEA fabrication, reduction in the number of assembly steps for MEAs, use of scatterfield microscopy and in-line diagnostics for cell and component quality control to measure catalyst loading and detect defects in catalyst-coated membranes and gas diffusion electrodes (GDEs), and fabrication technologies for high-pressure composite storage tanks. In the area of MEAs, the Manufacturing R&D program demonstrated a "one-pass" microporous layer and catalyst coating on carbon paper, reduced labor and material costs by >30% for paper structures compared to best cloth GDEs, and demonstrated a 30% reduction in platinum loading compared to best cloth-based anodes without losing performance.[15] Using an optical reflectometry technique, the program also detected surface defects and morphology in electrode layers, in both catalyst-coated membrane and gas diffusion electrode configurations, as well as surface defects in tubular solid oxide fuel cells.

In May of 2013, the program held a fuel cell manufacturing roundtable with Assistant Secretary for Energy Efficiency and Renewable Energy Dr. David Danielson, Connecticut Governor Dannel Malloy, and members of Connecticut's fuel cell manufacturing industry. In addition to the round table, senior DOE officials were able to tour three major hydrogen and fuel cell manufacturing plants in the area.

Basic Research

The Basic Energy Sciences program in the DOE Office of Science supports fundamental scientific research addressing critical challenges related to hydrogen storage, hydrogen production, and fuel cells. These basic research efforts complement the applied R&D projects supported by other offices in the Program. Progress in any one area of basic science is likely to spill over to other areas and bring advances on more than one front.

The subjects of basic research most relevant to the Program's key technologies are:

- Hydrogen Storage: Nanostructured materials; theory, modeling, and simulation to predict behavior and design new materials; and novel analytical and characterization tools.
- Fuel Cells: Nanostructured catalysts and materials; integrated nanoscale architectures; novel fuel cell membranes; innovative synthetic techniques; theory, modeling, and simulation of catalytic pathways, membranes, and fuel cells; and novel characterization techniques.
- Hydrogen Production: Approaches such as photobiological and direct photochemical production of hydrogen.

By maintaining close coordination between basic science research and applied R&D, the Program ensures that discoveries and related conceptual breakthroughs achieved in basic research programs will provide a foundation for the innovative design of materials and processes that will lead to improvements in the performance, cost, and reliability of fuel cell technologies and technologies for hydrogen production and storage. This is accomplished in various ways—for example, through bimonthly coordination meetings between the participating offices within DOE, and at the researcher level by having joint meetings with participation from principal investigators who are funded by the participating offices.

[14] See project report *IV.F.4 Synergistically Enhanced Materials and Design Parameters for Reducing the Cost of Hydrogen Storage Tanks* by Kevin Simmons.

[15] See project report *VI.5 High-Speed, Low-Cost Fabrication of Gas Diffusion Electrodes for Membrane Electrode Assemblies* by Emory De Castro.

In May 2013, the Program included 29 presentations and posters from Basic Energy Sciences-funded researchers on fundamental science related topics in conjunction with presentations by EERE and Advanced Research Projects Agency - Energy (ARPA-E) funded researchers in the 2013 Hydrogen and Fuel Cells Annual Merit Review and Peer Evaluation (AMR).[16]

Technology Validation

In FY 2013, the Technology Validation program continued efforts toward real-world evaluation of fuel cell bus technologies at various transit authorities, and monitoring performance of fuel cells in stationary power, backup power, and material handling equipment applications. These activities led to the validation of light-duty FCEV performance and durability through analysis of dynamometer and real-world vehicle performance data. The program collected and analyzed data from fuel cell buses from three transit agencies: AC Transit (Oakland, California), CTTRANSIT (Hartford, Connecticut), and SunLine (Thousand Palms, California) and found that the new fuel cell bus designs have about 1.9 times the fuel economy of diesel buses, and approximately 2.3 times the fuel economy of compressed natural gas buses.[17]

The program was able to independently validate systems integration of commercial and advanced prototype hydrogen production, compression, dispensing, and fuel cell technologies. Specific activities included performing accelerated life testing of both diaphragm and piston hydrogen compressors. The program collected valuable data from state-of-the-art hydrogen fueling facilities, such as those operated by the California Air Resources Board (CARB), Proton OnSite, and GTI, to provide feedback on sensitive data related to hydrogen infrastructure to stakeholders. Finally, the program validated a system of reclamation and recycling of hydrogen that is wasted (flared or vented) in various industrial operations.

Safety, Codes and Standards

The Hydrogen Safety, Codes and Standards program continued to achieve significant accomplishments with respect to critical regulations, codes, and standards in FY 2013. For example, in December 2012, the Global Technical Regulation on hydrogen-fuelled vehicles was submitted to the United Nations Economic Commission for Europe Working Party 29 (UN ECE WP.29) and was accepted in June 2013. This regulation will serve as the technical underpinning for the United States Federal Motor Vehicle Safety Standard. The program also continued to support R&D to provide the technical basis for codes and standards development, with projects in a wide range of areas, including fuel specification, separation distances, materials and components compatibility, and hydrogen sensor technologies.

The program developed integrated algorithms for conducting Quantitative Risk Assessments for gaseous hydrogen facilities and vehicles that are applied to identified risk drivers and associated consequences, including further reducing separation distances and identified ignition and jet light up boundaries of jet flames for circular unintended releases with increased confidence and initiated a study on non-circular releases. The program developed a template that includes basic codes and standards requirements, including those related to the California Risk Management Plan requirements that will be used in California. The program continues to develop training material for first responders and code officials and have educated over 26,000 first responders and code officials to-date (online[18] and in-person).

The program also developed the first mobile app for the Fuel Cell Technologies Office. The app, available free of charge for iPhones and iPads, integrates H2incidents.org and H2bestpractices.org into a single, searchable application and includes safety planning guidance and checklist features.[19]

Education

The Education program facilitates hydrogen and fuel cell demonstrations and supports commercialization by providing technically accurate and objective information to key target audiences both directly and indirectly involved in the use of hydrogen and fuel cells. Funding from prior appropriations supported the program's activities.

In FY 2013 the Fuel Cell Technologies Office published more than 80 success stories through news articles, blogs, press releases, and media announcements and conducted more than 15 webinars, averaging more than 150 attendees per webinar. Activities reached at least 3,000 people at key conferences and meetings, including the Fuel Cell Expo

[16] 2013 Annual Merit Review Proceedings, http://www.hydrogen.energy.gov/annual_review13_proceedings.html

[17] Fuel Cell Buses in U.S. Transit Fleets: Current Status 2012, http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/fceb_status_2012.pdf

[18] Hydrogen Safety for First Responders, http://www.hydrogen.energy.gov/firstresponders.html and Introduction to Hydrogen Safety for Code Officials, http://www.hydrogen.energy.gov/training/code_official_training/

[19] Energy Department Launches App on Hydrogen Use, September 12, 2013, http://apps1.eere.energy.gov/news/progress_alerts.cfm/news_id=20553

in Japan, AIChE conference, and the AMR. The program is also continuing to train middle school and high school teachers based on prior years' funding through "H2 Educate!" reaching a cumulative of 10,000 teachers, in 35 states; 90% of participants stated that the training resources increased the effectiveness of their lesson plans.

Market Transformation

To ensure that the benefits of the Program's efforts are realized in the marketplace, in FY 2013 the Market Transformation program continued to facilitate the growth of early markets for fuel cells used in portable, stationary, and specialty-vehicle applications. Market Transformation activities are helping to reduce the cost of fuel cells by enabling economies of scale through early market deployments; these early deployments also help to overcome a number of barriers, including the lack of operating performance data, the need for applicable codes and standards, and the need for user acceptance.

Current key objectives of the Market Transformation program are to build on past successes in material handling equipment (MHE) (e.g., lift trucks or forklifts) and emergency backup power applications by exploring other emerging applications for market viability. FY 2013 accomplishments included launching a new project to demonstrate commercial viability of fuel cell-powered airport ground support baggage tractors, demonstrating fuel cell-powered electric medium-duty hybrid trucks for parcel delivery applications, and beginning design development of fuel cell auxiliary power systems for refrigerated trucks. These projects are highly leveraged, with an average of more than half of the projects' funds being provided by DOE's partners. The market transformation team also demonstrated the world's first landfill gas-to-hydrogen fuel system for fuel cell-powered lift trucks at the BMW plant in Greer, South Carolina, which has the world's largest fuel cell-powered lift truck fleet (more than 300) to date.

Systems Analysis and Integration

The Systems Analysis program supports decision making by providing a greater understanding of technology gaps, options and risks, and examining the interaction of individual technologies and components and their contributions to the performance of larger systems, e.g., the entire hydrogen fuel system, from production to utilization. The program also analyzes cross-cutting issues, such as the integration of hydrogen and fuel cell systems with the electrical sector and the use of renewable fuels. Particular emphasis is given to assessing stationary fuel cell applications and the implications of various approaches to establishing hydrogen infrastructure.

The Systems Analysis program activity made several significant contributions to the Program during FY 2013. The cost of hydrogen infrastructure was compared to infrastructure for other advanced fuel vehicles and opportunities of reducing the infrastructure costs were examined by utilizing using stakeholder input and exploring synergies with other fuels such as natural gas. The JOBS and economic impacts of fuel cells model continues to be enhanced by Argonne National Laboratory and RCF Economic and Financial Consulting as they add the capability to assess employment impacts of infrastructure development. Infrastructure and early market analyses were conducted to better understand early market hurdles such as cash flow and station utilization, and supply and demand issues. The Greenhouse Gases Regulated Emissions and Energy Use in Transportation (GREET) model is being enhanced to evaluate greenhouse gas emissions and petroleum use on a well-to-wheels basis for hydrogen pathways with various onboard storage options, and incorporating water consumption analysis in the model.

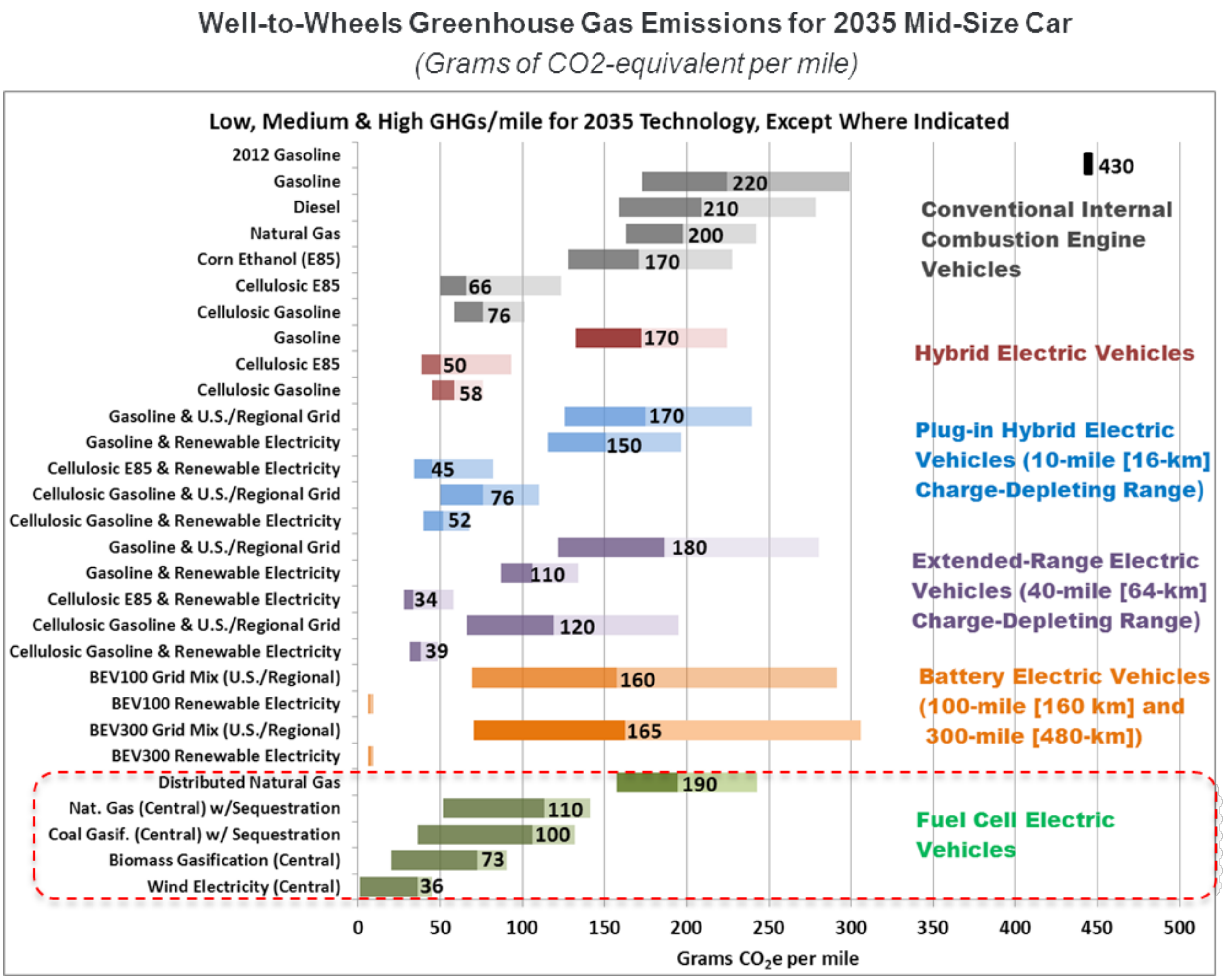
In addition, the Systems Analysis program conducted critical vehicle portfolio well-to-wheel analysis in collaboration with the Bioenergy Technologies and Vehicles Technologies Offices to estimate the lifecycle greenhouse gas (GHG) emissions resulting from several fuel/vehicle pathways, for a portfolio of future mid-size cars. The data and major assumptions and results are documented in a DOE records.[20] The results of the analysis show that GHG emissions could be reduced to approximately 35 g of CO_{2eq} per mile compared to the current gasoline internal combustion engine of 430 g of CO_{2eq} per mile, as shown in Figure 5.

American Recovery and Reinvestment Act of 2009 Projects

The American Recovery and Reinvestment Act of 2009 (Recovery Act or ARRA) has been a critical component of the Program's efforts to accelerate the commercialization and deployment of fuel cells in the marketplace.

As of October 2013, more than 500 fuel cell lift trucks and a total of 820 fuel cell backup power systems for cellular communications towers and stationary backup power systems had been deployed—surpassing the original deployment goal of up to 1,000 fuel cells—and over 95% of the Recovery Act project funds had been spent by the

[20] Fuel Cell Technologies Office Program Records, http://hydrogen.energy.gov/program_records.html



E85 – 85% ethanol 15% gasoline; BEV – battery electric vehicle; CO_2e – CO_2-equivalent

FIGURE 5. Well-to-Wheels Greenhouse Gas Emissions for 2035 Mid-Size Car.[21]

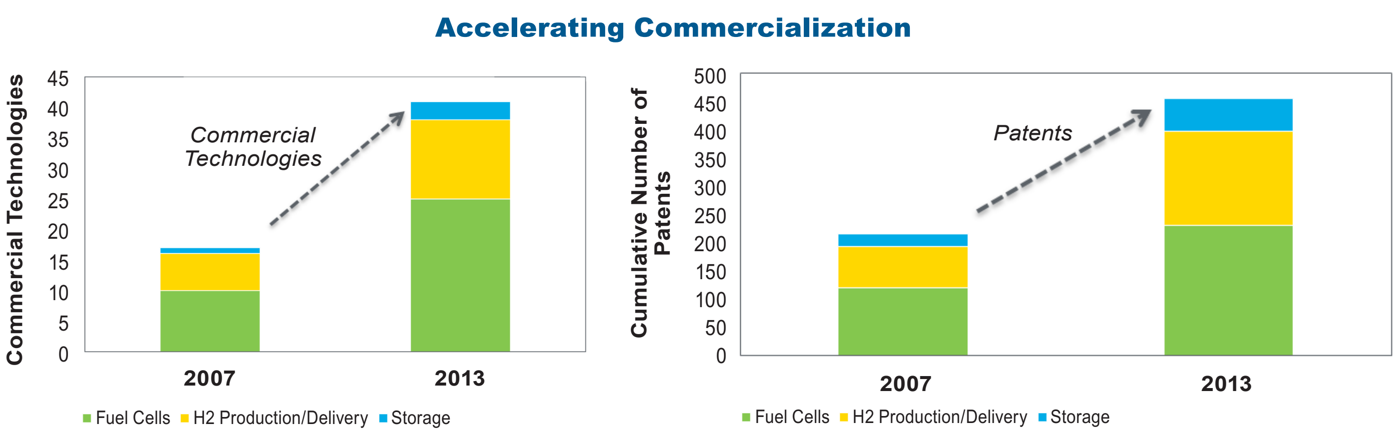


FIGURE 6. Cumulative number of commercial products on the market as a result of funding by the DOE Fuel Cell Technologies Office.[22]

[21] DOE Hydrogen and Fuel Cells Program Record #13005, http://hydrogen.energy.gov/pdfs/13005_well_to_wheels_ghg_oil_ldvs.pdf

[22] Pathways to Commercial Success: Technologies and Products Supported by The Fuel Cell Technologies Program, Pacific Northwest National Laboratory, September 2012, www.hydrogenandfuelcells.energy.gov/pdfs/pathways_2013.pdf

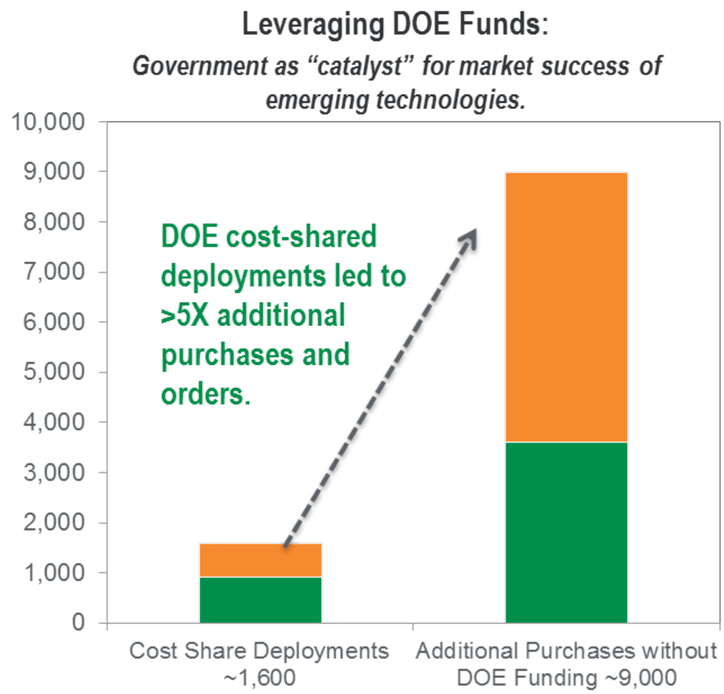


FIGURE 7. Early market deployments of approximately 1,600 fuel cells have led to approximately 9,000 additional purchases by major companies (including Coca-Cola, Sprint, Sysco, FedEx, and others) **with no additional DOE funding.**

projects. The National Renewable Energy Laboratory's (NREL's) National Fuel Cell Technology Evaluation Center (NFCTEC) has established data reporting protocols with each of the project teams. Composite Data Products (CDPs) and Detailed Data Products showing progress to date have been prepared. The CDPs are available on the NREL NFCTEC website.[23] Of the original twelve projects, nine have been successfully completed.

Successful DOE deployments of fuel cells (including deployments from ARRA funding as well as Market Transformation projects) have led to industry orders of almost 5,000 fuel cell forklifts and almost 3,500 fuel cell backup power systems, with no additional DOE funding.[24]

OTHER PROGRAM ACTIVITIES AND HIGHLIGHTS FROM FY 2013

Tracking Commercialization

One indicator of the robustness and innovative vitality of an RD&D program is the number of patents applied for and granted, and the number of technologies commercialized. The Program continued to assess the commercial benefits of funding by tracking the commercial products and technologies developed with the support of the EERE Fuel Cell Technologies Office (the Office). R&D efforts funded by the Office have resulted in more than 450 patents, 40 commercial technologies, and 65 technologies that are projected to be commercialized within three to five years.[25] In addition, EERE's investment of $50 million in specific hydrogen and fuel cell projects led to more than $300 million in revenue and investments of approximately $14 million in specific projects led to a nearly $130 million in additional private investment.

Awards & Distinctions

During the last year, a number of researchers within the Program were recognized through various awards. For example:

[23] http://www.nrel.gov/hydrogen/proj_fc_market_demo.html
[24] DOE Hydrogen and Fuel Cells Program Record #13007 and #13008, http://hydrogen.energy.gov/program_records.html
[25] 2013 Pathways to Commercial Success: Technologies and Products Supported by the Fuel Cell Technologies Office, http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/pathways_2013.pdf

- Electrocatalysis magazine dedicated its December 2012 issue to celebrate Radoslav Adzic, a Fuel Cell Technologies Office-supported research scientist at Brookhaven National Laboratory.
- Dr. Maria Ghirardi was named to NREL's Research Fellows Council, the laboratory's top advisory council comprised of internationally recognized NREL scientists and engineers.
- Dr. Felix Paulauskas, an EERE-supported fuel cell scientist, was recognized by the Oak Ridge National Laboratory (ORNL) as the 2012 Inventor of the Year for distinguished, sustained, and cumulative contributions to ORNL's patent portfolio, which are the basis for establishment of carbon fiber initiatives and significant program growth, new ORNL facilities, and future opportunities for developing and demonstrating pioneering new approaches to producing carbon fibers.
- Dr. Bryan Pivovar was recognized with the Charles W. Tobias Young Investigator Award from the Electrochemical Society for his work advancing polymer electrolyte fuels and liquid fed fuel cell systems.
- Dr. Piotr Zelenay of Los Alamos National Laboratory won the 2013 Research Award presented by the Energy Technology Division of The Electrochemical Society for his research on polymer electrolyte fuel cells, including direct-methanol fuel cells, precious-metal/non-precious metal electrocatalysis, membrane and membrane electrode assembly development, and performance optimization of fuel cell materials and components.

Key Reports/Publications

Every year, the Hydrogen and Fuel Cells Program commissions a number of key reports, providing vital information to industry and the research community. Some of these are released on an annual basis—such as the *Market Report (**2012 Fuel Cell Technologies Market Report**)*, the commercialization report (***2013 Pathways to Commercial Success: Technologies and Products Supported by the Fuel Cell Technologies Office***), and the ***State of the States: Fuel Cells in America 2013*** report—while others are published when studies are complete, projects have ended, or key milestones have been reached. Key examples include:

- The ***2012 Fuel Cell Technologies Market Report*** finds that commercial markets for fuel cells continue to expand, including in the stationary back-up power and material handling equipment markets. Approximately 30,000 fuel cell systems were shipped worldwide in 2012, up nearly 35% over 2011 and more than 320% since 2008. http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/2012_market_report.pdf
- ***2013 Pathways to Commercial Success: Technologies and Products Supported by the Fuel Cell Technologies Office,*** the Program's annual commercialization report, indicates that Fuel Cell Technologies Office efforts have successfully generated more than 450 patents, 41 commercial technologies, and 66 technologies that are projected to be commercial within the next three to five years. http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/pathways_2013.pdf
- ***State of the States: Fuel Cells in America 2013***, the fourth annual report on state activities, details fuel cell and hydrogen activities and policies in the 50 states and the District of Columbia. http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/state_of_the_states_2013.pdf
- ***Business Case for Fuel Cells 2012*** illustrates how top American companies are using fuel cells in their business operations to advance their sustainability goals, save millions of dollars in electricity costs, and reduce carbon emissions by hundreds of thousands of metric tons per year. www.hydrogenandfuelcells.energy.gov/pdfs/business_case_fuel_cells_2012.pdf
- ***REPORT ON RFI DE-FOA-000753: High-Accuracy Hydrogen Meters*** summarizes the current status of meters for hydrogen fueling with information collected from publically available documents and a Request for Information, excluding any proprietary/company sensitive information. http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/rfi_responses_hydrogen_meters.pdf
- ***Hydrogen Compression, Storage, and Dispensing Cost (CSD) Reduction Workshop Report*** includes proceedings from the Hydrogen CSD Cost Reduction Workshop that took place March 20–21, 2013. http://www1.eere.energy.gov/hydrogenandfuelcells/wkshp_hydrogen_csd.html
- ***Economic Impact of Fuel Cell Deployment in Forklifts and for Backup Power under the American Recovery and Reinvestment Act*** estimates the economic impacts associated with expenditures under the Recovery Act and includes estimates of the total employment, earnings, and economic output using the JOBS and economic impacts of Fuel Cells model, also developed by Argonne. http://www1.eere.energy.gov/hydrogenandfuelcells/fc_publications.html#fc_general

- ***Evaluation of the Total Cost of Ownership of Fuel Cell-Powered Material Handling Equipment*** assesses the total cost of ownership of fuel cell MHE and compares it to the cost of ownership of traditional battery-powered MHE. http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/fuel_cell_mhe_cost.pdf
- ***Blending Hydrogen into Natural Gas Pipeline Networks: A Review of Key Issues*** focuses on using hydrogen both as a fuel and as an energy storage tool and details the issues related to blending hydrogen into natural gas pipeline networks. http://www1.eere.energy.gov/hydrogenandfuelcells/news_detail.html?news_id=19093
- ***Vessel Cold-Ironing Using a Barge Mounted PEM Fuel Cell: Project Scoping and Feasibility*** examines the feasibility of a hydrogen-fueled polymer electrolyte membrane fuel cell barge to provide electrical power to vessels at anchorage or at berth. http://www1.eere.energy.gov/hydrogenandfuelcells/fc_publications.html#fc_aux
- ***Fuel Cell Buses in U.S. Transit Fleets: Current Status 2012*** report shows that the fuel economy of fuel cell electric buses is 1.8 to 2 times higher than conventional diesel buses (4 mpg) and compressed natural gas buses (3 mpg). http://www1.eere.energy.gov/hydrogenandfuelcells/news_detail.html?news_id=18910
- ***The Hydrogen Safety Best Practices Manual*** is an online manual that captures the wealth of knowledge and experience related to the safe handling and use of hydrogen that exists as a result of its extensive history in a wide variety of applications. http://h2bestpractices.org/

New Funding Opportunity Announcements (FOAs) and Awards

- **$1 million to advance cost-competitive hydrogen fuel.** To help meet this aggressive goal by 2020, the projects selected through this Program will help identify cost-effective materials and processes to produce hydrogen from renewable energy sources and natural gas.
- **$9 million to accelerate the development of hydrogen and fuel cell technologies for use in vehicles, backup power systems, and hydrogen refueling components.** This FOA closed on July 12, 2013.
- **$4 million to address critical challenges and barriers for low-cost, low-carbon hydrogen production.** The new funding opportunity solicits projects focused on innovative materials, processes, and systems that are needed to establish the technical and cost feasibility for renewable and low carbon hydrogen production. Concept papers were due November 26, 2013, and full applications are due January 31, 2014.
- **$4 million to address critical challenges and barriers to advanced hydrogen delivery technology development.** The new funding opportunity solicits projects focused on innovative hydrogen delivery materials, components, and systems needed to establish the technical and cost feasibility for renewable and low-carbon hydrogen delivery. Concept papers were due December 9, 2013, and full applications are due February 14, 2014.
- **$4 million to develop advanced hydrogen storage systems and novel materials to provide adequate onboard storage for a wide range of applications including FCEVs, and for emerging fuel cell applications such as material handling equipment.** Concept papers were due November 11, 2013 and full applications are due January 17, 2014.
- **$4.5 million awarded to lower the cost, improve the durability, and increase the efficiency of next-generation fuel cell systems.**
- **Small Business Innovation Research (SBIR)/Small Business Technology Transfer (STTR) Phase I Release 2 funding opportunity included a hydrogen dispenser technologies topic.** Applications were due in February 2013.
- **SBIR/STTR Phase I Release 2 Award Winners included hydrogen dispenser and hydrogen sensor projects.**
- **SBIR/STTR award winners included a hydrogen-from-water electrolysis project.**

Requests for Information (RFI)

- Automotive Fuel Cell Cost and Durability Target collected feedback from stakeholders regarding proposed cost and durability targets for fuel cells designed for automotive applications. The proposed cost target is $40/kW for automotive fuel cell systems and the proposed durability target is 5,000 hours, which corresponds to approximately 150,000 miles. This RFI closed on April 1, 2013.[26]

[26] http://www1.eere.energy.gov/hydrogenandfuelcells/news_detail.html?news_id=18989

- Hydrogen and Fuel Cell Technology Readiness collected feedback from stakeholders regarding technology validation and deployment activities aimed at ensuring commercial readiness and stimulating commercialization of fuel cell and hydrogen technologies. This RFI closed on April 10, 2013.[27]
- Home Hydrogen Refueling Systems and Potential H-Prize Topics collected feedback from stakeholders about a potential H-Prize competition involving home hydrogen refueling systems. This RFI closed on May 24, 2013.[28]
- Hydrogen Delivery Technologies collected feedback from interested stakeholders regarding hydrogen delivery research and development activities aimed at lowering the cost of hydrogen delivery technologies. This RFI closed on June 13, 2013.[29]
- Rotating Disk Electrode Diagnostics for Proton Exchange Membrane Fuel Cell Electrocatalyst Screening collected feedback from interested stakeholders regarding the use of rotating disk electrode experiments and best practices for experimental conditions for characterization of the activity and durability of proton exchange membrane fuel cell oxygen reduction reaction electrocatalysts. This RFI closed on July 12, 2013.[30]

INTERNATIONAL ACTIVITIES

International Partnership for Hydrogen and Fuel Cells in the Economy

The International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE) includes 17 member countries (Australia, Austria, Brazil, Canada, China, France, Germany, Iceland, India, Italy, Japan, Norway, the Republic of Korea, the Russian Federation, South Africa, the United Kingdom, and the United States) and the European Commission. The IPHE is a forum for governments to work together to advance worldwide progress in hydrogen and fuel cell technologies. IPHE also offers a mechanism for international R&D managers, researchers, and policymakers to share program strategies. IPHE members agreed to embark upon a second term starting in November 2013. The Chair of the IPHE was recently transferred from Germany to Japan. The United States and Germany are now Vice Chairs.[31]

International Energy Agency

The United States is involved in international collaboration on hydrogen and fuel cell R&D through the International Energy Agency (IEA) implementing agreements; the United States is a member of both the Advanced Fuel Cells Implementing Agreement (AFCIA) and the Hydrogen Implementing Agreement (HIA). These agreements provide a mechanism for member countries to share the results of R&D and analysis activities. The AFCIA has several annexes: Molten Carbonate Fuel Cells, Polymer Electrolyte Fuel Cells, Solid Oxide Fuel Cells, Fuel Cells for Stationary Applications, Fuel Cells for Transportation, Fuel Cells for Portable Power, and Systems Analysis. Participating countries include Australia, Austria, Belgium, Denmark, Finland, France, Germany, Italy, Japan, Korea, Mexico, Sweden, Switzerland, and the United States. The IEA HIA is focused on RD&D and analysis of hydrogen technologies. Tasks include Hydrogen Safety, Biohydrogen, Fundamental and Applied Hydrogen Storage Materials Development, Small-Scale Reformers for On-site Hydrogen Supply, Wind Energy and Hydrogen Integration, High-Temperature Production of Hydrogen, Advanced Materials for Hydrogen from Water Photolysis, Near- Market Routes to Hydrogen by Co-Gasification with Biomass, Large Scale Hydrogen Delivery Infrastructure, Distributed and Community Hydrogen for Remote Communities, and Global Hydrogen Systems Analysis. Members of the HIA include Australia, Denmark, the European Commission, Finland, France, Germany, Greece, Iceland, Italy, Japan, Korea, Lithuania, New Zealand, Norway, Spain, Sweden, Switzerland, Turkey, Taiwan, United Nations Industrial Development Organization International Centre for Hydrogen Energy Technologies, and the United States. The United States is a strong contributor to numerous IEA tasks and activities.[32]

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[27] http://www1.eere.energy.gov/hydrogenandfuelcells/news_detail.html?news_id=19089
[28] http://www1.eere.energy.gov/hydrogenandfuelcells/news_detail.html?news_id=19249
[29] http://www1.eere.energy.gov/hydrogenandfuelcells/news_detail.html?news_id=19306
[30] http://www1.eere.energy.gov/hydrogenandfuelcells/news_detail.html?news_id=19437
[31] International Partnership for Hydrogen and Fuel Cells in the Economy, http://www1.eere.energy.gov/hydrogenandfuelcells/international_partnership.html
[32] International Energy Agency, http://www1.eere.energy.gov/hydrogenandfuelcells/international_energy_agency.html

EXTERNAL COORDINATION, INPUT, AND ASSESSMENTS

H_2USA Partnership

In 2013, the Energy Department announced H_2USA—a new public-private partnership focused on advancing hydrogen infrastructure to support more transportation energy options for U.S. consumers, including FCEVs. The new partnership brings together automakers, government agencies, gas suppliers, and the hydrogen and fuel cell industries to coordinate research and identify cost-effective solutions to deploy infrastructure that can deliver affordable, clean hydrogen fuel in the United States. H_2USA held its launch meeting in Washington, D.C., in August. The meeting was attended by 55 representatives of the 26 current participating organizations, including U.S. Department of Energy representatives Dr. David Danielson, Assistant Secretary of Energy Efficiency and Renewable Energy and Steven Chalk, Deputy Assistant Secretary for Renewable Energy.

Hydrogen and Fuel Cells Technical Advisory Committee (HTAC)

As required by the Energy Policy Act of 2005, HTAC was created in 2006 to advise the Secretary of Energy on issues related to the development of hydrogen and fuel cell technologies and to provide recommendations regarding DOE's programs, plans, and activities, as well as on the safety, economic, and environmental issues related to hydrogen and fuel cells. HTAC members include representatives of domestic industry, academia, professional societies, government agencies, financial organizations, and environmental groups, as well as experts in the area of hydrogen safety. HTAC met three times in FY 2013—twice in person and once via webinar. In May 2013, HTAC released its fifth annual report, which summarizes hydrogen and fuel cell technology, domestic and international progress in RD&D projects, commercialization activities, and policy initiatives.[33]

Former Secretary of Energy, Dr. Steven Chu, launched an HTAC subcommittee focusing on hydrogen production in May of 2012, the Hydrogen Production Expert Panel. A major HTAC activity in FY 2012 was the publication of this committee's report. The Steering Committee of the panel offered overall recommendations after considering presentations by the expert panel as well as the findings from the working groups. The panel was charged with providing recommendations to DOE regarding both policy and investments in R&D to enable the widespread production of affordable, low-carbon hydrogen—taking into consideration relevant market and business forces, technology barriers, and policy barriers, as well as the impact of safety codes and standards. HPEP collected input from experts from industry, academia, and national laboratories during a May 2012 workshop and developed recommendations based on that input. HTAC was established under Section 807 of the Energy Policy Act of 2005 to provide technical and programmatic advice to the Energy Secretary on DOE's hydrogen research, development, and demonstration efforts. Key findings were included in the final report that is posted online.[34]

Federal Inter-Agency Coordination

The Hydrogen and Fuel Cell Interagency Task Force, mandated by the Energy Policy Act of 2005, includes senior representatives from federal agencies supporting hydrogen and fuel cell activities, with the DOE/EERE serving as chair. The Hydrogen and Fuel Cell Interagency Working Group, co-chaired by DOE and the White House Office of Science and Technology Policy, continues to meet monthly to share expertise and information about ongoing programs and results, to coordinate the activities of federal entities involved in hydrogen and fuel cell RD&D, and to ensure efficient use of taxpayer resources. A key example of interagency collaboration included a Memorandum of Understanding between DOE's Fuel Cell Technology Office and the National Science Foundation to coordinate basic and applied research, particularly on hydrogen production from renewables. In addition, the Office is working to complete an interagency federal fleet strategy plan to identify locations and vehicle classes to better pinpoint FCEV opportunities. The strategy is under development and expected to be completed in FY 2014.

The National Academies

The National Research Council (NRC) of the National Academies provides ongoing technical and programmatic reviews and input to the Hydrogen and Fuel Cells Program. The NRC has conducted independent reviews of both the Program and the R&D activities of the U.S. DRIVE partnership. Formerly known as the FreedomCAR and Fuel Partnership, the U.S. DRIVE partnership advances an extensive portfolio of advanced automotive and energy

[33] 2012 HTAC Annual Report, http://www.hydrogen.energy.gov/pdfs/2012_htac_annual_report.pdf
[34] Report of the Hydrogen Production Expert Panel (May 2013), http://www.hydrogen.energy.gov/advisory_htac.html#reports

infrastructure technologies, including batteries and electric-drive components, advanced combustion engines, lightweight materials, and hydrogen and fuel cell technologies.

Clean Energy Manufacturing Initiative

The Clean Energy Manufacturing Initiative (CEMI) is a strategic integration and commitment of manufacturing efforts across EERE's clean energy technology offices and the Advanced Manufacturing Office, focusing on American competitiveness in clean energy manufacturing. The objectives are to increase U.S. competitiveness in the production of clean energy products by strategically invest in technologies that leverage American competitive advantages and overcome competitive disadvantages, and increase U.S. manufacturing competitiveness by strategically investing in technologies and practices to enable U.S. manufacturers to increase their competitiveness through energy efficiency, combined heat and power, and taking advantage of low-cost domestic energy sources.

The Office is an active participant in CEMI and is working to increase funding for manufacturing R&D and EERE focus on energy productivity resources for manufacturers. Through an Advanced Manufacturing Office competitive funding opportunity, CEMI is supporting innovative and transformational manufacturing processes and materials across multiple technologies, including high-volume manufacturing processes for low-cost, high-quality MEAs for fuel cells.

EERE's CEMI is partnering with the Council on Competitiveness to convene the nation's private and public sector leaders in a series of successive dialogues to identify barriers to U.S. competitiveness in clean energy manufacturing, as well as solutions to overcome those barriers through public-private partnership models. The first of these regional summits was held on June 21, 2013, in Toledo, Ohio, and showcased regional clean energy manufacturing activities and encouraged a dialogue about how the Initiative can strengthen national and regional manufacturing competitiveness and foster regional stakeholder networking and partnerships. Five additional regional summits have been planned. In addition, CEMI and the Council on Competitiveness held the inaugural American Energy and Manufacturing Competitiveness Summit in December 2013, a first-of-its-kind annual gathering of preeminent leaders from industry, government, academia, labor, and the national laboratories to address critical national imperatives in manufacturing and energy. A fuel cell manufacturing session was organized by the Office in conjunction with CEMI at these summits.

National Fuel Cell Technology Evaluation Center at the Energy Systems Integration Facility

Following Energy Secretary Ernest Moniz's visit to DOE's NREL in September 2013, the Department unveiled a one-of-its-kind national secure data center dedicated to the independent analysis of advanced hydrogen and fuel cell technologies at the Department's Energy Systems Integration Facility (ESIF) located at NREL in Golden, Colorado. The National Fuel Cell Technology Evaluation Center (NFCTEC)[35] allows industry, academia, and government organizations to submit and review data gathered from projects to advance cost-effective fuel cell technology. NFCTEC will also help accelerate the commercialization of fuel cell technologies by strengthening data collection from fuel cell systems and components operating under real-world conditions, and analysis of these detailed data that can be compared to technical targets. The NFCTEC is housed within an ESIF area specifically designed for the secure management, storage, and processing of proprietary data from industry and other stakeholders. Aggregated analysis results that show the status and progress of the technology but do not identify individual companies are available to the public.

DOE Fuel Cell Tech Team

The DOE Fuel Cell Tech Team was created in November 2012 in recognition of the importance of hydrogen and fuel cells in the Department's portfolio and the benefit of greater coordination across offices. The Fuel Cell Tech Team includes members from multiple DOE offices including EERE, the Offices of Science, Fossil Energy, and the Advanced Research Projects Agency. Endorsement of the team by the Secretary and the Under Secretary of Energy along with relevant Assistant Secretaries from the Offices of Science, Fossil Energy, and ARPA-E underscore the importance of fuel cells and the need to directly address key recommendations by the Department's federal advisory committee. Examples of collaboration include best practices/protocols on diagnostics, workshop planning (e.g., natural gas for fuel cells), and biweekly meetings and presentations.

[35] National Fuel Cell Technology Evaluation Center http://www.nrel.gov/hydrogen/facilities_nfctec.html

FY 2013 Annual Merit Review and Peer Evaluation

The Program's AMR took place May 13–17 in Arlington, Virginia, and provided an opportunity for the Program to obtain expert peer reviews of the projects it supports and to report its accomplishments and progress. For the fifth time, this meeting was held in conjunction with the annual review of DOE's Vehicle Technologies Office. During the AMR, reviewers evaluate the Program's projects and make recommendations; DOE uses these evaluations, along with other review processes, to make project funding decisions for the upcoming fiscal year. The review also provides a forum for promoting collaborations, the exchange of ideas, and technology transfer. This year, more than 1,500 participants attended, and more than 200 experts peer-reviewed 145 of the Program's projects—conducting a total of more than 900 individual project reviews, with an average of more than six reviewers per project. The report summarizing the results and comments from these reviews is available at www.hydrogen.energy.gov/annual_review12_report.html. The 2014 Annual Merit Review and Peer Evaluation Meeting will be held June 16–20, in Washington, D.C.

Funds Saved through Active Project Management

The AMR is a key part of the Program's comprehensive approach toward active management of its projects. Termination of underperforming projects—identified through the AMR as well as through other Go/No-Go decisions (with criteria defined in the project scope of work)—helped the Office redirect $7.6 million in funding in FY 2013, $6.8 million in FY 2012, and over $37 million over the past five years.

DOE Cross-Cutting Activities

Grid Integration: Integration of energy efficiency and renewable energy technologies into the grid at scale is a major challenge facing deployment of all clean energy technologies. EERE is working to address some of these issues through a new cross-cutting initiative focused on integrating clean energy technologies into the energy system in a safe, reliable, and cost effective manner at a relevant scale to support the nation's goals of 80% clean electricity by 2035 and reducing oil imports by 33% by 2025. All of the participating technologies offices, including the Fuel Cell Technologies Office, are determining the high impact RD&D necessary to enable the integration of energy efficiency and renewable energy technologies into the energy system at a scale necessary to realize this vision.

Carbon Fiber: High quality carbon fiber is essential to addressing the needs of the automotive industry as well as emerging clean energy industries. Customers in these industrial markets use carbon fiber for necessary performance benefits but have not explored the full range of possibilities due to high manufacturing costs. The primary objective of EERE's cross-cutting carbon fiber initiative is to scale up the technology to market development scale (1,000-fold above the anticipated pilot scale throughput). One of the Office's goals is to produce low cost carbon fiber from novel polymer precursors in higher yield and at lower cost than the incumbent carbon fiber made from specialty-grade peroxyacetyl nitrate.

Wide Bandgap Semiconductors for Clean Energy Initiative: Wide bandgap (WBG) semiconductor materials allow power electronic components to be smaller, faster, more reliable, and more efficient than their silicon-based counterparts. These capabilities make it possible to reduce weight, volume, and life-cycle costs in a wide range of power applications. EERE's technology offices, through the Advanced Manufacturing Office, are working together to harness these capabilities to lead to dramatic energy savings in industrial processing and consumer appliances, accelerate widespread use of electric vehicles and fuel cells, and help integrate renewable energy onto the electric grid. In support of this cross-cutting initiative, the Office has successfully launched fuel cell specific efforts in the development of WBG energy conversion materials and initiated cross-office and cross-agency R&D collaborations for innovative WBG for photoelectrochemical hydrogen production. The Office has also begun to evaluate the current gaps in innovative WBG power electronics to improve efficiency and lifetime of renewable/integrated electrolysis.

CONCLUSION

The need for clean, sustainable energy, combined with the need to reduce emissions, has come together to form a global imperative—one that demands new technologies and new approaches for the way we produce and use energy. Widespread use of hydrogen and fuel cells can play a substantial role in a portfolio of clean energy technologies that will overcome key energy challenges. In addition, growing interest and investment among leading world economies, such as Germany, Japan, and South Korea, underscores the global market potential for these technologies. FY 2013 brought the renewal of the International Partnership for Hydrogen and Fuel Cells in the Economy, a global partnership on hydrogen and fuel cells, with more than 17 countries around the world.

The United States continues to be one of the world's largest and fastest growing markets for fuel cell and hydrogen technologies. In 2012, nearly 80 percent of total investment in the global fuel cell industry was made in U.S. companies.[36] Major companies—such as Coca-Cola, FedEx, Sysco, Wegmans, and Whole Foods—are deploying fuel cell forklifts in their warehouses and distribution facilities. As of October 2013, DOE's Recovery Act efforts have deployed more than 1,300 fuel cells systems, surpassing the original Recovery Act deployment goal of up to 1,000 fuel cells. In the wake of those initial purchases, private businesses have ordered more than 5,000 additional fuel cell forklifts and 3,500 fuel cell emergency backup power systems with no DOE funding.[37] These rapidly growing markets have helped create and keep jobs in the United States.

Another indicator of the robustness and innovative vitality of a thriving market is the number of patents granted, and the number of technologies commercialized. EERE-funded R&D has resulted in more than 450 patents, 40 commercial technologies, and 65 technologies that are projected to be commercialized within three to five years.[38] In addition, EERE's investment of $50 million in specific hydrogen and fuel cell projects led to more than $300 million in revenue and investments of approximately $14 million in specific projects led to a nearly $130 million in additional private investment.

FY 2013 was a productive year for the Program in terms of technical accomplishments as well. For example, the Program introduced several changes in the transportation fuel cell system cost projection assumptions, which resulted in an increase in the projected cost status to $55/kW. Updating previous numbers with the same assumptions and requirements shows a decrease in the transportation fuel cell system cost of more than 50% since 2006 and 30% since 2008.

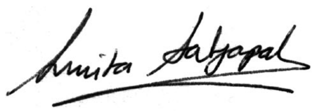
We've made tremendous progress, but innovative R&D breakthroughs won't be enough—infrastructure remains a key challenge to the widespread adoption of FCEVs. To overcome these challenges, DOE, together with other federal agencies, automakers, state government, academic institutions, and additional stakeholders, has formed a public-private partnership called H_2USA to promote the widespread adoption of FCEVs. The partnership's first action is to form a strategy to coordinate vehicle and infrastructure rollout, conduct situational assessment and analysis, and identify synergies and opportunities to leverage other alternative fueling infrastructure—such as natural gas—to enable cost reductions and economies of scale. H_2USA is also focusing on identifying actions to incentivize early adopters and evaluating the business cases required for commercialization of FCEVs and hydrogen infrastructure technologies. While the research community is working toward finding technical solutions, this partnership is going to be working on accelerating a national infrastructure by tackling the largest barriers: location, financing, codes and standards, and equipment costs.

FY 2013 was also a landmark year for industry, with many auto manufacturers announcing FCEV commercialization plans; Toyota, Nissan, Hyundai, General Motors, Honda, Mercedes/Daimler, and Ford have all committed to putting FCEVs on the road, some as early as the 2015–2017 timeframe. In November 2013 at the Tokyo Motor Show, Toyota unveiled their concept model FCEV, stating that the cars will be on the market in 2015. Hyundai Motor Co., has said it will start leasing its Tucson FCEV in the spring of 2014 with three years of fuel and maintenance at no cost. Honda Motor Co., who has leased an FCEV for several years, unveiled its next-generation version at the Los Angeles Auto Show in November as well. Major industry partnerships were also announced: GM and Hyundai; Toyota and BMW; and Daimler, Ford, and Nissan. Major progress by independent gas providers such as Air Products, Linde, and Air Liquide was also announced.

Moving forward, the Program's emphasis on the transportation sector will be strengthened by the creation of an Office of Sustainable Transportation within EERE that will include the Vehicle Technologies Office and the Bioenergy Technology Office as well as the Fuel Cell Technologies Office. This new office will allow the opportunity for additional cross-cutting activities and a closer collaborative relationship between all advanced vehicle technology R&D. However, the Program will continue to pursue a broad portfolio of R&D activities for fuel cell applications across multiple sectors including stationary applications. Efforts will span the full spectrum of technology readiness, including near term markets like material handling equipment and backup power, mid-term markets like combined heat and power, and auxiliary power units, and longer-term markets like FCEVs.

[36] 2012 Fuel Cell Technologies Market Report, http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/2012_market_report.pdf
[37] DOE Hydrogen and Fuel Cells Program Record #13007 and 13008
[38] 2013 Pathways to Commercial Success: Technologies and Products Supported by the Fuel Cell Technologies Office, http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/pathways_2013.pdf

This is a critical time for fuel cells and hydrogen. DOE's Hydrogen and Fuel Cell Program will continue to work in close collaboration with key stakeholders, and will continue its strong commitment to effective stewardship of tax payer dollars in support of its mission to enable the energy, environmental, and economic security of the nation.



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